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Environmental Justice: A Case of Socio-environmental Vulnerability in Rio de Janeiro

Gabriela da Costa Silva

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Article abstract

Environmental justice addresses the unequal environmental burden often borne by minorities and low-income populations. In Brazil, many studies confirm extreme socio-environmental inequities in urban areas. Analysis based on socio-environmental vulnerability allows us to understand the intra-urban spatial distribution of socio-environmental differences and to provide insight for the development of planning policies that enhance the capacity of communities to respond to multiple risks (social, environmental, etc.) (Mendonça, 2004). This study examines the levels of socio-environmental vulnerability in the Jacarepaguá lowlands of Rio de Janeiro, taking into account the existing strengths and limitations of public administrations in their efforts to balance private and public interests in regards to environmental justice.

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Dossier thématique *Aspects de l'environnement urbain au Brésil*
Aspects of the urban environment in Brazil Special Issue

ENVIRONMENTAL JUSTICE: A CASE OF SOCIO-ENVIRONMENTAL VULNERABILITY IN RIO DE JANEIRO

Gabriela DA COSTA SILVA

RÉSUMÉ

La question de la justice environnementale renvoie aux inégalités dans le fardeau environnemental que subissent le plus souvent les minorités et les personnes à faible revenu. Des recherches effectuées au Brésil ont recensé des situations d'injustice socio-environnementale grave dans les zones urbaines. Cette analyse s'intéresse plus particulièrement à la vulnérabilité socio-environnementale afin de déterminer dans quelle mesure les différences socio-environnementales se répartissent dans l'espace intra-urbain et de constituer une base de connaissances pour que la capacité de réaction des communautés aux risques multiples (sociaux, environnementaux, etc.) soit prise en compte dans les décisions en matière d'urbanisme (Mendonça, 2004). Cette étude a pour objet d'évaluer les niveaux de vulnérabilité socio-environnementale dans la région des basses-terres de Jacarepaguá à Rio de Janeiro. Ce faisant, nous abordons les points forts et les limites des pouvoirs publics dont le rôle est de concilier les intérêts privés et publics en matière de justice environnementale.

MOTS-CLÉS ▪ justice environnementale, vulnérabilité socio-environnementale, indicateurs socio-environnementaux

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ABSTRACT

Environmental justice addresses the unequal environmental burden often borne by minorities and low-income populations. In Brazil, many studies confirm extreme socio-environmental inequities in urban areas. Analysis based on socio-environmental vulnerability allows us to understand the intra-urban spatial distribution of socio-environmental differences and to provide insight for the development of planning policies that enhance the capacity of communities to respond to multiple risks (social, environmental, etc.) (Mendonça, 2004). This study examines the levels of socio-environmental vulnerability in the Jacarepaguá lowlands of Rio de Janeiro, taking into account the existing strengths and limitations of public administrations in their efforts to balance private and public interests in regards to environmental justice.

KEYWORDS ▪ Environmental justice, socio-environmental vulnerability, socio-environmental indicators.

Author's coordinates: Gabriela Da Costa Silva, Postdoctoral Researcher at Université du Québec à Montréal, Postdoctoral Research Fellow at Foreign Affairs and International Trade Canada,e-mail: gabriela_silva@UCS.INRS.Ca

1. ADDRESSING ENVIRONMENTAL JUSTICE THROUGH SOCIO-ENVIRONMENTAL VULNERABILITY

The paradigm of environmental justice adopts a holistic approach to formulate public policies. It is based on citizen participation in environmental decisions and communities' empowerment, assuring inter-sector cooperation, inter-agencies coordination, and innovative partnerships' strategies (Bullard, 2004; Heiman, 1996). Increased community participation in government decision-making produces many important benefits, including the reduction of potential environmental risks (Roseland, 2005).

Studies based on socio-environmental vulnerability provide guidelines for public administrators in decision-making processes regarding environmental management and planning (Villa and McLeod, 2002; McHarg, 1969). Socio-environmental vulnerability is the result of marginal and economically deprived groups (social vulnerability) settling in areas of environmental risk or degradation (environmental vulnerability) (Alves, 2006). Studies have shown that an uneven provision of urban infrastructure and services is a reflection of social inequality. Universal access by the population to public amenities and utilities is a key element of distributive justice (Harvey, 1976).

In many Brazilian cities, the spread of areas of privilege, which contributes to the increase of social segregation, is a consequence of socio-political inequalities (Silva, 2007). Jacarepaguá Lowland, a major area of urban expansion in Rio de Janeiro, is an example of the difficulties facing state and municipal governments in promoting urban sustainable development. Real estate interests have shaped the overall pattern of urban development. On the one hand, the evolution of the urban fabric is co-determined by public administrations and real estate companies dedicated to the housing and infrastructure needs of the wealthy. On the other hand, the area's rapid urbanization is increasing stress on infrastructure, compounding the inefficiency of housing for the low-income residents and water and sewerage collection and treatment systems. Effluent discharges from these facilities have caused significant environmental impacts.

This paper examines the levels of socio-environmental vulnerability within the lowlands of Jacarepaguá, taking into account the various ways in which public administrations attempt to balance private and public interests with regards to environmental justice. Social and environmental indexes are used to assess the vulnerability of local communities to inadequate urban infrastructure and to determine the socio-environmental vulnerability of the study area (see Figure 1).

2. THE IMPORTANCE OF THE JACAREPAGUÁ LOWLANDS IN THE URBAN DEVELOPMENT OF RIO DE JANEIRO

The development of Rio de Janeiro in both social and economic terms is characterized by the pattern of urban sprawl which in some cases can be considered as a cause of environmental injustice. The production of urban spaces for the elite began in the 1870s, when economically privileged social classes moved to the south in areas benefiting from government sponsored transportation programs (Leitão, 1995). Before 1930, the wealthy moved to the "new" neighborhoods3 located in the south: Copacabana, Ipanema, Leblon and Gávea. Bourgeoisie, or middle-income classes, lived in the "old" neighborhoods of Catete, Laranjeiras, Flamengo and Botafogo in the south, and Andaraí, Vila Isabel, Tijuca, Aldeia Campista and Rio Comprido in the north. The working, low-income populations settled in the industrial fringe of São Cristóvão and its suburbs (see Figure 2). State and municipal government authorities determined the patterns of occupation and urban development by investing in urban infrastructure for the middle and upper classes in peripheral areas in the southern and northern parts of the city while ignoring the fact that suburbs were home to the working class (Abreu, 1997).

[3] In this paper, we refer to "neighborhood" as *bairro* in Brazilian cities. A *bairro* represents the smallest planning unit defined by the municipal administrations and is also one of the census tracts used by the Brazilian Institute of Geography and Statistics (IBGE).

Source: IPP (1997)

Fig. 1 – *Jacarepaguá Lowland*

Source: IPP (1997)

Fig. 2 – *Jacarepaguá Lowland in Rio de Janeiro City*

From the end of the 19th century to the early 1920s, residential towers were built along the shoreline of Copacabana replacing the single-family dwellings. Urban density increased as the real estate boom in Copacabana continued throughout the 1950s (Leitão, 1995)[4]. Meanwhile, inefficient public transportation systems "encouraged" the working class to move closer to job opportunities in industry and services. The poor lived in slums on vacant land, especially in areas with difficult access, such as slopes, mangroves, or river banks (Abreu, 1997). In fact, the geomorphology of Rio de Janeiro, composed mainly by mountains and lowlands, determined the spatial dynamics of urban sprawl. Between the 1950s and 1970s, in order to improve vehicular flow and accessibility within the city, the state government invested in expressways, tunnels and overpasses (Abreu, 1997). After the 1970s, the built-up areas expanded westward along the shores of Ipanema and Leblon. Indeed, the "cooperation" between government and real estate companies helped concentrate development in the southern parts but increased segregation across the city along income lines. Since these neighborhoods were intended for high-income groups only, government engaged in slum clearance and was responsible for the relocation of displaced households. At that time, upper class households settled in the neighborhoods of São Conrado and Barra da Tijuca, which launched a population movement westward into the Jacarepaguá Lowlands and further expanded the city limits (Leitão, 1995)[5].

