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Notes on the occupation of the slopes of the Tijuca Massif, in Rio de Janeiro

Abstract

Mountains frame the landscape of the city of Rio de Janeiro and serve as support for the Atlantic forest and the urban fabric on its borders that gradually advances on it. This article analyzes the process of urban settlement on the slopes of the city of Rio de Janeiro, from a comparative analysis of landscape morphology. It focuses on the Tijuca Massif, whose slopes experience constant urban pressure from real-estate interests and territorial disputes around the edges of the Atlantic forest. This article describes occupation patterns found on the slopes of the city and specifically in the Tijuca Massif and points out the effects of local urban planning legislation on the landscape, linking them to the territorial appropriation processes and resulting environmental conflicts. The border between the Atlantic forest and the urban fabric on the slopes of Rio de Janeiro is an heterogeneous, unstable, and dynamic transition zone with different levels of occupation (strips), whose internal structural logic affect the configuration of the others, causing impacts, tension, and conflicts. These strips form a gradient of occupation, where the inner strips (mixed bands) are the ones that suffer the most dynamic changes, affecting and impacting the outer ones. Within these mixed bands, high income strata neighborhoods and *favelas* (slums) establish contiguous and complementary relationships among themselves. This picture demonstrates that urban planning, management, and the logic of urban occupation on the slopes of Rio de Janeiro need to evolve through a process of adjustment toward a regenerative urbanism, in which open spaces exert a structuring role to connect, articulate, and guarantee landscape resilience against geological hazards and mitigate the antithesis between the forest, formal settlements and the slums.

Keywords

Landscape. Landscape morphology. Urban hillslopes. Legislation. Morphological patterns. Open spaces.

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NOTAS SOBRE LA OCUPACIÓN DE LADERAS DEL MACIZO DE TIJUCA, EN RÍO DE JANEIRO

Resumen

Las montañas estructuran el paisaje de la ciudad de Rio de Janeiro y actúan como soporte del bosque Atlántico y de la mancha urbana alrededor, que avanza gradualmente sobre éste. El presente artículo analiza el proceso de ocupación urbana en las zonas de ladera de la ciudad de Rio de Janeiro, a partir de una lectura comparativa de la morfología del paisaje, enfocada en el Macizo de Tijuca, cuyas laderas experimentan una constante presión urbana debido a la valorización inmobiliaria y a las disputas territoriales en las áreas fronterizas del bosque Atlántico. Este artículo tiene como objetivo caracterizar los patrones de ocupación que se encontraron en las zonas de ladera de la ciudad y del Macizo de Tijuca en particular, y apuntar a los efectos de la legislación urbanística local sobre el paisaje, relacionándolo a los procesos de apropiación territorial. El área fronteriza entre el bosque Atlántico y la malla urbana en las laderas de Rio de Janeiro se caracteriza como una zona de transición, heterogénea, inestable y dinámica, donde es posible diferenciar diferentes fajas de ocupación, cuyas lógicas internas de estructuración afectan la configuración de las demás. Estas fajas conforman un gradiente de ocupación, donde las franja internas (fajas de mezcla) son las que sufren transformaciones más dinámicas, afectando e impactando las externas. En estas fajas de mezcla se localiza una constelación de núcleos de ocupación habitados por diferentes estratos sociales, con características formales e informales, es decir, regulares e irregulares desde el punto de vista urbanístico y de propiedad de la tierra, que establecen entre sí una relación imbricada de contigüidad y complementariedad. Se argumenta que la planificación urbanística, la gestión y la lógica da ocupación urbana en las laderas cariocas necesitan pasar por un proceso de ajuste, en dirección a un urbanismo regenerador, en el cual los espacios libres ejerzan un papel estructurador en la conexión, articulación y en la resiliencia del paisaje frente a los riesgos geológicos y en la mitigación de la antítesis entre el bosque, los territorios formalmente ocupados y las favelas.

Palabras clave

Paisaje. Morfología del paisaje. Ocupación de laderas urbanas. Legislación. Patrones morfológicos. Espacios libres.

NOTAS SOBRE A OCUPAÇÃO DAS ENCOSTAS NO MACIÇO DA TIJUCA, NO RIO DE JANEIRO

Resumo

As montanhas estruturam a paisagem da cidade do Rio de Janeiro e servem de suporte para a floresta Atlântica e para a mancha urbana ao seu redor, que avança gradativamente sobre ela. O presente artigo analisa o processo de ocupação urbana nas encostas da cidade do Rio de Janeiro, a partir de uma leitura comparativa da morfologia da paisagem, com foco no Maciço da Tijuca, cujas encostas vivenciam uma constante pressão urbana decorrente da valorização imobiliária e das disputas territoriais nas bordas da floresta Atlântica. Este artigo tem como objetivo caracterizar os padrões de ocupação encontrados nas encostas da cidade, e do Maciço da Tijuca, em particular e apontar os efeitos da legislação urbanística local sobre a paisagem, relacionando-os aos processos de apropriação territorial. A zona de fronteira entre a floresta Atlântica e a malha urbana nas encostas do Rio de Janeiro caracteriza-se como uma zona de transição, heterogênea, instável e dinâmica, onde é possível discernir diferentes faixas de ocupação, cujas lógicas internas de estruturação afetam a configuração das demais. Essas faixas conformam um gradiente de ocupação, onde as faixas internas (faixas de mescla) são as que sofrem transformações mais dinâmicas, afetando e impactando as externas. Nestas faixas de mescla se localiza uma constelação de núcleos de ocupação habitados por diferentes extratos sociais, com características formais e informais, isto é, regulares e irregulares do ponto de vista urbanístico e fundiário, que estabelecem entre si uma relação imbricada de contiguidade e complementaridade. Este quadro demonstra que o planejamento urbano, a gestão e a lógica da ocupação urbana nas encostas cariocas necessitam passar por um processo de ajuste, em direção a um urbanismo regenerador, no qual os espaços livres exerçam um papel estruturador na conexão, articulação e na resiliência da paisagem frente aos riscos geológicos e na mitigação da antítese entre a floresta, os territórios formalmente ocupados e as favelas.

Palavras-chave

Paisagem. Morfologia da paisagem. Ocupação de encostas urbanas. Legislação. Padrões morfológicos. Espaços livres

Introduction

What are the characteristics of the landscape on the hillsides of the city of Rio de Janeiro?

What are the relationships between the spatial patterns that shape this landscape and the urban occupation process taking place on the hillsides? What impact does local urbanistic law have on this process and on the social and spatial organization of the Rio de Janeiro hillsides?

As Pierre Gourou said, landscapes ask us questions. Aziz AB' Saber and Maurício de Almeida Abreu taught us that today's landscape is a legacy of the past. We must understand this landscape in order to understand it and properly intervene in it.

The landscape's morphology reflects the logic of the processes that have shaped it over time. The Rio de Janeiro hillsides have seen several processes that have left their marks in the landscape, including deforestation, the exploitation of mineral and vegetation resources, farming, road building, urban settlement, illegal settlements, territorial disputes, landslides, reforestation, natural regeneration, social polarization, and spatial segregation. Soares (2006) and Guerra (2005) point out that territorial disputes in the boundary between the city and the forest on the slopes of the Tijuca Massif express social and environmental conflicts[1] resulting from processes taking place over different periods in history.

The urban pressure over the urban slopes exerted by the real-estate market, expanding slums and illegal land parceling that date back to the 19th century and strongly intensified over the 20th century have boosted social and environmental conflicts in the interface between the conventional urban fabric and the forest, leading to a situation of social and spatial segregation that characterizes this territory. This pressure is also the main cause of the reduction in the forest area[2], which in turn induces higher vulnerability to landslides following heavy rainfall on the region. When landslides reach the urban fabric, they can have catastrophic consequences.

The purpose of this article is to identify the morphological patterns of urban occupation of the Rio de Janeiro hillsides, discuss pattern-process relationships, and demonstrate how municipal urbanistic legislation has influenced this configuration. The methodology adopted in this study included a comparative analysis of the landscape, based on interdisciplinary theoretical and conceptual references and supported by an analysis of urban occupation dynamics over time employing primary and secondary sources, field surveys, ArcGIS mapping on a neighborhood scale (1:2000), and analyses of summary tables, theme matrices, maps, interpretative diagrams, and longitudinal profiles[3].

The patches of urban occupation on Rio de Janeiro hillsides are mixed with and interpenetrate forest patches surrounding them, producing an extremely heterogeneous area in process of transformation. Like the forest, which consists of a gradient of vegetation fragments in different successional stages[4], the urban fabric up the slopes is not uniform, and it is comprised of different social and spatial fabrics.

This research focused on the process of urban occupation of the slopes of the Tijuca Massif, which is home to the only Brazilian national park fully located within a city, and where three urban clusters, located in the basin of the Carioca River (1), at the confluence between the São Conrado and Rainha River basins (2), and in the basin of the Cachoeira River (3) were analyzed (Figure 1).

[1] In this study, the term social and environmental conflicts means confrontations or litigations inherent to the values and interests of society in regard to social and environmental issues associated with the appropriation, control, and use of land, as well as the resulting living conditions.

[2] Based on aerial photographs taken in 1972, 1984, and 1996 and their respective updates, field surveys, and maps starting on the 40-meter elevation at the 1:10,000 scale, Coelho Netto et al (GEOHECO-UFRJ/SMAC-RJ, 2000) demonstrated that advancing urban occupation on the hillsides was the chief cause of deforestation in the city of Rio de Janeiro.

[3] This article presents parts of the findings of the study called "*A Ocupação das Encostas no Rio de Janeiro: Morfologia, Legislação e Processos Socioambientais*" (The Occupation of Rio de Janeiro Hillsides: Morphology, Legislation, and Social and Environmental Processes, Schlee, 2011), developed as part of the UFRJ Architecture Graduate Program using a trans-scale approach on three scales of analysis: the city of Rio de Janeiro and its context in comparison with four other Brazilian cities (Florianópolis, Vitória, São Paulo, and Belo Horizonte), considering geo-biophysical, landscape, hillside occupation, and protection-regulation aspects; a description of the occupation of massifs and isolated hills of the city of Rio de Janeiro in an intra-urban context; and the urban occupation in the Tijuca Massif.- Analyses on the other scales are found in Schlee, 2013a and Schlee, 2013b.