Before the 1970s, Barra da Tijuca with its geomorphologic characteristics and surrounded by the Pedra Branca and Tijuca hills was very difficult to urbanize and remained mostly uninhabited. Until then, the local government preserved the region as a rural and agricultural residential area under a specific legislation that defined it as Residential Zone 3 (ZR-3, Zona Residencial), according to the Agache Plan[6]. In 1950, the state authorities prepared a road network plan and a building facade plan to regulate urban morphology[7]. In 1956, the Mayor of Rio de Janeiro commissioned the architect and urban planner Lucio Costa to prepare a master plan for the Jacarepaguá Lowlands. Lucio Costa was also mandated to serve as head of a team of consultants (GT-BJ, Grupo de Trabalho da Baixada de Jacarepaguá)[8]. Its role was to define the plan intervention boundaries, building construction regulations, road construction models, private property limits, and the viability of new building construction projects.

The purpose of the plan was to urbanize Barra da Tijuca and the rest of the Jacarepaguá Lowlands by developing a new business center situated in the old historical part of the city of Barra da Tijuca, and by building the new commercial center of Santa Cruz[9]. The area emerged as a metropolitan hub that restructured urban space by joining and diffusing city centers, connecting the city from east to west (see Figure 3). The master plan would serve as well as a legal instrument to discourage predatory real estate activities and indiscriminate land occupation. Also known as the "Pilot Plan", it defined the area as Special Zone 5 (ZE-5, Zona Especial) (Cardoso, 1989) [10]. We emphasize that by 1963, the Doxiadis Plan[11] had already established that urban development be concentrated in the northern region of the Jacarepaguá Lowlands and link up with the new road network crossing north-south (Silva, 2004).

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[4] The 2000 Brazilian Census estimated population density in Copacabana to be six times higher than in Rio de Janeiro, respectively 333.6 inhab./sq km and 58.6 inhab./sq km (IPP, 2001c).

[5] Jacarepaguá Lowlands are divided into three administrative zones: Barra da Tijuca, Jacarepaguá and Cidade de Deus.

[6] Decree nº 6.000/1937 created the Residential Zone 3. The Agache Plan (1931), the first urban planning scheme after the infrastructure plans of Mayor Pereira Passos (1902-1905), proposed to build a link from the center of the city to Sepetiba and Santa Cruz passing through the Jacarepaguá Lowlands (Costa, 1969).

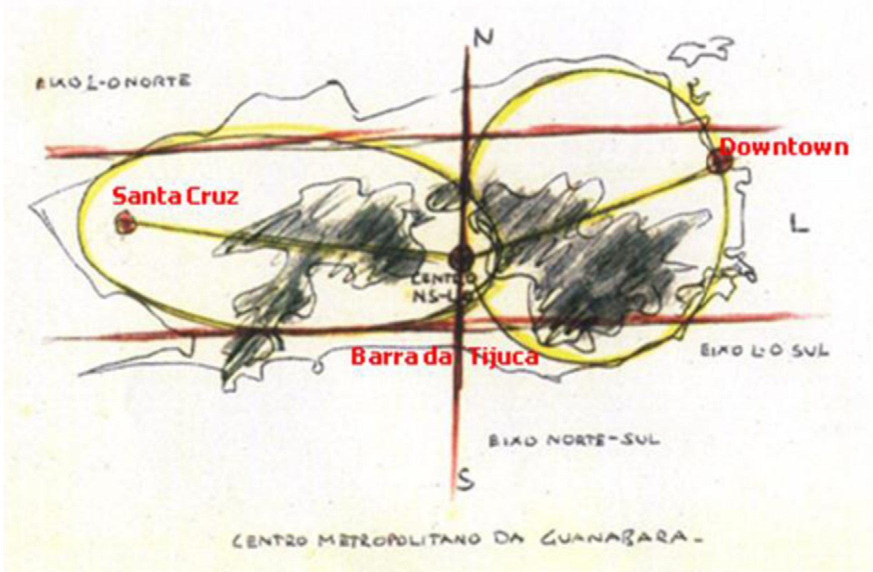
[7] P.A. nº 5596 established a building facade plan (*Plano de Alinhamento*), according to the road system plan conceived by the Road System Department (DER, Departamento de Estradas e Rodagem).

[8] In 1974, the group was transformed into the Superintendence of Development of Barra da Tijuca (SUDEBAR, Superintendência de Desenvolvimento da Barra de Tijuca). Between 1974 and 1979, SUDEBAR was in charge of urban development in Barra da Tijuca.

[9] The new center of Santa Cruz was included in the Doxiadis Plan of 1963 (Abreu, 1988).

[10] In accordance with the specific urban regulation for Special Zone 5 (ZE-5, Zona Especial), the Region of Barra da Tijuca was divided into 46 sub-zones, from A-1 to A-46 (Silva, 2004).

[11] In 1963, Governor Carlos Lacerda approved the Doxiadis Plan to urbanize the State of Guanabara, which was a former Brazilian state that existed between 1960 and 1975. The City of Rio de Janeiro is located in this territory (Abreu, 1988).



Source: Modified from Costa (1969)

Fig. 3 – *Urban plan for Jacarepaguá Lowland*

However, over the course of the last three decades the area went from being a residential-rural place of tranquility to a bustling residential-commercial place also known as "the Miami of Brazil". The rural landscape was altered as real estate agencies promoted and sold homes and apartments to middle and upper income classes. Government investments in urban infrastructure and the sprouting of slums also brought major changes to the morphology. From 1991 to 2000, the average growth index of the slum population in Barra da Tijuca peaked at 2.23, the highest in Jacarepaguá Lowlands where the overall population doubled (see Table 1). To this day, Barra da Tijuca continues to experience a sustained increase in demographic growth, one of the fastest growing regions of Rio de Janeiro. The number of inhabitants in Barra da Tijuca (XXIV RA, Administrative Region) grew from 2,580 in 1960 to 174,135 in 2000 (see Table 2). Its rate of growth was 21.91 times faster than Jacarepaguá (XVI RA), a neighboring administrative region which has also seen an increase in population due to Barra da Tijuca sprawl.[12]

Urban sprawl in the Jacarapeguá Lowlands (see Figure 4), especially in Barra da Tijuca, corresponds to the third phase of Rio de Janeiro's urban development (Cardoso, 1989). The first phase began when suburban sprawled towards the Santa Cruz Lowland area. The second phase occurred in the south, along the shores of Copacabana to Leblon, where occupation was limited to a strip of land between the sea and Mount Tijuca. During the third phase, the state government invested in road infrastructure to increase access to areas to the west and beyond to the Jacarapeguá Lowlands (Pinheiro and Pinheiro, 2001; see Figure 5 and Figure 6). The Jacarapeguá Lowlands represent 25% of the entire land base of Rio de Janeiro (293.42 km2 out of a total of 1,182.296 km2) while the wealthier areas to the south make up only 4%, or 43.88 km^2 (Silva, 2009).

Real estate agents and brokers have contributed to significantly improve this area's socioeconomic status by shifting their focus to the middle and upper class housing markets. Thus, the area's urbanization process helped further the interest of real estate promoters and consumers (see Figure 7). With a middle to high status, the Human Development Index (IDH) of Barra da Tijuca ranks fifth across Rio de Janeiro (see Table 3; IPP, 2001b).[13]

[12] The City of Rio de Janeiro is divided into five major planning areas called *Áreas de Planejamento* (AP), which in turn are divided into 33 administrative regions called *Regiões Administrativas* (RA). Jacarepaguá Lowlands are part of the municipal planning area 4 (AP-4), which is divided into three administrative regions: Barra da Tijuca (XXIV RA), Jacarepaguá (XVI RA), and Cidade de Deus (XXXIV RA). Each region is then divided into neighborhoods.

[13] The Municipal Human Development Index (IDH is a composite of the sum of the means of three indexes: Longevity Index (IDH-L), Education Index (IDH-E), and Income Index (IDH-R) (IPP, 2001b).