[4] The city of Rio de Janeiro occupies an area of 122,456 hectares, 22 percent of which consists of forests (forests in advance stages of regeneration, altered forests, banana groves) and 11 percent of grassland. RIO DE JANEIRO/SMAC, 2010 (Uso do Solo e Cobertura Vegetal, In: http://sigfloresta.rio.rj.gov.br).

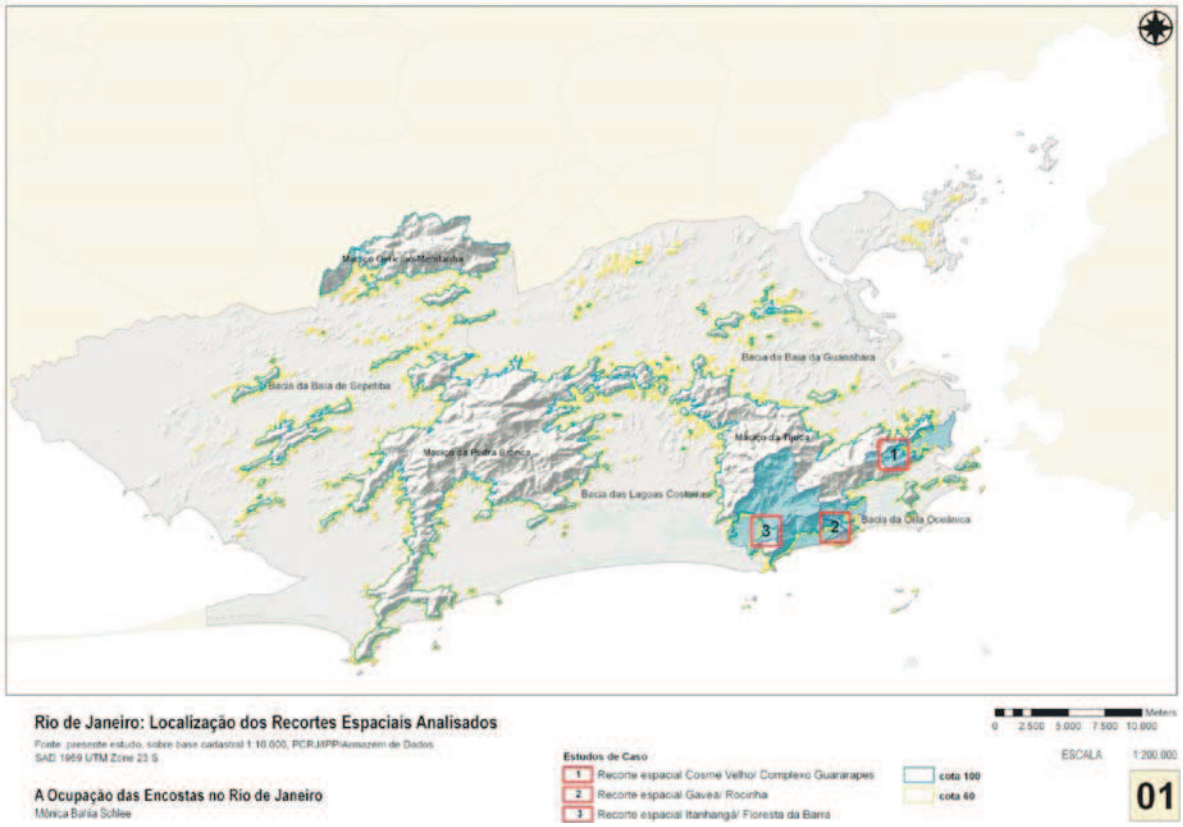


Figure 1: Location of the analyzed urban clusters. Source: Schlee, 2011.

Urban occupation in the three urban clusters is located next to the drainage headwaters, with extremely variable declivity, shape, and aspects. Upstream, there are slopes covered by dense and well-preserved forests, outcrops, and rocky escarpments. The analyzed urban clusters encompass high-income strata gated neighborhoods and *favelas* (slums) that are both spatially contiguous but socially apart, all interweaved with forest fragments. Those urban clusters are heterogeneous and diversified, both spatially and in terms of social configuration, even internally. The occupation of these territories has, on the one hand, specific characteristics conditioned by social and environmental relationships that generated and structured the urbanization processes in these areas, and, on the other hand, shared characteristics resulting from changes in Rio de Janeiro's urban context.

Cluster 1 is located on the east side of the Tijuca Massif, in the basin of the Carioca River, and it covers part of the Cosme Velho and Santa Teresa districts as well as the Guararapes, Vila Cândido, and Cerro-Corá slums. This territory is part of the gradient rupture zone (structural step) and it features heterogeneous landscape fragments, including forests in different successional stages (advanced, altered, and recomposing stages) protected in part by the Tijuca National Park and other municipal protection areas; sparse grassland; different patterns of urbanization; rocky escarpments that have great impact in the Rio de Janeiro landscape (Corcovado and Morro

Dona Marta) and a history of landslides, the last of which happened in 2010. Urban occupation in this territory rests on narrow valleys and halfway up the slopes.

Cluster 2 is located south of the Tijuca Massif, between the basin that drains to the São Conrado beach and the Rainha River basin. It covers the upper areas of the Gávea district, which is occupied by high-income strata gated neighborhoods, next to Rocinha, Latin America's largest slum. Over the past 30 years, the Rocinha occupation has crossed the divide between these basins, advancing on the Gávea district, one of Rio de Janeiro's most expensive areas. This cluster lays on two opposing amphitheaters that include rocky escarpments of great impact on the landscape (Morro Dois Irmãos), steep slopes with a history of landslides (the last also happened in 2010), and forests in advance stage of regeneration, in part protected by environmental legislation. This cluster spreads over concave slopes and the divides.

Figure 2

Cluster 1: The occupation axis coincides with the Carioca River valley bottom; slums are found on the right bank of this river, halfway up the slope.
Photo: Mônica Bahia Schlee, 2010

luster 2: The occupation axis started along the valley bottom on both basins (São Conrado and Rainha River basin) and spread over concave slopes and divides. In the back, we see Rocinha, whose occupation crossed the water divide towards Gávea District along the valley bottom.
Photo: Mônica Bahia Schlee, 2010.

Cluster 3: This urban cluster encompasses high-income strata gated neighborhoods and the Floresta da Barra slum, which developed halfway up the slope on the left bank of the Cachoeira River.
Photo: Marcio Lopes, 2010.

Cluster 3 is located on the southwest side of the Tijuca Massif, in the Cachoeira River basin. It is part of the Itanhangá district, also between high income strata gated neighborhoods that border the Tijuca National Park to the north and the Floresta da Barra slum. This portion of the Tijuca Massif features a complex geomorphology, with rocky escarpments of great impact on the landscape, broad valleys that form rolling, mainly concave ramps, covered by vegetation in advanced stages of development, and enclaves and deposits of rocky blocks and sedimentary material produced by past landslides. Of the three investigated clusters, this has the most recent occupation, which extends halfway up the slopes.

Theoretical basis

The term "landscape" was coined in the 15th century. Over time, it has changed gradually as a result of interpretations of reality that were limited to the degree of knowledge at the time they were formulated. Initially associated with the materialized expression of a fragment of nature seen through a frame, it has absorbed new interpretations as it incorporated concepts associated with ecology, landscape ecology, and systems theory, which then began to support and inform landscape planning and analyses from the 1950s on (TROLL, 1950; ODUM, 1953; MCHARG, 1969; CORRÊA and ROSENDAHL, 2004). The concept gained momentum as an interactive, dynamic, heterogeneous, and unstable combination of physical, biological, and anthropic aspects, as demonstrated by Bertrand (1971) and Forman (1986 and 1995). The approach adopted in the present study incorporates the concept of landscape as a complex, heterogeneous, and interactive system that brings together several combinations of aspects and plural processes reflected in it – derived from the natural support, from the built support, and from social and cultural relationships – interacting in different times and scales (SCHLEE et al 2009 and SCHLEE 2011).

The study of landscape morphology analyzes the configuration of landscape as a result of factors interrelated to the processes that originated it, its structure, patterns, types, and interrelations, within a historical perspective. Sauer (1925) revolutionized the study of landscape by suggesting a morphologic method of synthesis, emphasizing the importance of identifying the types and patterns that structure it and the relationships among the elements that provide its form and content. The theoretical and methodological contributions of Panerai (1999), Lamas (1992), and Kostof (1991) are helpful to understand the formation of the structure of urban landscape. The contribution of Reis (2006) on the forms of organization of urban sprawl in São Paulo and of Alonso (1999) on the transformation of the landscape of the Florianópolis hillsides, in addition to the seminal works of Villaça (1998) and Abreu (1987, 1994 and 2001), which focused on historical, social, economic, and functional processes associated with the formation of the Brazilian territory at large, are especially helpful references in investigating the morphology of the landscape of Rio de Janeiro hillsides.

The concept of frontier was initially associated with the idea of a limit between different territorial patches, which can act as abrupt and impenetrable barriers or as a seam between two types of fabric or fragments

that touch and establish some sort of connection (FORMAN, 1995). In the present study, the concept of frontier incorporates the notion of an inflexion region between different urban and social fabrics in a process of transformation and interpenetration (PANERAI, 1999).

The social and spatial organization in this frontier region expresses the social polarization and the process of spatial segregation that separate the affluent from the poor, which is underway in several Brazilian cities, as Villaça (1998) demonstrated. Over the past decades, different social strata have become increasingly isolated in segregated spaces, a situation that discourages heterogeneous groups from interacting, even within slums.

According to Villaça (1998), urban spatial segregation is a spatial organization trend inherent to the Brazilian intra-urban structure, in which social strata or urban functions tend to concentrate spatially, without preventing the presence of other classes in the same space.