Table 1
Slum Population Growth in Área de Planejamento 4 (AP-4)

City and Administrative Regions (RA)	Homes 1991	Homes 2000	Growth Index	Population 1991	Population 2000	Growth Index
Rio de Janeiro	226,141	308,581	1.36	882,483	1,092,476	1.23
Jacarepaguá Lowlands	18,790	41,289	2.19	72,182	144,394	2.00
XVI RA. Jacarepaguá	14,847	31,952	2.15	56,817	111,448	1.96
XXIV RA. Barra da Tijuca	3,547	8,820	2.48	13,915	31,107	2.23
XXXIV RA. Cidade de Deus	396	517	1.30	1,450	1,839	1.26

Source: IPP (2001a)

Table 2
Demographic Growth of Barra da Tijuca Population*

City and Administrative Regions (RA)	1960	1970	1980	1991	2000	Growth Index
Rio de Janeiro	3,307,163	4,251,618	5,090,700	5,480,778	5,851,914	1.77
XVI RA. Jacarepaguá	164,092	235,238	315,623	428,073	506,760	3.09
XXIV RA. Barra da Tijuca	2,580	5,779	40,726	98,229	174,135	6.74

Source: Modified from IPP (2001c)

* It does not include slum population.

Source: IPP (1997)

Fig. 4 – *Jacarepaguá Lowland according to geomorphologic and hydrological marks*

Source: SMAC (2000)

Fig. 5 – *Barra da Tijuca and Lagoon Tijuca, 1955*

Source: SMAC (2000)

Fig. 6 – *Barra da Tijuca and Lagoon Tijuca, 1999*

Source: Silva (2009)

Fig. 7 – *Residential condominium in Barra da Tijuca neighborhood*

Table 3
Municipal Human Development Index (IDH) in Jacarepaguá Lowlands Watershed, from 1991 to 2000

Administrative Regions	Longevity Index (IDH-L)		Education Index (IDH-E)		Income Index (IDH-R)		Municipal Human Development Index (IDH)	
	1991	2000	1991	2000	1991	2000	1991	2000
XXIV RA. Barra da Tijuca	0.741	0.795	0.891	0.961	0.978	1.000	0.870	0.918
XVI RA. Jacarepaguá	0.731	0.780	0.892	0.933	0.770	0.819	0.798	0.844

Source: Modified from IPP (2001b).

Several reasons can account for this unprecedented scale and rate of urbanization. First, real estate agencies had based their marketing campaigns on natural features such as beaches, lagoons, and mountains to attract potential buyers. They "sold" the area to privileged families searching for security and leisure (Leitão, 1995). Second, one third of the area belonged to only four property owners who had hardly subdivided their land into lots. This form of land tenure contributed to the intensification of urban development. Third, in the 1970s and 1980s the federal government "helped" fund real estate agencies with housing lines of credits from the Housing Financial System (SFH, Sistema Financeiro de Habitação). In Barra da Tijuca, 25 to 30 floor apartment towers were constructed alongside axial roads and around small centers, which extended the built-up areas and increased population density (Cardoso, 1996; Pinheiro and Pinheiro, 2001). Between 1980 and 2000, population density in Barra da Tijuca (XXIV RA) increased by a factor of 4.25, in contrast to 1.15 in the city and 1.49 in Jacarepaguá (XIV RA) (IPP, 2001c). Finally, public investments in infrastructure mainly in the construction of the road network in accordance with the Pilot Plan increased the likelihood that real estate agencies achieve high profit margins and become a leading player in the growth and development of the urban fabric (Leitão, 1995).

The Pilot Plan has undergone several changes since its implementation. The most striking modification is the increase in land use density or intensity provisions. This was a direct result of pressure from the real estate lobby to persuade the municipal government to modify the building code (Ribeiro, 1990; Leitão, 1995). Most of the proposed changes to the original plan were approved in the late 1970s. For example, changes included raising the maximum building height regulations, and rezoning single-family to multi-family housing etc[14]. Moreover, Decree nº 324 which made the Pilot Plan legally binding was modified into Decree nº 3046/1981 following appeals by the real estate lobby[15]. Once this law was passed, building height regulations and lot subdivision requirements were altered to benefit private capital interests, allowing the construction of residential apartment hotel units all along the Barra da Tijuca seashore (Silva, 2004).The influence of private interests in public affairs has continued to this day, as new urban regulations were introduced in the plan (Schmidt, 2000). For example, the Municipal Law nº 2128/1994 established new planning guidelines: building heights, the urban growth boundary and building types and functions. Also, the Complementary Municipal Law nº 41/1999 approved the construction of residential apartment hotel units that had been prohibited in 1985 (Silva, 2004).

Under the new set of laws, the main beneficiaries were real estate companies. From 1998 to 2005, 58% of the total area zoned for development in the city (19,713,912 m2) was in the Jacarepaguá Lowlands (11,388,466 m2) (SMU, 2005b). In 2005, 46% of building start-ups in the city were located in the Jacarepaguá Lowlands (SMU, 2005a). Most of the private and public investments for the Pan-American Games 2007 held in Rio de Janeiro were concentrated in the Jacarepaguá Lowlands. The massive infra-structure projects are the most likely reason why rapid urban expansion took place. In addition, during 2005, investments were made primarily in residential areas, which represented 65% of the total investment for the city as a whole and 93% of the total investment in the Jacarepaguá Lowlands (SMU, 2005a).

[14] In 1984, the Parliamentary Commission of Inquiry (CPI, Comissão Parlamentar de Inquérito) of the City Council (Câmara dos Vereadores) received many accusations during the mayoral terms of Marcos Tamoio (1975-1979) (Silva, 2004).

[15] Decree nº 3046/81 regulated Zona Especial 5 (ZE-5, Especial Zone 5) and its neighborhoods.

It is important to emphasize that the Pilot Plan set aside a vast area for low-income and social housing. The so called "Parallel Plan" aimed to give an opportunity for poor families to live in Itanhangá, Barra da Tijuca, Jacarepaguá and Recreio dos Bandeirantes. The fact that the municipality never went ahead with this plan is evidence that the sole intention was to attract middle and upper classes to the area, giving rights to real estate property owners only and promoting forms of social segregation in the city (Silva, 2004). Therefore, growth of slum population tends to be higher in Barra da Tijuca and in Jacarepaguá than in the general population. In 2000, Barra da Tijuca (XXIV RA) had 36 slums, more than half as many as the 76 slums found in Jacarepaguá (XVI RA). In relation to population size, slums in Barra da Tijuca region are small: 56.5% are home to less than 500 people, and the average population per slum is 441 inhabitants. The situation in Jacarepaguá differs sharply with a slum population mean of 1,038 people (IPP, 2000). In comparison, between 1991 and 2000, the most populated slums in the Rio das Pedras neighborhood had increased by a factor of 2.23, reflecting not only the demographic expansion of Jacarepaguá (1.96 times more populated) but also of Barra da Tijuca (2.23 times) (IPP, 2000) (see Figure 8). These increases are most likely related to economic development and job opportunities for the low-income and low-skilled classes, hired in the services sector or as domestic workers (Kasahara, 2002)[16].

3. URBAN INFRASTRUCTURE LEADING TO ENVIRONMENTAL (IN) JUSTICE

Environmental inequalities exist within cities. It is also true for Brazilian municipalities. Urban areas tend to produce a social scenario in ways that lead to environmental injustice because they are likely to benefit the elite at the expense of marginalized individuals and groups. In general, urban development reflects wider distorted and destructive social and economic dynamics which may create unequal and unjust conditions for resource use. The distribution of environmental hazards and the access to natural resources within cities are therefore a result of social and economic dynamics (Silva, 2004; Heynen, 2004).

Negative environmental externalities associated with the extensive development of the Jacarepaguá Lowlands have resulted in the deterioration of quality of life. Despite massive public investments in some infrastructure projects that significantly spurred the real estate market[17], the increase in socio-environmental vulnerability and therefore environmental injustice is somehow linked to the low efficiency of urban infrastructure.

Several reasons can explain this trend. First, the absence of an affordable housing policy aimed at minorities and low-income families who are more likely to live in substandard dwellings. Indeed, slums formed in the area because the state and municipal governments in order to defend the interests of local real estate agencies did not endorse the guidelines of the Pilot Plan to implement the Parallel Plan. Therefore, poor families started building their houses either close to water bodies – rivers, canals and streams – or on hillsides. Since favelas lack sanitary disposal and rainwater drainage systems, raw sewage is discharged in rivers, streams, or lagoons (see Figure 9). They are also more vulnerable to landslides.

The second reason is based on the fact that in these poor communities, household waste is not collected by the municipal administration but instead is discharged or carried by rainfall into watercourses, burned on vacant public land, or discarded on vacant private property. The irregular occupation of land by slum housing or condominiums, which are generally constructed haphazardly on river embankments, violates several state and municipal laws on environmental protection (see Figure 10). For example, in 2000 around 50,000 residents lived in nine slums located on the edges of the Tijuca and Camorim Lagoons, the most polluted lagoons in the Jacarepaguá Lowland watershed (Silva, 2004). In addition, since February 2009 the municipal government is demolishing irregularly-built houses located along Canal Marapendi, with the intention of reinstating the original plan that was developed for Lucio Costa and reducing environmental risk (see Figure 11).

The third and most significant reason relates to the absence of water distribution and wastewater collection infrastructure. An integrated sanitation system was never put into service in the area. The solution imposed by the state government to real estate companies was to construct small private sewage treatment plants for each residential

[16] According to Kasahara (2002), 40% of Rio das Pedras residents work as gardeners, sale representatives and servants.

[17] Among public investments, we highlight the construction of a modern road network mainly between 1966 and 1982, which improved access to the region and increased investment in large scale residential condominium projects. For example: the road pavement in Alvorada Avenue (Ayrton Senna Avenue), the implementation of Rio-Santos Road (Américas Avenue) and Lagoa-Barra Highway, and the opening of the Dois Irmãos Tunnel (Leitão, 1995). In addition, from 1980 to 1983, the state government financed some urban services, such as water, electricity and gas (Leitão, 1995; Gonçalves, 1999).

Source: Silva (2009)

Fig. 8 – *Vertical growth of poor houses at Slum Rio das Pedras*

Source: Silva (2009)

Fig. 9 – *Poor family house on the edges of Canal Sernambetiba*

Source: Silva (2009)

Fig. 10 – *Medium-income family house on the edges of Canal Marapendi*

Source: Silva (2009)

Fig. 11 – *Demolishiment of house on the edges of Canal Marapendi*

condominium complex. Up until 2001, the public authority had never invested in sewerage services, a fact that led to more than 20 years of socio-environmental conflicts and caused water resources degradation in the Jacarepaguá Lowland watershed. Citizens demanded that sewerage facilities be constructed in Barra da Tijuca (XXIV RA), because it was the only area in the Jacarepaguá Lowlands still without an integrated sanitation system. Toward this end, a social movement emerged in February 1981 with the creation of the Association of Inhabitants and Friends of Barra da Tijuca (AMABARRA). In 1982, discussions began with the state government to provide an efficient sanitation system capable of solving or avoiding environmental problems, including surface water pollution and water table contamination (Evangelista, 1989).

Contrary to other socio-environmental conflicts in Brazilian cities where low-income residents organize themselves and form social movements, in the case of Barra da Tijuca, middle to high income residents advocated for improved facilities. All residential start-ups were obliged by law to build and operate private small sewage treatment plants before a construction license was issued. However, because of their high cost of maintenance and of disposing sewage in the public sanitary landfill in Gramacho City, some residential condominiums discharged the effluents in natura i.e. in water bodies (Bredariol, 1997). After 1985, AMABARRA required that a permanent solution to wastewater and sewage treatment be found. Water pollution was a serious problem in Ipanema once a submarine emissary was installed in 1975. The public administration decided unilaterally to build a submarine emissary and a sewage plant for primary treatment of wastewater in Barra da Tijuca in 1986. Although the state government planned to start construction two years later, it took until February 2001, after years of social, political and technical conflicts, to finally launch the project.

The struggle for sanitation facilities lasted 20 years when the state administration began the Sanitation Program of Barra da Tijuca, Recreio dos Bandeirantes and Jacarépaguá (PSBJ). The project includes the construction of a sewage treatment plan, subterranean and submarine emissaries, pipelines, pumping stations, sewage pumps, collecting sewers and building connections (see Figure 12, CEDAE, 2008)[18]. Despite its scope, the program was never designed to service the entire Jacarepaguá Lowlands territory. For instance, only after 2006 the PSBJ included Recreio dos Bandeirantes. Still today, other neighborhoods such as Camorim, Grumari, Vargem Pequena and Vargem Grande are left out of the program and without facilities (see Figure 13). The program was extended from March 2003 to the end of 2011, because of unfavorable climatic conditions during the construction of the submarine emissary and state governments' delay in paying engineering companies (Silva, 2009)[19].

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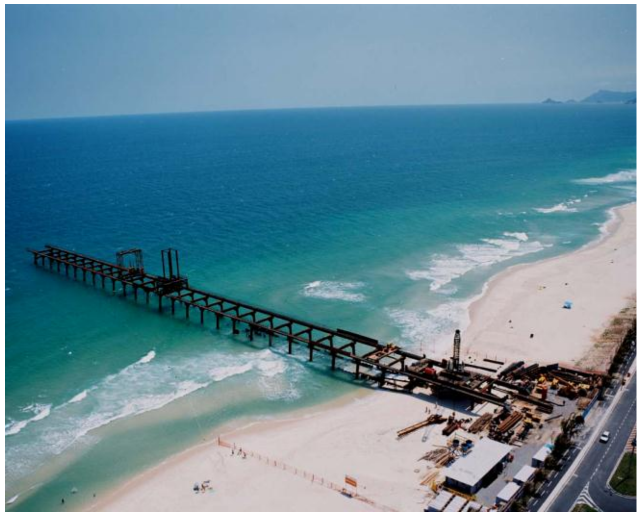
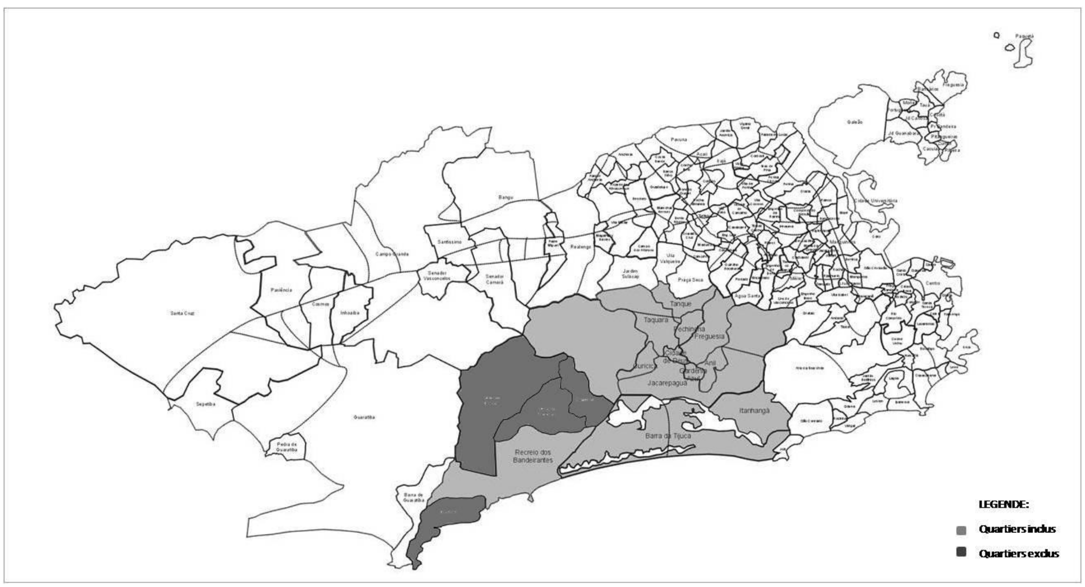
[18] The sewerage collection and transport system in the Jacarepaguá Lowlands consists mainly of a network of underground sewers pipes and pumping stations that carry sewage first to a treatment plant and then to underwater facilities that discharge sewage effluents directly into the sea.