As showed by Caldeira (2000), in this polarized social and spatial organization, in spite of sharing the same territory, different social strata do not have direct contact with each other. This isolation strategy is a response to the need of middle and upper strata to organize and promote a process of differentiation, driven by the recent democratization of society, under which working classes have gained rights and occupied physical and political spaces.

Relationships of exclusion versus inclusion and appreciation versus depreciation happen both between formal settlements and slums (*favelas*) and within the slums. According to Valladares (2005), slums are on average poorer areas but not in a uniform way. They congregate a diversified social structure that results from social mobility processes, the acceptance of an illegal status and of spatial segregation that are part of the city's development dynamics.

Based on this theoretical framework, the frontier zone between the forest and the city becomes fluid and heterogeneous, and is subject to continuous transformation. The transition area, where extremes come in contact, brings out hybrid elements. Rio de Janeiro's hillsides can thus be considered peri-urban areas or zones of contact and conflict between opposite poles, between the forest matrix and the city matrix, and between distinct social classes.

Configuration of the occupation of Rio de Janeiro's hillsides. Spatial patterns and notes on transformation processes

When analyzing the urbanization process of dispersion in progress in Brazil, Reis (2006) noticed the fragmentation of the fabric in the outskirts of consolidated urban areas, in which isolated nuclei amidst open spaces formed constellations that resembled a nebula on the territory. This constellation pattern over the territory also applies to urban occupation on Rio de Janeiro hillsides; however, in the latter case the territorial organization of the clusters has specific characteristics that are inherent to the local intra-urban development process.

The hillside landscape morphology, expressed in the spatial patterns observed, reflects the logic of the processes that have produced it over time and the influence of the legislation applying to it. The boundary area between the forest and the urban fabric on Rio de Janeiro hillsides is a heterogeneous and dynamic zone of transition and instability. This zone reveals strips with specific configurations, whose internal structuring logic has impacted the configuration of other strips. They include:

- Preserved forests with isolated clusters of urban occupation (a fabric in which the forest is the predominant land coverage matrix);
- A mix of forest fragments and urban clusters, in which forest prevails (a fabric in which the land coverage matrix consists of a mix of forest and dispersed clusters);
- A mix of dispersed urban clusters (which encompass regular and irregular occupation in urbanistic and land ownership terms) and forest fragments, in which urban occupation prevails (a fabric in which the land coverage matrix consists of a mix of forest and denser urban clusters);
- Consolidated urban occupation with isolate focuses of forest fragments (consolidated urban fabric in which the land coverage matrix is the urban fabric).

These strips form a gradient of urban occupation and protection of the forest, in which internal strips (mixed bands) have experienced more dynamic transformations and where social and environmental stress and conflict are more evident, impacting external strips. These mixed strips are also areas with predominant hybrid open spaces, which can help to challenge the physical limitation imposed by abrupt barriers that prevent the contact and the interaction between diverse social strata. These barriers consist of material elements (the coast, walls, fences, gates, segregated yards, etc.) or immaterial aspects (insecurity, prejudice, social polarization, and spatial segregation).

The Rio de Janeiro urban landscape is framed by mountains (Tijuca, Pedra Branca, and Gericinó-Mendanha massifs) surrounded by river and coastal plains. These massifs are crossed by a network of river channels, with a radial pattern. They also preserve a significant portion of the Atlantic Forest, in different successional stages (forests in advanced stage of regeneration, secondary forests, and pioneer forests), grasslands, and rocky escarpments. Landslides are typical phenomena in the mountainous areas of Rio de Janeiro, as pointed out by Coelho Netto (GEOHECO-UFRJ/SMAC-PCRJ, 2000).

The urban occupation of Rio de Janeiro hillsides takes place in a poli-nuclear and discontinuous pattern, expanding through tentacles over the penetrating and connecting axes of the original nuclei. This occupation generally coincides with the valley bottoms (SCHLEE, 2011). The poli-nuclear occupation pattern of Rio de Janeiro hillsides mixes islands (nuclei or clusters) of disperse urbanization (high-income settlements) and denser urbanization (slums). The clusters spread along the borders of the massifs and along the roads crossing them, all surrounded by and interweaved with the forest patches.

The city's main growth vectors developed lengthwise, starting from downtown (on the east side of the city) towards northwest and southwest, producing a discontinuous urban matrix intersected by coastal massifs, mountain ranges, isolated hills, and rocky coasts. The south zone, on the seacoast, was planned to shelter the wealthier population; the north zone, following the railways, tramways, and main roads, was meant to seclude the poorer population (ABREU, 1987). However, a simple analysis of population dynamics and its spatial organization shows that the picture is not so simple.

Social and spatial organization

While the population of the city of Rio de Janeiro grew at a constant rate of 7 percent a year over the past three decades, tending to level off, the number of dwellers of the city's slums increased from 16 percent of the total population in 1991 to 19 percent in 2000 and to 22 percent in 2010, as shown in Table 3.

Out of the 1,021 Rio de Janeiro slums counted in 2010, 202, or 35 percent of the total, are located on hillsides and have all or part of their territory located above the 60-meter elevation[5], as shown in Table 4. Especially in Planning Area 2 (south zone), as well as in AP 1 (downtown), most of the slums are located on the hillsides. About 80 percent and 60 percent, respectively, of the slums in these Planning Areas are located above the 60-meter elevation. In AP 4 (southwest zone), slums on the slopes correspond to 33 percent of all slums located in this Planning Area.

In terms of social and spatial organization, of all urban areas above the 60-meter elevation, 67 percent comprise middle and upper class buildings, and about 33 percent consist of slum buildings. Of all urban areas above the 100-meter level, about 57 percent comprise middle-class buildings and about 43 percent consist of slum buildings, which shows the polarized social and spatial organization of urban occupation of Rio de Janeiro hillsides.

Occupation

The occupation of the Rio de Janeiro hillsides above the 60-meter elevation is mostly urban dwellings, consisting of 70 percent of all areas occupied. Farming comprises another 25 percent and only 5 percent is associated with mining activity. The occupation of the Tijuca Massif is quite different from the two other massifs (Pedra Branca and Gericinó-Mendanha) in terms of composition. The Tijuca Massif has a mostly urban occupation, whereas the other two massifs are occupied mostly by farming activity. Mining is sparse and found mainly where the Tijuca and Pedra Branca massifs meet, on the north slope of the Pedra Branca Massif and on isolated mountain ranges.

The occupied area of Rio de Janeiro hillsides above the 100-meter elevation comprises approximately 7 percent of the total territorial area, as shown in Table 8. In this area, about 3 percent is urban occupation and about 3 percent farming. There is still a large portion of open spaces, with about 93

[5] The 60-meter and 100-meter elevations above sea level "theoretically" represent the legal limit for urban occupation on the city's hillsides, based on a 1970 ordinance.

Table 3: City: Population dynamics

	2010	% in 2010	2000-2010 change (%)	2000	% in 2000	1991-2000 change (%)	1991	% in 1991	1980-1991 change (%)	1980	% in 1980
City	6,323,037	100	7	5,857,879	100	6	5,480,768	100	7	5,090,723	100
Favelas (slums)	1,393,314	22		1,092,958	19	19	882,483	16			

Source: this study, after data provided by Instituto Municipal de Urbanismo Pereira Passos – IPP/ Armazem de Dados and IBGE 2010 census.

Table 4: City: Shantytowns above the 60-meter elevation

Planning Areas (AP)	Total slum area (ha)	Slum area above the 60-meter elevation (ha)	Number of slums above the 60-meter elevation	%
City	4,686.56	1,621.48	202	35
Planning Area 1 (downtown)	241.47	145.67	24	60
Planning Area 2 (south zone)	422.21	335.04	32	79
Planning Area 3 (north zone)	1,842.69	908.86	107	49
Planning Area 4 (southwest zone)	703.76	231.91	39	33
Planning Area 5 (northwest zone)	1,476.44	429.44	71	29

Source: This study, after Table 2642 prepared in 2010, Instituto Municipal de Urbanismo Pereira Passos – IPP/ DIG – Gerência de Cartografia, 1999, 2004 aerophotogrammetric survey, 2004, 2008 satellite image, and the Low-Income Settlement System (SABREN).

Table 5: City: Formal and informal urban areas above the 60-meter elevation

Informal area (slums)	13,117,038	1,312	33
Formal area (middle and high income strata)	26,166,205	2,617	67
Total	39,283,243	3,928	100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/ DIG – Gerência de Cartografia, 2004

Table 6: City: Formal and informal urban areas above the 100-meter elevation

Informal area (slums)	5.179.478	518	43
Formal area (middle and high income strata)	6.945.543	695	57
Total	12.125.021	1.213	100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/ DIG – Gerência de Cartografia, 2004

Table 7. City: Occupation above the 60-meter elevation

Land Use	Área (ha)	% of area occupied	% of total area
Urbanized area (urban dwellings)	2.720	69	8
Farming area	1.004	25	3
Mining	217	5	1
AREA OCCUPIED	3.940	100	12
OPEN SPACES: un-urbanized area	30.128		88
TOTAL AREA	34.069		100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/ DIG – Gerência de Cartografia, 2004

Table 8: City: Occupation above the 100-meter elevation

Land Use	Área (ha)	% of area occupied	% of total area
Urbanized area (urban dwellings and related uses)	913	49	3
Farming area	853	46	3
Mining	97	5	0
AREA OCCUPIED	1,862	100	7
OPEN SPACES: un-urbanized area	25,483		93
TOTAL AREA	27,345		100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/DIG – Gerência de Cartografia, 2004

Table 9: City: Occupation between the 60-meter and 100-meter elevations

Land Use	Área (ha)	% of area occupied	% of total area
Urbanized area (urban dwellings and related uses)	1,778	87	26
Farming area	151	7	2
Mining	120	6	2
AREA OCCUPIED	2,049	100	30
OPEN SPACES: un-urbanized area	4,674		70
TOTAL AREA	6,724		100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/DIG – Gerência de Cartografia, 2004

percent of the total territorial area above the 100-meter elevation featuring trees, bushes, grasses, rocky outcrops, and bodies of water. Above the 100-meter elevation, 49 percent of occupation consists of urban dwellings and 46 percent of farming.