[19] Until 6th June 2009, the state government invested in the PSBJ R$ 464,809,022.30 and will invest another R$ 107,762,484.94 (Respectively CAN$ 267,280,623.28 and CAN$ 61,967,007.44, according to the Brazilian Central Bank in June 16th, 2009).



Source: CEDAE (2006)

Fig. 12 – *Construction of submarine emissary*



Source: CEDAE (2006)

Fig. 13 – *Neighborhoods Assisted and Not Assisted by the Program of Sewerage in Barra da Tijuca, Recreio dos Bandeirantes and Jacarepaguá (PSBJ), in Jacarepaguá Lowland*

On the one hand, as the real property market in Barra da Tijuca has improved conditions for middle and upper income classes, it has driven urban development to unprecedented levels in the area and the entire Jacarepaguá Lowlands. On the other hand, profit-seeking private developers, an inefficient sanitation network and relaxed legislation combine and interact to give rise to several environmental problems. For example, in Lagoons Tijuca and Camorim the Municipal Cleaning Company (COMLURB) collected, from October 1998 to February 2003, 3,328 tons of aquatic plants and floating garbage, an average of 61.6 tons a month. In some periods of the year, especially in the summer, wind direction and air currents cause tidal changes where the deeper water rises to the surface. When the water turns over, hydrogen sulfide gas is released, which although beneficial to fish and plants gives off a sulfurous bad smell. The resulting eutrophication process reduces the water surface and depth. In 2000, both lagoons had a mean depth of less than a meter, ranging from a minimum of 30 cm and a maximum of 12.7 meters (CREA-RJ, 2000; see Figure 6). According to Hough (2000), the average natural sedimentation rate is one millimeter per year. In some areas of Lagoon Camorim the 1980 mean depth of two meters (or 200 cm) decreased to 10 cm in 2000 (Portella, 2001),a rate 10 times higher than natural sedimentation. The lagoons in Barra da Tijuca, Lagoons Tijuca, Camorim and Jacarepaguá were classified in 2001 as hypertrophic, highly fertile and supersaturated in phosphorus and nitrogen. Also, the excessive phytoplankton growth contributes to increased water turbidity, unsuitable recreational uses, and a depleted habitat for desirable fish. On the contrary, Lagoons Marapendi and Lagoinha were classified as eutrophic, greener and murkier with higher amounts of nutrients and algae (SEMADS, 2001).

4. SOCIAL-ENVIRONMENTAL VULNERABILITY IN THE JACAREPAGUÁ LOWLANDS

Social-environmental vulnerability refers to damage caused by socioeconomic and environmental hazards. Urbanization in the Jacarepaguá Lowlands has lead to inequitable urban development and segregation due to an unequal distribution of resources across advantaged and disadvantaged neighborhoods. Indeed, land use policy has been influenced by exclusionary practices based on real estate interests, have enhanced property values and excluded “undesirable” poor communities.

In order to assess the current situation in the Jacarepaguá Lowlands, we defined a Social-environmental Vulnerability Index (SEVI). This index is designed to provide insights into the processes that can negatively influence the sustainable development of municipalities (Silva, 2006). The purpose of the SEVI is to examine the vulnerability of a territory, especially watersheds, in relation to urban public services (sanitation, water supply and garbage removal) and to local socioeconomic conditions (average family income and level of schooling). We strongly believe that socioeconomic and environmental vulnerability indicators help policy-makers achieve sustainable development goals. The indicator method is an efficient and standardized way to characterize vulnerability in an overall sense, taking into account socioeconomic and environmental (urban infrastructure) factors. The SEVI is an environmental management tool for decision-making focusing around issues of politics, economics and social and cultural factors at the local scale and concentrating on planned outcomes.

The SEVI builds a connection between indicators of environmental and sanitation public services to the socioeconomic conditions of the local population. It is based on the work of the Brazilian Institute of Geography and Statistics (IBGE). It measures the percentage of the population living in vulnerable conditions. In order to calculate this index, two complementary indices were used: the Socioeconomic Vulnerability Index (SVI) and the Environmental Vulnerability Index (EVI). The SEVI equation is equal to the arithmetic mean between the SVI and the EVI, that is: SEVI = (SVI + EVI)/2. Table 4 shows the weight of these and the various complementary indexes. According to Silva (2006), the range of values for the SEVI, SVI and EVI are between 0 and 1. The value 1 corresponds to the highest degree of vulnerability for a spatial unit and the value 0 is the lowest degree of vulnerability. The results of the indicators that compose SVI and EVI are presented in percentile values, varying between 0% and 100% (see Table 5).

Drawing on statistical data from the Brazilian Census 2000 (IBGE, 2000), the degree of social-environmental vulnerability in the Jacarepaguá Lowlands was determined. The Census uses political and administrative boundaries to define neighborhoods (or bairros). Socioeconomic and environmental variables that we considered vulnerable were chosen to calculate the Socio-environmental Vulnerability Index (SEVI). We began our analysis by calculating the Socioeconomic Vulnerability Index (SVI) based on socioeconomic indicators (average family income and level of schooling). We followed-up with the Environmental Vulnerability Index (EVI) which is based on environmental indicators related to urban infrastructure, such as sewage services, water supply and garbage disposal (see Table 6). The methodology used to calculate the indices is described in the following sections.

Table 4
Weights of the indicators that compose the SVI and the EVI

Vulnerability Indices	Lowest	Highest
Socio-environmental Vulnerability Index (SEVI)	**0**	**1**
Socioeconomic Vulnerability Index (SVI)	**0**	**0.5**
Indicator of Vulnerability in Average Family Income (IVAFI)	0	0.25
Indicator of Vulnerability in Level of Schooling (IVLS)	0	0.25
Environmental Vulnerability Index (EVI)	**0**	**0.5**
Indicator of Vulnerability in Sewage Services (IVSS)	0	0.166
Indicator of Vulnerability in Water Supply (IVWS)	0	0.166
Indicator of Vulnerability in Garbage Disposal (IVGD)	0	0.166

Source: Based on Silva (2006).

Table 5
Degree of vulnerability according to SEVI, SVI and EVI

Degree of Vulnerability	SEVI, SVI and EVI	Indicator Components
Low	0 to 0.1	0% to 10%
Medium	0.1 to 0.2	10% to 20%
High	0.2 to 0.4	20% to 40%
Very High	0.4 to 0.6	40% to 60%
Extreme	0.6 to 1	60% to 100%

Source: Based on Silva (2006).

4.1 Methodology and results of the Socioeconomic Vulnerability Index (SVI)

The first stage of the methodology examines the socioeconomic systems that might increase susceptibility towards environmental features. Socioeconomic vulnerability, thus, refers to the communities' economic, institutional, technical and cultural capacity to avoid or to face changes in the socioeconomic system. Here, the analysis of the socioeconomic vulnerability of the Jacarepaguá Lowlands considers two important parameters: family income and education.

We started with the Indicator of Vulnerability in Average Family Income (IVAFI), which determines the percentage of the local population more vulnerable to impoverishment. To calculate the IVAFI we used only variables classified as vulnerable in Table 6, such as: "> 1 and < 2 MS" (I5), "> 1/2 and < 1 MS" (I6), "< 1/2 MS" (I7), and "No income" (I8). The equation for the IVAFI is here expressed: IVAFI = (I5 + I6 + I7 + I8)/100. Then, we determined the Indicator of Vulnerability in Level of Schooling (IVLS), which refers to the percentage of inhabitants more than 15 years old with an education level deemed vulnerable (Table 6), such as: "4 to 7 years" (E4), "1 to 3 years" (E5), "Illiterate or less than one year" (E6). The equation for the IVLS is here expressed: IVLS = (E4 + E5 + E6)/100. Finally, to calculate the Socioeconomic Vulnerability Index (SVI) we relied on the results of the Indicator of Vulnerability in Average Family Income (IVAFI) and the Indicator of Vulnerability in Level of Schooling (IVLS), which is expressed in the following equation: SVI = (IVAFI + IVLS)/200.