On the borders of the slopes, between the 60-meter and 100-meter elevations, 30 percent of the total territorial area is occupied, as shown in Table 9. Out of this percentage, about 26 percent corresponds to urban occupation (urban dwellings and related uses), 2 percent farming, and 2 percent mining. About 70 percent of the territorial area in this strip is composed of open spaces. In this strip, occupation is mostly urban (dwellings and related uses), comprising about 87 percent of the area, with farming accounting for 7 percent, and mining taking up 6 percent.

Uses

The analysis of the land use (IPP/PCRJ, 2004) revealed that about 93 percent of the total occupied area above the 60-meter elevation comprises dwellings, 2 percent consists of leisure activities, and 2 percent of institutional uses, as shown in Table 10. Commercial uses, services, manufacturing, and transportation are found, but not significant.

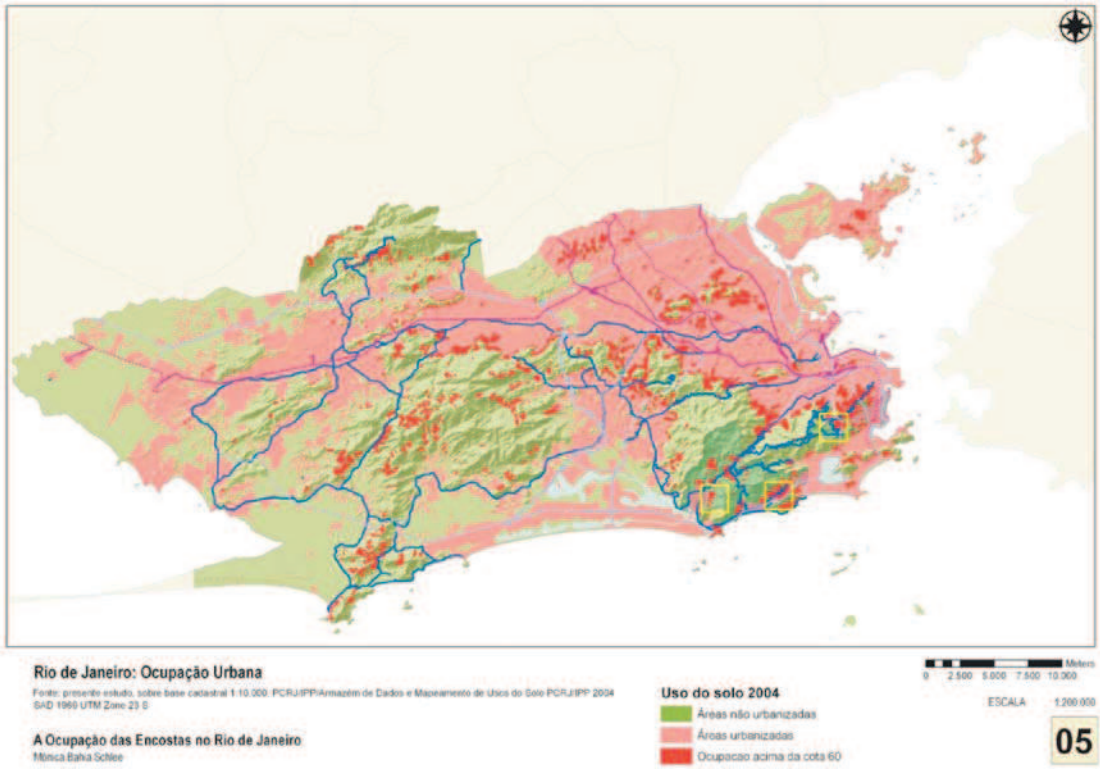


Figure 3: Rio de Janeiro urban occupation. Source: Schlee, 2011

Figure 4: Occupation clusters (nuclei) on the slopes. Source: Schlee, 2011

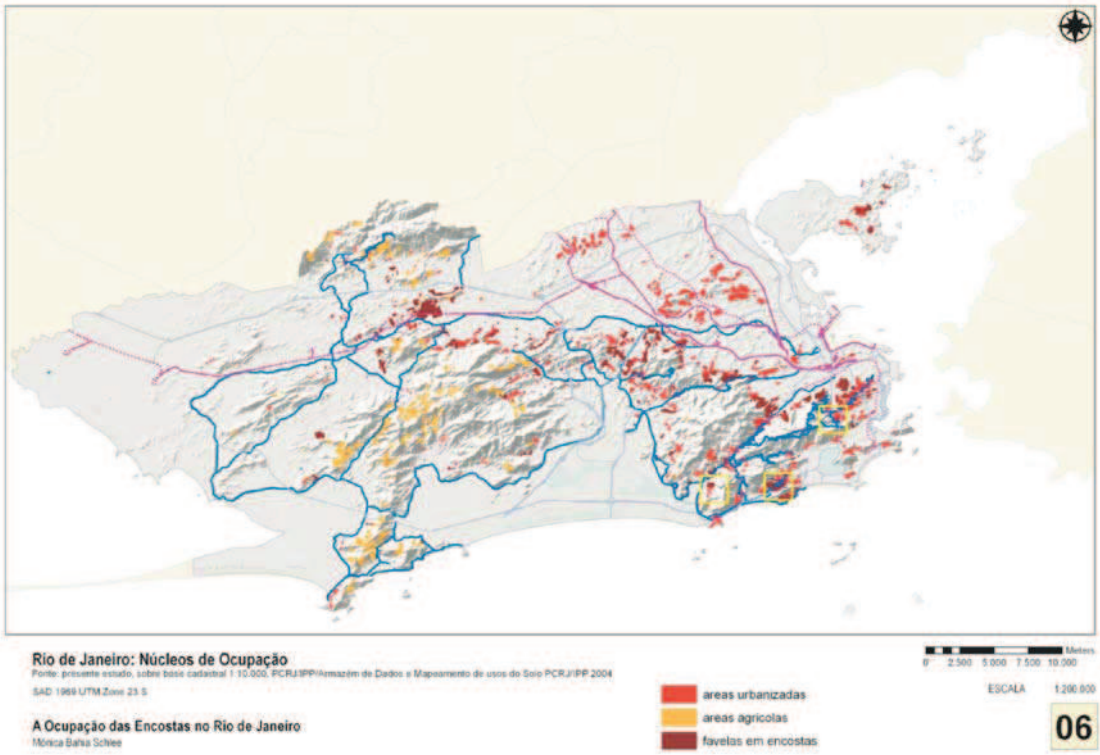


Table 10: City: Urban area uses above the 60-meter elevation

Land Use	Area (square meters)	Area (ha)	%
Dwellings (formal)	12,221,100	1,222	45
Dwellings (informal)	13,117,038	1,312	48
Leisure	644,786	64	2
Areas without buildings	451,031	45	2
Institutional uses (healthcare and education)	318,954	32	1
Institutional uses (other) and public infrastructure	269,361	27	1
Commerce and services	119,866	12	0
Industrial	51,934	5	0
Transport	5,873	1	0
Total	27,199,943	2,720	100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/ DIG – Gerência de Cartografia, 2004

Table 11: City: Urban area uses above the 100-meter elevation

Land Use	Area (square meters)	Area (ha)	%
Dwellings (formal)	3,752,512	375	40
Dwellings (informal)	5,179,478	518	55
Leisure	286,105	29	3
Areas without buildings	20,893	2	0
Institutional uses (healthcare and education)	55,064	6	1
Institutional uses (other) and public infrastructure	93,454	9	1
Industrial	25,419	3	0
Transport	2,932	0	0
Total	9,415,857	942	100

Source: this study, after land use mapping, Instituto Municipal de Urbanismo Pereira Passos – IPP/ DIG – Gerência de Cartografia, 2004

As shown in Table 11, above the 100-meter elevation dwellings are still prevalent, representing nearly 95 percent of the total occupied area in 2010 (Censo IBGE, 2010), and another 3 percent is used by leisure facilities and 2 percent by institutional facilities. Industrial use exists, but it is not significant.

Over 70 percent of open spaces above the 60-meter elevation is covered with forest vegetation in different successional stages. In 15 percent of these open spaces, the forest was replaced by invasive grass species. Above the 100-meter level, over 75 percent of the area has tree cover. Grass vegetation is found mainly on the north and west slopes of the Tijuca and Pedra Branca massifs and on isolated mountain ranges.

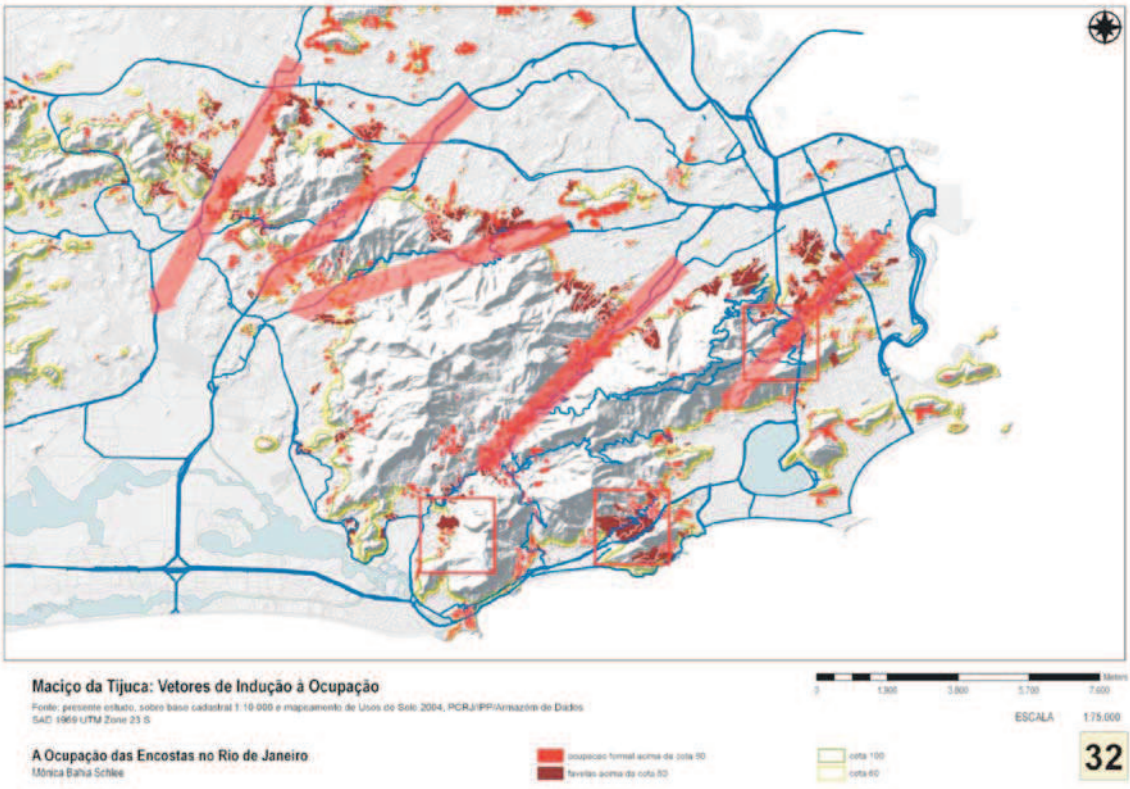
How did these strips originate? What processes are associated with this configuration in the Tijuca Massif?