The results of these indices confirmed what we had initially assumed. The years of schooling an individual has completed are reflected in the type of occupations which carry higher prestige in society and earnings. That is, in general terms, occupation status and income increase with the level of schooling.

Table 6
Socioeconomic and environmental indicators that compose the SEVI.[20]

Degree of Vulnerability	Socioeconomic Indicators: *Average Family Income*	Socioeconomic Indicators: *Level of Schooling*	Environmental Indicators: *Sewage Services*	Environmental Indicators: *Water Supply*	Environmental Indicators: *Garbage Disposal*
Non-Vulnerable	> 20 MS (I1)	> 15 years (E1)	Public sewer system (S1)	Connected to water supply system – with plumbing in one room or more (W1)	Directly collected (G1)
	> 10 and < 20 MS (I2)	11 to 14 years (E2)	Septic tank (S2)	Connected to well (in the lot) - with plumbing in one room or more (W2)	
	> 5 and < 10 MS (I3)	8 to 10 years (E3)		With another kind of water supply - with plumbing in one room or more (W3)	
	> 2 and < 5 MS (I4)				
Vulnerable	> 1 and < 2 MS (I5)	4 to 7 years (E4)	Primitive cesspool (S3)	Connected to water supply system - with plumbing in the lot (W4)	Indirectly collected (G2)
	> 1/2 and < 1 MS (I6)	1 to 3 years (E5)	Sewage disposal in ditch (S4)	Connected to well (in the lot) - with plumbing in the lot (W5)	Incinerated (in the lot) (G3)
	< 1/2 MS (I7)	Illiterate or less than one year (E6)	Sewage disposal in river, lake or sea (S5)	Connected to well (in the lot) - without plumbing (W6)	Buried (in the lot) (G4)
	No income (I8)		Another kind of sewage disposal (S6)	Another kind - with plumbing in the lot (W7)	Thrown in vacant lot (G5)
			Neither bathroom nor latrine (S7)	Another kind - without plumbing in the lot (W8)	Thrown into river, lake or sea (G6)
					Another kind of garbage disposal (G7)

Source: Silva (2009)

[20] In Table 6, "I" refers to income, "E" refers to education, "S" refers to sewerage, "W" refers to water, "G" refers to garbage, and "MS" refers to the Brazilian minimum monthly wage, which is R$ 465 (or CAN$ 270.96 according to the Brazilian Central Bank as of June 16th, 2009).

First, the results of the Indicator of Vulnerability in Average Family Income (IVAFI) show that the least vulnerable neighbourhoods are Barra da Tijuca followed by Joá, and Camorim and Cidade de Deus, at the other end of the scale, are the most vulnerable. In relation to other areas in the metropolitan region of Rio de Janeiro, the Jacarepaguá Lowlands was an area of high vulnerability in 1991 (IVAFI = 32.18) which reached a medium level of vulnerability in 2000 (IVAFI = 19.96) (Silva 2006). Second, the results of the Indicator of Vulnerability in Level of Schooling (IVLS) of the Jacarepaguá Lowlands show that the least vulnerable neighbourhood is, again, Barra da Tijuca, which implies that the majority of its population is more educated than in other areas. In Barra da Tijuca, 61.55% of inhabitants have more than 15 years of schooling. In contrast, in Grumari, 25.78% of its population is illiterate or with less than one year of education. In comparison to other areas, the IVLS in the Jacarepaguá Lowlands dropped from 42.49% in 1991, a very high level of vulnerability to 34.37% in 2000 (Silva 2006).

Finally, the results of the Socioeconomic Vulnerability Index (SVI) show that the socioeconomic vulnerability of Barra da Tijuca, the neighborhood at the center of the plan of Lucio Costa in the 1970s, is low when compared to Camorim, Vargem Pequena and Grumari (see Table 7; see Figure 14). It is important to mention that the state government denied these three neighborhoods together with Vargem Grande from the Sanitation Program of Barra da Tijuca, Recreio dos Bandeirantes and Jacarepaguá (PSBJ). Moreover, Barra da Tijuca, the lowest vulnerability neighborhood in terms of family income and education benefited from the construction of a submarine emissary and the main sewage treatment plant. However, conditions remained the same in seven neighborhoods (Jacarepaguá, Gardênia Azul, Cidade de Deus, Camorim, Vargem Pequena, Vargem Grande and Grumari) characterized by very high vulnerability for family income and extreme vulnerability for level of schooling. Despite these contrasts, the results of the Socioeconomic Vulnerability Index (SVI) show that the Jacarepaguá Lowlands are one of the least vulnerable areas compared to the data obtained from the 1991 Brazilian Census for the metropolitan region of Rio de Janeiro (Silva, 2006).

4.2 Methodology and results of the Environmental Vulnerability Index (EVI)

The second stage of the methodology addresses urban infrastructure systems. This focus is premised on the view that their absence or low efficiency tends to damage natural resources and to increase communities' susceptibility to environmental hazards. We identified three components: sewage services, water supply and garbage disposal. These indicators reflect the quality of the public services offered to local communities by the state government (for sewage services and water supply), and by the municipal administration (garbage disposal).

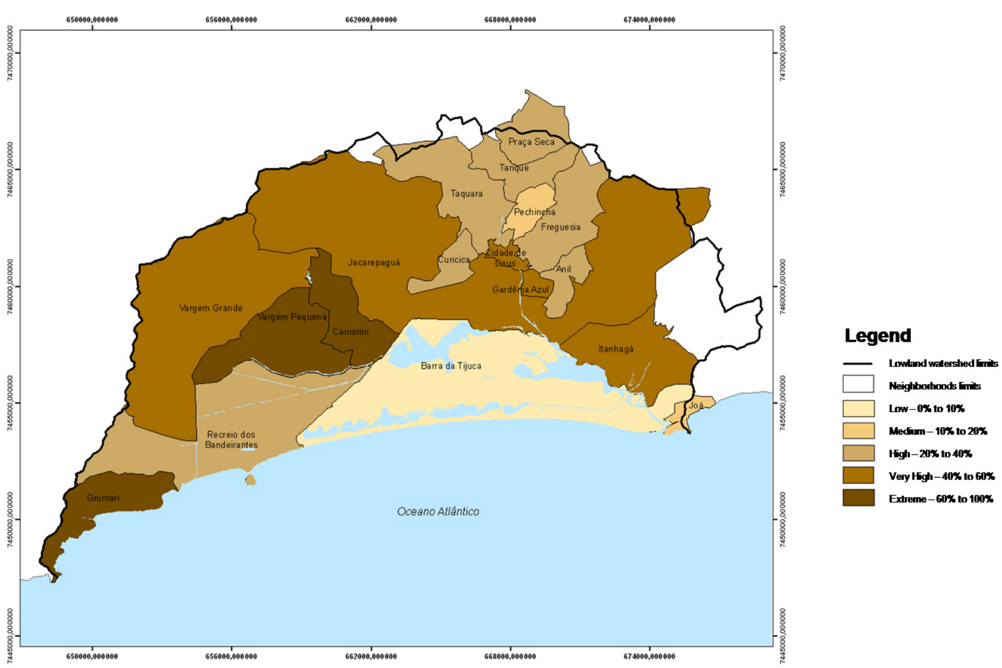
Based on the Indicator of Vulnerability in Sewage Services (IVSS), which determines the percentage of the local population living in vulnerable housing, access to adequate sanitation facilities was initially examined. To calculate the IVSS we used only the variables classified as vulnerable in Table 6, such as: "Primitive cesspool" (S3), "Sewage disposal in ditch" (S4), "Sewage disposal in river, lake or sea" (S5), "Another kind of sewage disposal" (S6), and "Neither bathroom nor latrine" (S7). The equation for the IVSS is here expressed: IVSS = (S3 + S4 + S5 + S6 + S7)/100. Then, the Indicator of Vulnerability in Water Supply (IVWS), which refers to the percentage of residents with inadequate water supply, was calculated using the following variables (see Table 6): "Connected to water supply system - with plumbing in the lot" (W4), "Connected to well (in the lot) - with plumbing in the lot" (W5), "Connected to well (in the lot) - without plumbing" (W6), "Another kind - with plumbing in the lot" (W7), and "Another kind - without plumbing in the lot" (W8).The equation for the IVWS is here expressed: IVWS = (W4 + W5 + W6 + W7 + W8)/100. For the calculation of the Indicator of Vulnerability in Garbage Disposal (IVGD), which refers to the percentage of residents with inadequate garbage removal and disposal (see Table 6), the variables used were: "Indirectly collected" (G2), "Incinerated (in the lot)" (G3), "Buried (in the lot)" (G4), "Thrown in vacant lot" (G5), "Thrown into river, lake or sea" (G6), "Another kind of garbage disposal" (G7). The equation for the IVGD is here expressed: IVGD = (G2 + G3 + G4 + G5 + G6 + G7)/100. Finally, to calculate the Environmental Vulnerability Index (EVI) we relied on the results of the Indicator of Vulnerability in Sewage Services (IVSS), the Indicator of Vulnerability in Water Supply (IVWS), and the Indicator of Vulnerability in Garbage Disposal (IVGD), which is expressed in the following equation: EVI = (IVSS + IVWS + IVGD)/300.