As the city grew, rising real-estate prices in the south zone along the seafront encouraged the construction of roads across the massifs, to facilitate mobility towards the shore and create new areas attractive to development. Some city expansion vectors crossed the Tijuca Massif from northeast to southwest, inducing the occupation of the massif by high and middle-income strata, which were followed by the low-income strata.

In addition to the pressure exerted by occupation along the borders, these axes originated and connected several clusters (nuclei) of formal and informal occupation. The first axis linked the downtown area to the south zone and originated the Santa Teresa district. Another one connected the Tijuca district to the Barra da Tijuca district over a huge valley bottom whose occupation gave rise to the Alto da Boa Vista and Itanhangá districts. A third one connected the Grajaú and Vila Isabel districts to the Jacarepaguá and Barra da Tijuca districts. The first clusters (nuclei) of occupation were established along these axes.

As Abreu (1987, 1994, and 2005), Heynemann (1995), and Soares (2006) have demonstrated, the urban occupation process on the slopes of the Tijuca

Figure 5: The main vectors that induced the occupation of the Tijuca Massif. Source: Schlee, 2011.



Massif started with the decline of coffee farming in the 19th century. That is when territorial disputes grew fiercer and, consequently, the conflicts between the aristocracy of foreign origin, former slaves and *quilombolas*, and the Portuguese-Brazilian middle class intensify. The decline of farming on the slopes of the Tijuca Massif, the rise in land prices driven not only by large landowners but also by small land renters pushed out of the core of the city by the huge urban reform of the turn of the 20th century, and the move of the textile industry to outside the city boundaries, coupled with the opening of new roads and the building of tram lines, have caused a gradual occupation of this massif, both by wealthier as well as poorer families, who settled along the massif's borders and circulation axes (Abreu 1987, 1994; Bonduki, 1998; Vaz, 2002; Silva, 2005). The privileged location of the Tijuca Massif, the closest to downtown Rio de Janeiro, and the uneven distribution of the labor force and labor spaces within the city enhanced this process.

Although public land predominates on the slopes of the Tijuca Massif due to the existence of the Tijuca National Park and the peripheral forested reserves originating during early land parceling, most of the slums studied are situated on private, rather than public, landholdings. The *favelas'* processes of informal occupation stemmed from a variety of situations, ranging from collective land acquisition, permitted occupation consented by original owners or by religious institutions to invasion and irregular occupation of non-legalized parceling, to non-implementation of community facilities by the public government, as demonstrated by Marx (1991), Abreu (1994 e 2001), Silva (2005), and Schlee (2011).

Formal and informal urban occupation started simultaneously in the three investigated clusters, in spite of singularities inherent to local processes. In all three case studies, we noticed a clear association between the current configuration of urban occupation and landownership and past land processes. The gradual process leading from a religious and territorial defense use to farming and housing gathers similarities and specific aspects in the three territories investigated. Catholic orders owned land both in the Cosme Velho and Alto Gávea districts. These properties were gradually transferred using different means to other social agents (SCHLEE, 2011). As described by Abreu (2001), private owners used to donate plots to the Catholic church or sorority religious institutions to shelter their workers. In time, those areas gradually ceased to be administered by the church, were sold or transferred to the residents and became more dense due to migration and the lack of a social housing policy. The presence of the working class dates back to the pre-urban period, suggesting an interwoven relationship between these different strata for many decades.

As farming gradually declined and the mountains and forests became increasingly valuable for the foreign and local elites, rural properties and country dwellings (*chácaras*) sprouted in these areas, initially with peri-urban characteristics, used as second residence (ABREU, 1987; CAVALCANTI, 1997). The power relations of the elites ultimately superseded the religious orders in the occupation of the hillsides. However, the latter maintained part of their properties to house churches,

schools, and hospitals, as seen in the areas studied (SCHLEE, 2011). Larger farms and second residences (*chácaras*) gradually split into smaller properties during the 19th century (CAVALCANTI, 1997; SCHLEE, 2002).

The role of urbanistic legislation

Urban planning legislation played a prominent role on the process of production and reproduction of the landscape of the city of Rio de Janeiro. From using river water, logging firewood, and producing charcoal for the city dwellers to the fleeting and devastating coffee farms, the first use of the hillsides was mainly associated with a utilitarian function, exploiting natural resources for productive purposes. Throughout the city development process, the expansion of urban occupation of its hillsides relied on a superposition of different legal instruments enacted to control and regulate buildings and parceling of private property.

Zoning in Rio de Janeiro was first applied as an instrument of urban planning and management in the 19th century, and was consolidated by a number of ordinances over the 20th century, as demonstrated by Borges (2007). In 1918, Rio de Janeiro's urban area was first subdivided into three zones that comprised the downtown area and the areas situated in between the coast and the mountains, based on their geographical position and property value (BORGES, 2007). The gradual separation between residential and non-residential zones was consolidated in 1935. Since then, the city was divided into residential, commercial, port, industrial, and farming zones.

At the same time, the formalization of urbanistic mechanisms to regulate land occupation ushered in an extremely fragmented urbanistic practice. Since then, the application of zoning in hillside occupation regulation was heavily influenced by individual, case-by-case permits (Approved Alignment Projects - PAA and Approved Development Projects - PAL).

The gradual movement that parceled the slopes of the Tijuca Massif increased in the 1930s and 1940s, spreading to the hillsides in the south zone, north zone, and more recently to the slopes of the Jacarepaguá and Itanhangá districts. Most of the records of land development in the southeast and northeast section of the Tijuca Massif date back to that period. Under these urbanistic mechanisms (PAAs and PALs), the occupation of the Rio de Janeiro hillsides became a patchwork of fragmented, individual, and discontinuous small properties (SCHLEE, 2011).

Most of the properties located in Cluster 1 were registered in the 1930s and 1940s. The parceled land belonged to larger and smaller farms that already existed in the late 19th century. In Cluster 2, properties were registered mostly between the 1940s and 1960s. Cluster 3, properties were registered in the late 1940s and in the 1950s, 1960s, and 1970s.

Decree no. 5595/1935 required, for the first time in Rio de Janeiro, the need for securing a permit when developing a new property or subdividing areas facing public roads. It also required the donation of public open spaces (for

squares, parks and public buildings), the indication of property size, setback, maximum building areas, and open spaces in the interior of the plots and blocks.

Decree no. 6000/1937 turned the zoning instrument into a guideline for urban occupation and territorial management and relocated old factories situated next to rivers and streams in the city's valued hillsides, leaving behind workers without a permanent home, obsolete facilities, and valuable land waiting for a new use (Abreu 1987, Vaz 2002, and Silva, 2005).

On the other hand, although Decree no. 6000/1937 included a concern about the landscape aspect of Rio de Janeiro's mountains, such concern was punctual and disconnected from the concern about the impact of tall buildings on the landscape. The emphasis was on ensuring that the urban landscape could be seen from the mountains, and not the opposite. Until the late 1960s and early 1970s, there was little concern about protecting the mountains and the forest.

However, in response to the huge landslides of the late 1960s and the threat of impacting developments being approved for the hillsides of Rio de Janeiro's south zone, the ordinances enacted in the 1970s (decrees no. 3800/1970 and 6168/1973, and decree no. 322/1976, which are still in effect) represented a milestone towards landscape protection and recognition of the impacts of deforestation on soil stability on the hillsides and its association with the frequency of landslides on the city's massifs and mountains.

The first local initiative designed to protect the forests on the hillsides happened through state decree no. 3800/1970, which created a forest reserve zone (ZE 1). This was later ratified by municipal decree no. 322/1976, enacted to protect the vegetation on hillsides above the 60-meter elevation on the Pão de Açúcar, Urca, and Telégrafo mountains and on the Engenho Novo range; and above the 100-meter elevation on all other mountains and ranges of the municipality. This act also prohibited new private roads or new developments above the 100-meter elevation.

Decree no. E 6168/1973 prohibited private parties from building new roads above the 60-meter elevation on all Rio de Janeiro mountains. Buildings could be erected only on properties registered before 1973. This decree also determined that any land to be donated to public government in parceling licensing should be located below the 60-meter elevation. Based on decree-law no. 77/1975, which related building height with plot geographical position (hypsometry) in a specific area of the city (Lagoa Rodrigo de Freitas), decree no. 322/1976, expanded this ordinance to other areas of the city.

Decree no. 322/1976 maintained the ban on private development and roads in the areas located within ZE 1 (Forest Reserve Zone). Exceptions were properties previously registered on Approved Development Projects (PAL) facing known public roads. The parameters defined encompass an area of at least 10,000 square meters; residential use; single-family buildings and properties; up to two floors for buildings of any nature; minimum open space ranging from 80 percent to 90 percent of the property, depending on its size; and a minimum frontal setback of 5 meters (decree no. 322/1976, article 166). This ordinance did not provide any guidelines for soil permeability and elimination of native vegetation.

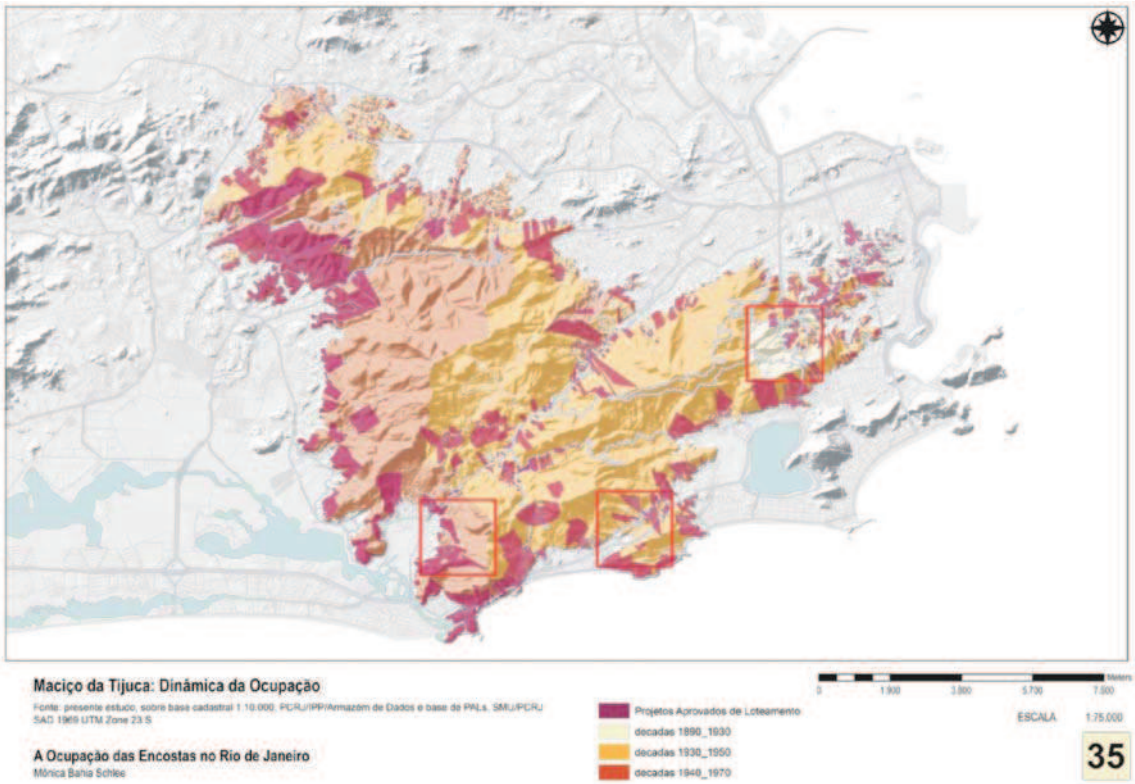


Figure 6: The occupation dynamics of the Tijuca Massif. Source: Schlee, 2011.

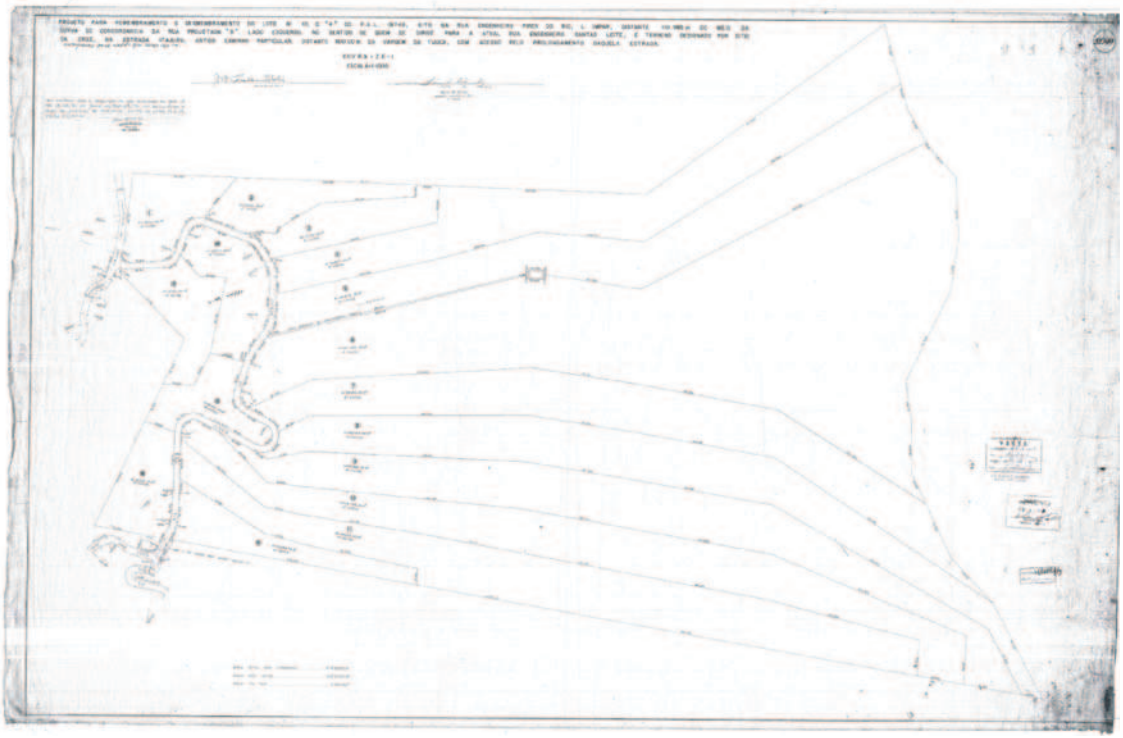


Figure 7: Example of an Approved Development Project. This one, no. 35149, was registered in 1978 and is located in Itanhangá (Cluster 3). Plots are extremely elongated and, according to the ArcGIS mapping, they extend into the Tijuca National Park. Source: PCRJ/SMU/GCT; Schlee, 2011.

The 1976 decree officially declared unoccupied areas or developments that were not fully legal by the date of its enactment "*non aedificandi.*" The act also defined, for areas bordering forest reserves between the 60-meter and 100-meter elevations, sparsely distributed single-family homes, which corresponded to ZR-1 (urban residential zone), and to ZR-6 (farming zone). By regulating building height in these zones through a provision that correlated building height and ground level, this ordinance intended to gradually reduce the height of the buildings towards the mountains. These provisions played a key role in forming the strips that characterize the border zone between the forest and the urban fabric on Rio de Janeiro hillsides. They defined a gradient in terms of building density and height and, consequently, a protection grading for the landscape (SCHLEE and ALBERNAZ, 2009; SCHLEE 2011).

Since the 1980s, as public authorities gradually took notice of the social dimension of the housing problem, ordinances were enacted to ease urbanistic and building standards and to legalize occupation on the hillsides, as well as to ensure the profit of the real-estate business in some areas of the city. Municipal decree no. 8321/1988 created more permissive conditions for occupying the hillsides than those provided under prior acts (1970, 1973, and 1976). In the same year, decree no. 7976/1988 changed decree no. "E" 6168/ 1973 in the northwest zone of the city. Even though decree no. 322/1976 defined zones of sparse occupation on the boundaries of the forest reserves protected by ZE-1, in the north and west zone of the city (where property prices were lower) more permissive zones became common on slope boundaries, including permits for higher buildings (SCHLEE and ALBERNAZ, 2009 and SCHLEE, 2011; SCHLEE, 2013).

In relation to slums, the legal instruments enacted since the 1990s have generic and simple parameters. In terms of use, they allow any activities supplementary to residential use, provided they do not pollute; do not bother the neighbors; do not imply trading or storing scrap material, flammable products (other than paints and varnishes) and explosives, liquefied petroleum gas, guns, and munition. Few ordinances determine limits or restrictions to occupation, as is the case of Rocinha, which was declared an Area of Special Social Interest under law no. 3351/2001. In 2007, Rocinha underwent a zoning process that divided it into sectors and defined the maximum number of floors allowed under this zoning. It also delimited areas unsuitable for occupation. However, this act did not define requirements for ventilation, hygiene, and structural safety. Moreover, the act designated geological and geotechnical risk areas and restricted building height in an incomplete and inconsistent manner. Regarding building height, in some sectors the defined height is higher than existing average and in other sectors it is lower. No criteria were established to explain and avoid these discrepancies[6].

In the city of Rio de Janeiro, land use and occupation ordinances never actually focused on regulating open spaces. Rules governing the allocation of public areas for this purpose were part of the Land Parceling Regulation (RPT), created under decree no. E 3800/1970 and under

[6] For a comparative analysis between the situation of Rocinha's buildings in 2009 and the parameters defined under the above act, see Consórcio Mayerhofer & Toledo, MPS e Locus, 2009.

decree no. 322/1976 (articles 52 and 53), and apply only to very large areas. Under the RPT, properties of more than 30,000 square meters owned by only one party must donate only 6 percent of their total area for public use, in the form of squares, parks, open spaces, or public facilities. Decree no. E 3800/1970 also determined that any parceling under 30,000 square meters having over 50 individual lots should set aside a recreation area equivalent to at least 12 square meters per lot, with a minimum average width of 10 meters. This percentage was later reduced to 3 square meters per housing unit.

Although in a contradictory manner, legislation played a key role as an active agent of transformation and protection of the landscape on the city's hillsides. The reach of its performance is simultaneously amplified and masked by its double side. On the one hand, legal instruments and management procedures promoted the property parceling of a significant portion of this territory, prioritized certain uses, and banned others, prompting occupation and leaving behind environmental and social liabilities that must be addressed. Urbanistic ordinances of the 1970s helped to protect the hillsides and urban forest before the establishment of the first municipal Conservation Units in the mid-1980s under several environmental acts and decrees (SCHLEE 2009, 2011 e 2013)[7]. Thus, Rio de Janeiro represents a singular case, where hillside protection by urbanistic legislation preceded protection by environmental and/or cultural legislation. Even so, public authorities have not been successful in preventing irregular occupation on the slopes of the Tijuca Massif or even on the slopes of the Tijuca National Park, which has been violated not only by low-income occupation but also by middle and upper-class gated neighborhoods, which sometimes also ignore the legislation.