The conclusion that can be drawn from these indices confirms the trend found in other Brazilian cities. Public administrations invest in high-income areas and provide infrastructure for their populations. The results of the Indicator of Vulnerability in Sewage Services (IVSS) show that one third of the Jacarepaguá Lowland neighbourhoods are not served with adequate sanitation facilities, for instance: Jacarepaguá, Itanhangá, Camorim, Vargem Pequena, Vargem Grande and

Table 7
Results of the Socioeconomic Vulnerability Index (SVI)

Neighborhoods	Average Family Income (IVAFI)		Level of Schooling (IVLS)		Socioeconomic Vulnerability Index (SVI)	
Jacarepaguá	43,83	Very High	63,2	Extreme	0,54	Very High
Anil	19,62	Medium	31,27	High	0,25	High
Gardênia Azul	45,94	Very High	66,73	Extreme	0,56	Very High
Cidade de Deus	53,69	Very High	60,66	Extreme	0,57	Very High
Curicica	29,64	High	48,17	Very High	0,39	High
Freguesia	20,3	High	28,57	High	0,24	High
Pechincha	16,15	Medium	23,14	High	0,20	Medium
Taquara	23,77	High	35,83	High	0,30	High
Tanque	27,88	High	42,22	Very High	0,35	High
Praça Seca	30,68	High	39,58	High	0,35	High
Joá	7,96	Low	13,04	Medium	0,11	Medium
Itanhangá	36,51	High	64,4	Extreme	0,50	Very High
Barra da Tijuca	5,96	Low	7,67	Low	0,07	**Low**
Camorim	56,29	Very High	66,06	Extreme	0,61	**Extreme**
Vargem Pequena	56,8	Very High	67,5	Extreme	0,62	**Extreme**
Vargem Grande	44,36	Very High	65,56	Extreme	0,55	Very High
Recreio dos Bandeirantes	22,23	High	35,56	High	0,29	High
Grumari	43,76	Very High	89,85	Extreme	0,67	**Extreme**

Source: Silva (2009)



Source: Silva (2009)

Fig. 14 – *Results of the Socioeconomic Vulnerability Index (SVI) in Jacarepaguá Lowland*

Grumari. This is most notable in Camorim where 85.23% of the population lives in extreme housing conditions. Compared to other areas in the metropolitan region of Rio de Janeiro, the Jacarepaguá Lowlands are rated at a medium vulnerability that decreased from 19.81 in 1991 to 12.62 in 2000 (Silva 2006). On the contrary, the results of the Indicator of Vulnerability in Water Supply (IVWS) show that 78% of its population has access to adequate water services, although 64.85% of the residents of Grumari, the most vulnerable area, must bear the burden of inadequate water supply. Again, compared to other areas in the metropolitan region of Rio de Janeiro, the level of vulnerability found for the Jacarepaguá Lowlands is low, which dropped from 4.12 in 1991 to 0.45 in 2000 (Silva 2006). Indeed, this decrease is a direct consequence of the willingness of the state government to provide universal water service coverage. The results of the Indicator of Vulnerability in Garbage Disposal (IVGD) show that only 39% of the population is provided with satisfactory garbage removal and disposal services. The neighborhoods of Grumari (IVGD = 65.63%) and Itanhangá (IVGD = 51.68%) reach extreme and very high vulnerability levels, respectively. Overall, the level of vulnerability of the Jacarepaguá Lowlands, which increased from 12.22 in 1991 to 15.81 in 2000 (Silva 2006), is considered to be medium.

The results of the Environmental Vulnerability Index (EVI) indicate low environmental vulnerability for Barra da Tijuca while Grumari with an extreme environmental situation stands at the opposite end of the spectrum (see Table 8; see Figure 15). As mentioned before, Camorim, Vargem Pequena, Vargem Grande and Grumari are left out of the state program to provide the Jacarepaguá Lowlands with sanitation facilities, despite their critical environmental vulnerability varying from high to extreme with regards to sewage services. In fact, only the areas settled prior to the implementation of the Pilot Plan are assigned low vulnerability scores.[21] In addition, the fact that these neighborhoods and some others still cannot count on an adequate public sewerage system is a major contributor to the pollution of water bodies. We can observe sewage discharges flowing without any treatment into rivers and canals, reaching the waters of local lagoons and the sea. Moreover, the vulnerability of some neighborhoods in terms of garbage collection and disposal also increases the risk of water pollution. Some of the waste is buried and seeps into the water table or is disposed of directly into water bodies.

4.3 Methodology and results of the Socio-environmental Vulnerability Index (SEVI)

The analysis of the socio-environmental vulnerability of the Jacarepaguá Lowlands draws on the results of the Socio-environmental Vulnerability Index (SEVI), which has a value equal to the arithmetic mean between the Socioeconomic Vulnerability Index (SVI) and the Environmental Vulnerability Index (EVI). The SEVI shows that Barra da Tijuca and Joá are neighborhoods with low socio-environmental vulnerability, while Grumari is faced with an extreme socio-environmental situation (see Table 9; see Figure 16). The SVI is a significant predictor of the socio-environmental vulnerability in the Jacarepaguá Lowlands. The Jacarepaguá Lowlands display a high vulnerability level compared to other areas in the metropolitan region of Rio de Janeiro, which decreased from 0.25 in 1991 to 0.18 in 2000 (Silva 2006).