[7] In 2004, 16 percent of the areas above the 100-meter elevation were protected exclusively under urbanistic legislation (ZE-1).

The restriction to hillside occupation represents a complex issue and express conflicts of interest and clashes when ordinances were designed. The legislation still lacks effective provisions that are technically suitable for sustainable management, adequate distribution of open spaces, effective protection of landscapes, and stabilization of the hillsides.

The mixed strips

The analyses confirmed the existence of the strips initially detected, which are associated with the axes that worked as occupation vectors and with the strategy of occupation restriction based on altimetry adopted by the municipal urbanistic legislation established in the 1970s. This legislation created a gradient of occupation restrictions associated with the 50-meter, 60-meter, and 100-meter elevations. This was the correct legal strategy within the limits of knowledge available at the time it was designed, considering it had to be applied to zoning at a time when more comprehensive scientific studies on the vulnerability of the hillsides and the risk of landslides were still incipient in Brazil. However, as demonstrated above, the urban occupation processes of the slopes of the Tijuca Massif are much more complex and imbricated. Both the configuration and the limits

of urban occupation on Rio de Janeiro hillsides do not exactly match the elevations used as parameters by urbanistic legislation, because a large portion of hillside occupation predates the law. Formal and informal occupations are highly contiguous and complementary and extend as far as the 300-meter elevation (in Gávea district), and up to the 500-meter elevation (in Alto da Boa Vista).

These strips form a gradient of urban occupation and protection of the forest, in which internal strips (mixed bands) have experienced more dynamic transformations and where social and environmental stress and conflict are more evident, impacting external strips. These strips form a gradient of occupation, where the inner strips (mixed bands) are the ones that suffer the most dynamic changes, affecting and impacting the outer ones. Within these mixed bands, high-income strata neighborhoods and *favelas* (slums) establish contiguous and complementary relationships among themselves. These mixed strips are also areas with predominant hybrid open spaces, which can help to challenge the physical limitation imposed by abrupt barriers that prevent the contact and the interaction between diverse social strata.

The first internal strip, which mixes forest fragments and urban clusters, in which forest prevails (a mix of forest and dispersed clusters), corresponds to the open spaces above 100-meter elevation delimited under the Approved Development Projects (PALs), which cannot be identified by satellite images, but which are registered in these documents. The second internal strips is a mix of dispersed urban clusters (which encompass regular and irregular occupation in urbanistic and land ownership terms) and forest fragments, in which urban occupation prevails (a mix of forest and more dense urban clusters), which corresponds to the area actually occupied. The external strips, which correspond to the forest and urban fabric matrices, represent two extremes in permanent opposition discussed and treated separately by urbanistic and environmental legislation.

The condescending attitude by city planning and management towards the excessive fragmentation of the urban territory and its discontinued formation has resulted on the one hand in an urban fabric that lacks interconnection. It is connected only through the main circulation arteries. On the other hand, it produced a complex and multifaceted land ownership situation, in which open spaces tend to gradually reduce in area, as a result of additions in building area, the elimination of native vegetation and the increasing in soil impermeability.

The occupation clusters (nuclei) within the mixed bands have unique nuances, both in relation to each other as well as internally, in terms of social strata. In the three investigated clusters, occupation in formal or regular areas developed uphill the valley bottoms, from winding roads generally set in diagonal to the elevation contour lines and spreads out like tree branches. Closed blocks are rare, once the back of the properties usually face the forest. In formal occupations, open spaces predominate. In slums, the opposite prevails. Intense segregation between the public and the

private domains and the prevalence of private spaces over collective spaces are common characteristics of formal and informal areas on Rio de Janeiro hillsides.

There is a clear grading in terms of density between and within the three clusters, and between the regulated subdivisions and the *favelas* (slums) in each of them. Proximity to water and to access ways, particularly roads, seems to guide social stratification within the slums. The analyzed slums vary greatly in terms of habitability and urban conditions. Inside the slums there are standards similar to those found in other Rio de Janeiro districts; and other extremely precarious dwellings, generally found on the outskirts of the slums or in areas of difficult access, emulating social and spatial differentiation seen in the city as a whole.

In the formally occupied areas (middle and high-income strata neighborhoods) of the investigated territories, occupation in higher elevation areas is more sparse and valued. In slums, the situation in terms of land value is inverted in two of the three analyzed territories (Cluster 1 and 2). In the slums located in these clusters, the higher the elevation the less consolidated is the occupation and the more precarious are the settlements, as already pointed out by Leitão (2009). Dwellings are more concentrated along the access roads and main internal connecting paths, where there is also a higher diversity of uses. In all the analyzed slums, the most recently occupied and most precarious areas, regardless of the level of occupation

Figure 8: Urban occupation in the Tijuca Massif. Source: Mônica Bahia Schlee, 2011.

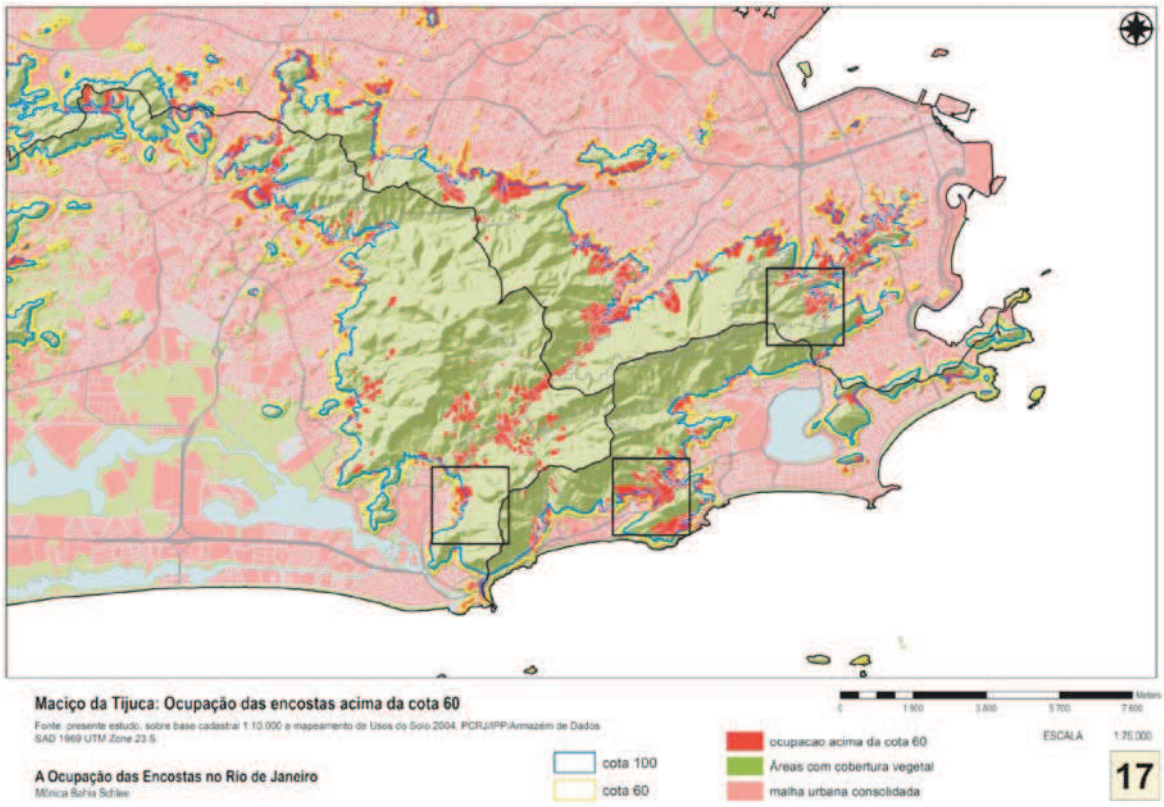
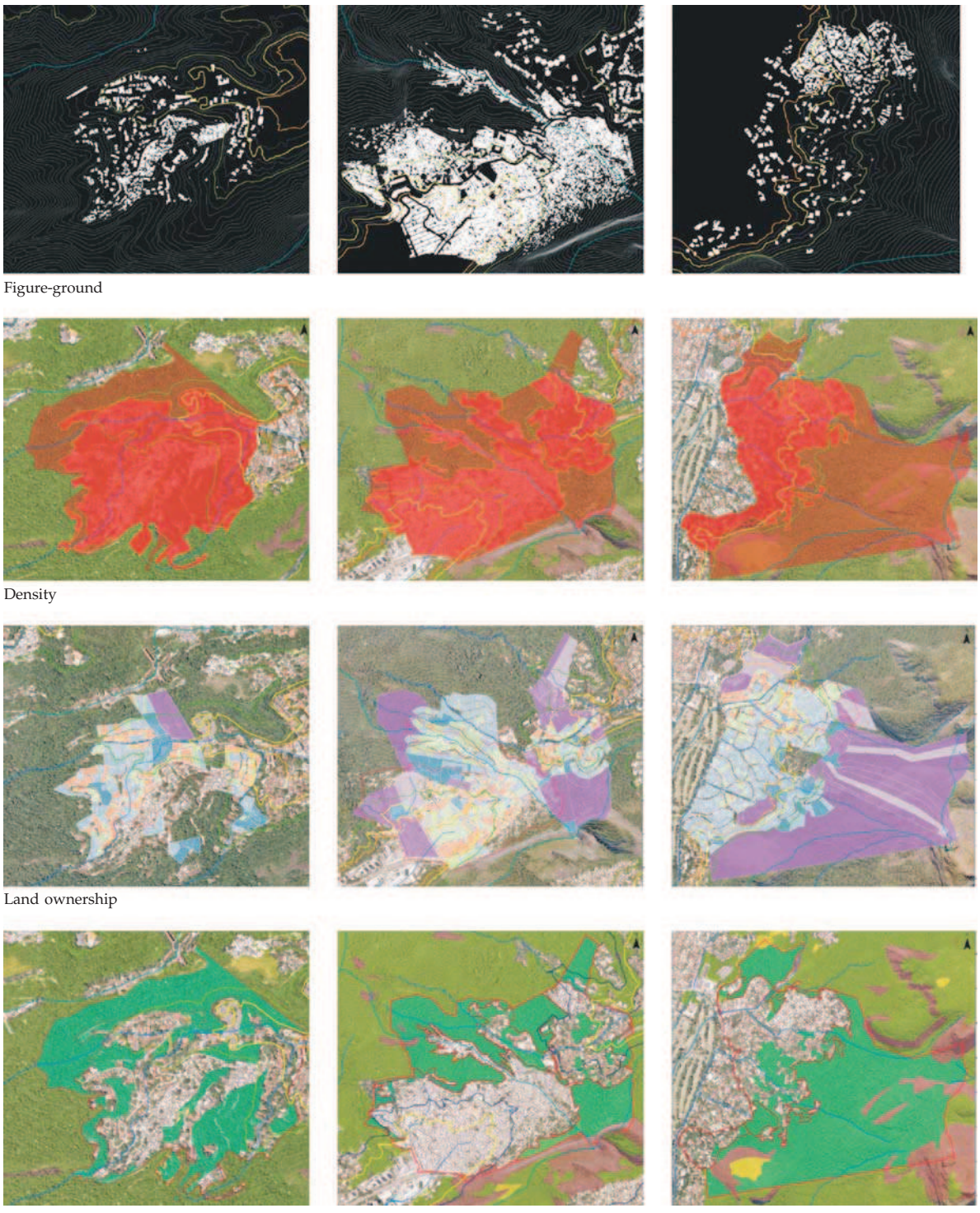