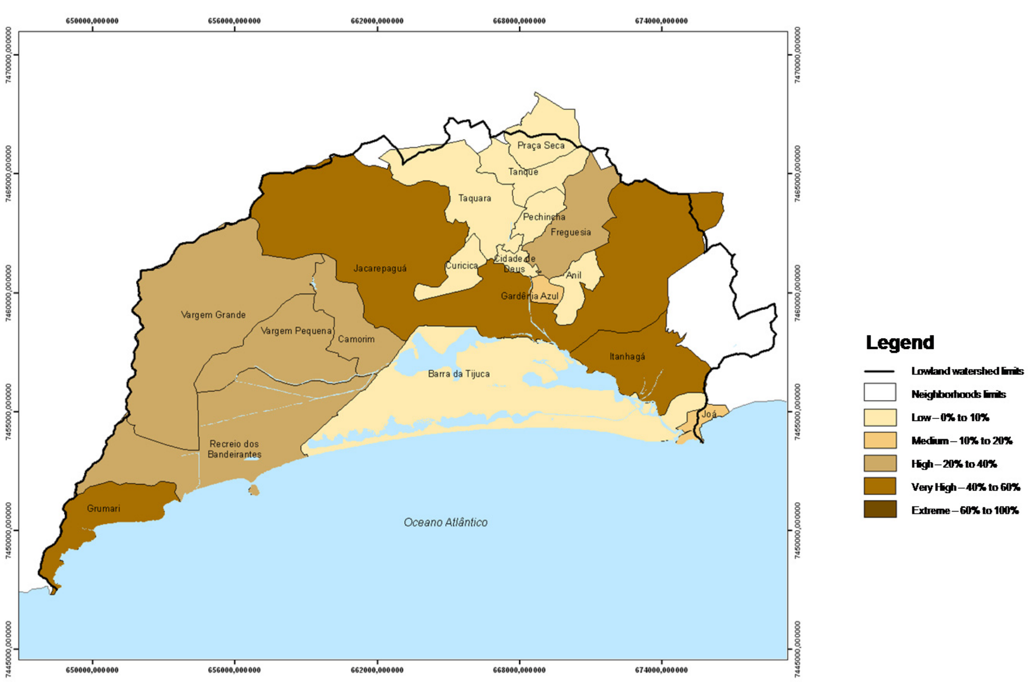
Clearly, urban environmental problems impact rich and poor communities in distinct ways. The purchasing power of the wealthy is significantly greater than the poor, and they can continue consuming natural resources without concern for their cost. On the other hand, when natural resources are rare or polluted the poor will be impacted first and the hardest. Due to their low socioeconomic mobility and status and sense of political powerlessness, most vulnerable populations do not have access to quality housing in neighborhoods with adequate urban infrastructure, such as: water supply, garbage collection and disposal, sanitation services, surface water drainage, etc. Living in these conditions, the poor face greater health risks (e.g.: water-related diseases) but also environmental risks (e.g.: flooding, landslide and other natural hazards). Despite social inequalities in health outcomes, pollution will affect eventually all income groups. Providing ineffective and inefficient services, over time, will adversely affect everyone regardless of income and education levels. For example, the lack of sewage and sanitary systems has resulted in polluted water bodies in littoral cities (Jacobs, 1991; Hardoy, 1992). In all Brazilian municipalities including the Jacarepaguá Lowlands, the role of public administration is vital to mitigate negative impacts on the urban environment and population by investing in sanitation and by introducing specific legislation to regulate and restore the environment.

[21] The neighborhoods included in the urbanization process of the Jacarepaguá Lowland region in the 1970's, based on the urban plan of Lucio Costa, are the following: Joá, Itanhangá, Barra da Tijuca, Camorim, Vargem Pequena, Vargem Grande, Recreio dos Bandeirantes, and Grumari. The other areas were urbanized before that period and serviced by a public sewer system, resulting in low environmental vulnerability for sewage services.

Table 8
Results of the Environmental Vulnerability Index (EVI)

Neighborhoods	Water Supply (IVWS)		Sewage Services (IVSS)		Garbage Disposal (IVGD)		Environmental Vulnerability Index (EVI)	
Jacarepaguá	4,05	Low	39,23	High	36,45	High	0,27	High
Anil	1,03	Low	9,05	Low	5,87	Low	0,05	Medium
Gardênia Azul	2,84	Low	24,85	High	18,1	Medium	0,15	High
Cidade de Deus	0,8	Low	8,29	Low	22,09	High	0,10	High
Curicica	1,81	Low	7,71	Low	2,12	Low	0,04	High
Freguesia	0,56	Low	4,36	Low	10,67	Medium	0,05	Medium
Pechincha	0,3	Low	1,58	Low	3,6	Low	0,02	Medium
Taquara	1,82	Low	8,59	Low	2,91	Low	0,04	Medium
Tanque	4,12	Low	5,71	Low	9,05	Low	0,06	High
Praça Seca	3,36	Low	4,55	Low	21,85	High	0,10	High
Joá	0,31	Low	10,25	Medium	0	Low	0,04	Low
Itanhangá	1,34	Low	37,48	High	51,68	Very High	0,30	High
Barra da Tijuca	1,65	Low	4,18	Low	6,09	Low	0,04	**Low**
Camorim	15,04	Medium	85,23	Extreme	14,27	Medium	0,38	Very High
Vargem Pequena	11,37	Medium	32,69	High	20,2	High	0,21	Very High
Vargem Grande	16,57	Medium	51,08	Very High	19,91	Medium	0,29	Very High
Recreio dos Bandeirantes	4,44	Low	16,87	Medium	12,28	Medium	0,11	Medium
Grumari	35,15	High	76,56	High	65,63	Extreme	0,59	**Extreme**

Source: Silva (2009)



Source: Silva (2009)

Fig. 15 – *Results of the Environmental Vulnerability Index (EVI) in Jacarepaguá Lowland*

CONCLUSION

The natural environment is the life system that supports human activities. With the aim to address the dichotomy between natural and urban processes, many researchers focus on issues of urban environmental quality. We argue that contemporary development practices, either private or public, are transforming not only urban morphologies but also landscapes that may reveal socio-environmental vulnerability and injustice.

This paper examined the urban settlement process taking place in the Jacarepaguá Lowlands since the 1970s. It was found that the region has attracted massive capital inflows. Both public and private investments are the most important socioeconomic growth drivers, particularly in Barra da Tijuca. Urbanization and urban expansion in many Brazilian cities are guided by the interests of powerful real estate companies. On the one hand, high-income classes have benefited from the investments made by municipal and state governments in the essential infrastructure needed for urbanization. The planning model adopted supports growth and development of the urban fabric to increase land value and therefore maximize profits for real estate investors. On the other hand, the socio-environmental conditions that result from the rapid urbanization has lead to the increase of vulnerability and injustice. For example, in the Jacarepaguá Lowlands, unsustainable housing for low-income communities and the lack of sewerage infrastructure to collect and treat effluents foster socio-environmental vulnerability.

Urban infrastructure should be provided to meet the needs of all populations and territories. As urbanization increases and infrastructure networks expand, nearly all dwellings must have individual connections. The principles of equality and effectiveness can be met only though homogeneous coverage standards. However, in many large cities of emerging countries, like Brazil, infrastructure needs have outpaced the expansion of supply (Silva, 2007). In the case of the Jacarepaguá Lowlands, several reasons can be given to explain this gap. First, it is important to observe that when the government invested in the essential infrastructure (e.g.: road system network, water provision, electricity and gas supply), only the urban dimension was taken into consideration. Second, since sanitation facilities dated back to the 1970s, the public administration did not address the need to protect the region's natural resources, which contributing to the water pollution in the Jacarepaguá Lowlands watershed. These factors lead, directly or indirectly, to environmental impacts such as: (i) inadequate use of natural recourses, (ii) transformation of urban land use, (iii) transformation of urban landscape, (iv) transformation of natural systems, etc; and environmental problems such as: (i) water quality deterioration, (ii) gradual degradation of mangroves, (iii) shrinking shorelines, etc. In fact, urban planning policies have been applied piecemeal, and therefore do not take into account the interconnectedness between the urban and natural systems operating within the urbanized area. In the Jacarepaguá Lowlands, the government has limited its interventions to the urban dimension only. Consequently, urban infrastructure used to reduce socio-environmental vulnerability and increase environmental justice has not been exploited to its full potential.

Third, some neighborhoods of the Jacarepaguá Lowlands watershed are left out of the Sanitation Program of Barra da Tijuca, Recreio dos Bandeirantes and Jacarepaguá (PSBJ). In addition to the implications of this exclusionary policy, a watershed-based approach has not been adopted by the state government as a planning framework to integrate socioeconomic and ecological systems[22]. Finally, the methodology and results of the Socio-environmental Vulnerability Index (SEVI) in the study area was useful in providing an overall understanding of the urban development practices and processes as a root cause of environmental injustice that is plaguing Rio de Janeiro. In an effort to reconcile socioeconomic development and environmental quality in the Jacarepaguá Lowlands, we recommend reforming the existing regional planning model.

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[22] A watershed is a topographic area, drained by a water body, commonly a main river, or a system connected to water bodies, usually its tributaries (Lima-e-SILVA, 1999; Polette, 2000; Brun and Lasserre, 2006). In Brazil, the Federal Law 9.433 (1997) is the political and legal impetus for developing land-use planning and management policies and practices on a watershed basis, leading to the establishment of the National Water Resources Plan (PNRH) and the National Water Resources Management System.

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