Figure 9: Comparative analyses of the three territories. Source: Mônica Bahia Schlee, 2011.



density, are generally located in fragile areas, which are more prone to landslides and flooding.

In Cluster 3, located nearby the Rio Cachoeira basin, in spite of a correlation between altimetry and the reduction in occupation density and in the increase of land value in formal areas, occupation characteristics in Floresta da Barra slum are entirely different, with well delimited properties and ample private open spaces found upstream the occupation, similarly to the adjacent formal occupation, as a result of a development process that was not concluded (and legalized) because the developer did not find it advantageous.

Cluster 1, located at the Carioca River basin, presents a more compact urban occupation than the other analyzed territories. In spite of a well-consolidated urbanization in this area, several vacant lots were identified. While planned parceling occurred along the valley bottoms, the *favelas* (slums) were set half way up the slopes.

Cluster 2, located within the Rainha River basin, presents a dramatic contrast between the formal and informal fabrics, in terms of density, building size, and parceling. The formal territory in Cluster 2 is less compact and subdivided than in Cluster 1 and less sparse than in Cluster 3. Rocinha, in turn, is the densest of the three investigated slums, especially downstream from Estrada da Gávea, the main road that crosses the occupation facing São Conrado district. Internally, there are remaining large lots and open spaces along Estrada da Gávea and on the outskirts of the settlement. As the occupation approaches the forest and the rocky escarpments, it becomes increasingly sparse, precarious, and scattered.

In Cluster 3, there is a strong contrast in terms of density, building size, and parceling of the areas occupied by the different social strata. However, both the formal and informal fabrics are the sparsest of the three areas analyzed. Inside the informal area, the higher density and fractioned parceling of the fabric occurs in the lower portion of the basin, and more spacing in the upper portion. In more recently occupied formal areas, such as the ones in Cluster 3, the densest areas, with smaller lots and buildings, are located in the lower portion of the basin, where the fabric is more subdivided and compact. In the upper portion of the basin, the lots and buildings are larger and more spaced, complying with the parameters defined in the legislation. Similarly, but driven by different causes, slums are denser downstream, where occupation is more consolidated. Upstream the structures are more precarious and scattered.

Public land predominates on the slopes of the Tijuca Massif due to the existence of the Tijuca National Park and the peripheral forested reserves. Contrary to widespread belief promulgated by the city government and the media, most of the studied slums are situated on private, rather than public, landholdings.

In relation to parceling, formally occupied areas in all investigated territories are a result of the land development system in which large areas were subdivided into smaller ones, implemented individually and separately at different times, in a process that resembles a warped patchwork. Most

parcels in the upper Carioca watershed date from 1930 to the late 1950s, and have sinuous designs with some inspiration from variations of the Garden City (*Cidade Jardim*). They consist of lots ranging in size from 225 m^2 to over 100,000 m^2. In the upper Carioca watershed (in the area that comprises the analyzed reach in Cosme Velho District), although small lots predominate, almost half of the urbanized area belongs to a few owners. One single lot of 10,000 m^2 occupied 10% of the total parceled area. Approximately 20% of the total number of lots range between 360 and 600 m^2, and about 40% range between 1,000 and 5,000 m^2.

In terms of land use, formal settlements tend toward mono-functionality, with a strong predominance of residential use and, secondarily, institutional uses (educational, cultural, religious and welfare). In the slums, the picture is quite different. In general, there is a great diversification of land uses, although residential use also predominates. Mixed use is quite impressive, with commercial use on the ground floor and residential use on upper floors. Commercial use mainly concentrates on the main access roads and main pedestrian alleys. Concerning institutional use, public education and religious uses of different orientations predominate.

In relation to open spaces, a common feature of all three investigated territories is the existence of linear green corridors that intercept and connect the remaining forest fragments in the back of private lots located at different elevations, which follow the contour lines, crossing the patches of occupation and connecting them crosswise. Open spaces with an environmental function (remaining forest fragments or reserves) usually concentrate on the higher portions of the watersheds. Conversely, open spaces with a leisure function (squares and public spaces) are rare on the analyzed hillsides. The small squares located at road intersections are a frequent feature. Forest reserves not donated or ceded to public government remained under private ownership and play an important role providing geo-biological support as well as reducing urban heat-island effects.

Outdoor recreation and daily interactions in formal settlements have become entirely private, with restricted access. Most of the private open spaces are out of sight of pedestrians on the streets, suspended and hidden behind vine-draped walls. In slums, open spaces used for recreation are located in the access or along the edges of the settlements, wherever there is available space. In most cases, these areas originate from public municipal initiatives, such as the Favela-Bairro project. In contrast, the small and scarce collective open spaces found in the middle of slums are shaped by a gradual occupation process and frequently modified and reorganized, as a result of a collective production, and combine different functions.

Circulation systems in the three analyzed territories consist of winding roads through the hillsides that join formal and informal settlements. These roads were opened generally in diagonal to the slopes or, in some cases, perpendicularly to the contour lines to overcome the steep slopes. Occupation clusters (nuclei) on divides are less common. Access to the slums in the investigated territories is provided by extensions of traffic roads that are part of the formal urban grid. Connecting paths between the initial

nuclei defined expansion vectors. These paths are branchy but not continuous and result in poorly connected locations. Of the three informal areas investigated, the most unique in terms of layout is Floresta da Barra, which developed from a ring-shaped road system, a solution found in more gentle slopes of rounded hills.

Conclusions

The processes that originated the occupation of the Rio de Janeiro hillsides, the efforts to protect forests, and the influence exerted by legislation since the 19th century guided the landscape structure in the city's mountainous areas, but also resulted in polarization, between the geo-biophysical and the sociocultural dimensions, trending towards spatial segregation among the three types of matrix: the forest matrix and the territories occupied by middle and high-income strata and the slums.

According to Villaça (1998), the complex urban structure of the city of Rio de Janeiro, the result of several forces pushing towards opposite directions and of several economic crises, and also the territorial regulation and planning process applied in the city (SCHLEE, 2011), originated a peculiar strategy of intra-urban spatial segregation. The social mix of the past, the process of population formation, and the urban growth in Rio de Janeiro have driven a spatial proximity of groups belonging to extreme opposites of the social pyramid on the city's hillsides, even if entirely isolated and delimited by walls, fences, or imaginary borders that define the territory of each social group.

It is essential to understand the structure and the dynamics of the landscape to devise suitable strategies to protect and manage it, as well as to ensure its resilience and regenerative capacity. We still lack management mechanisms that provide a systemic, continuous, and applied process of integrated (urbanistic, landscape, and environmental) planning, control of use and occupation in these areas, and the management of open spaces. This would help us mediate between environmental protection and the fair appropriation of urban land.

To do so, we must invert the planning and management logic and the strategies of planning the Rio de Janeiro mountainous landscape, still framed by a fragmented and stratified view that focuses on the built space, and adopt a systemic view of landscape with a focus on the open spaces, which considers the coexistence of distinct temporalities and the dynamics of change, reflecting the consensus between production and transformation agents, and ensuring the involvement of all social segments in the discussion and agreement of regulations.

Urban planning, management, and the logic of formal and informal occupation in the border between the forest and urban fabric on the hillsides must undergo an adjustment process, towards a regenerative urbanism, under which open spaces play a structuring role in the connection, articulation, and resilience of the landscape in face of geological

risks and in mitigating the antithesis between the forest, formally occupied territories, and slums, which are still seen as homogeneous and isolated units. Focusing on the relationships between open spaces and built spaces provides a non-fragmented vision of the social processes of hillside occupation, escaping the entrapment of the current dichotomic logic.

To enable the articulation between social and environmental appropriation of the hillsides, the collective appropriation of the open spaces, and the protection of the Atlantic forest in the slopes of Rio de Janeiro, it is necessary to plan the connection, location, distribution, and use of open spaces located on the hillsides, ensuring their multi-functionality and their collective appropriation. Only then can we design an effectively integrated zoning process, from the urbanistic and environmental perspectives.

In the face of this context, the reorganization of open spaces on hillsides, using their potential as a connection between the forests and the city, can produce a new urban planning concept, in which the impacts of urban occupation on the forest ecosystem are softened and in which social interactions can help mitigate spatial segregation and social polarization.

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