São Paulo Peri-Urban Dynamics: Some Social Causes and Environmental Consequences

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Introduction

There has been great expectation in Brazil that the decline in the rate of population growth of the São Paulo's Metropolitan Area would positively impact this metropolis, reducing the need for public investment in urban infrastructure and social policies. This local hypothesis relates to some extent to the so-called "urban transition theory", which assumes that with the long-term reduction of the rural-urban migration, cities could achieve a more sustainable pattern of development (Livi-Bacci and De Santis, 1998; Martine, 2001).

In fact, between the 1970s and the1990s, the rate of population growth declined remarkably in the São Paulo Metro Area, from 4.5% to 1.7% a year, reaching the national average. Different demographic projections, such as the one produced by the São Paulo State Bureau of Statistics (Seade) project a stable population for the Metro Area in the near future (Waldvogel et all, 2003). However, the expectations of a more sustainable development have not being fulfilled in the case of São Paulo. This has happened because while the center of the city is significantly losing population, the share of population living in peri-urban areas are still growing very fast, rising from 19% to 30% between 1991 and 2000. As a result of this urban dynamics, the region still demands strong public investment in transportation and other urban infrastructure, with considerable environmental impacts.

In general terms, the argument presented in this paper is that the connection between population growth and urban environment should not be considered in an abstract form, as if all urban environments and institutional contexts were the same. The interplay between population and environment must be considered in "concrete territories", with all their social and environmental diversity and their institutional complexity. In the case of Brazilian metropolitan areas, we propose that particular dynamics of the land market - affected by land use regulations, as well as by public

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policies (i.e., transportation and housing) - strongly influence the urban sprawl dynamics and its environmental impacts.

In view of these elements, the first objective of this paper (Section 1) is to understand the evidence on urban sprawl. In Section 2, we will try to discuss why this intra-urban dynamic is happening by comparing spatial patterns of population growth and real state investments. We intend to show that – surprisingly – the city is losing population exactly in the same places where real state investments are growing more significantly.[1] Population growth, on the other hand, happens mainly where the price of land is low.

In Section 3, we intend to argue that such sprawl is producing an important land use transformation, leading to the destruction of the natural environment around the Metropolitan Area and the contamination of water sources. We show that the urban sprawl is connected to the deforestation and occupation of environmentally protected areas, specially those with less environmental restrictions such as the APAs and APMs.[2] However, the connection between population growth and environmental degradation in São Paulo peri-urban area is not clear cut, as implied by most environmental literature (Mather & Needle, 2000; Allen & Barnes, 1985). Finally, we also present a brief conclusion trying to explore the arguments presented here from the point of view of public policies.

1. Urban sprawl and peri-urban areas

Map 1 below presents the spatial distribution of the rate of population growth of the census survey areas ("áreas de ponderação") of the urbanized area of São Paulo comprised by 21 municipalities.[3] It is possible to observe that the demographic growth of this region has been very uneven by distributed in the past decade. While the central

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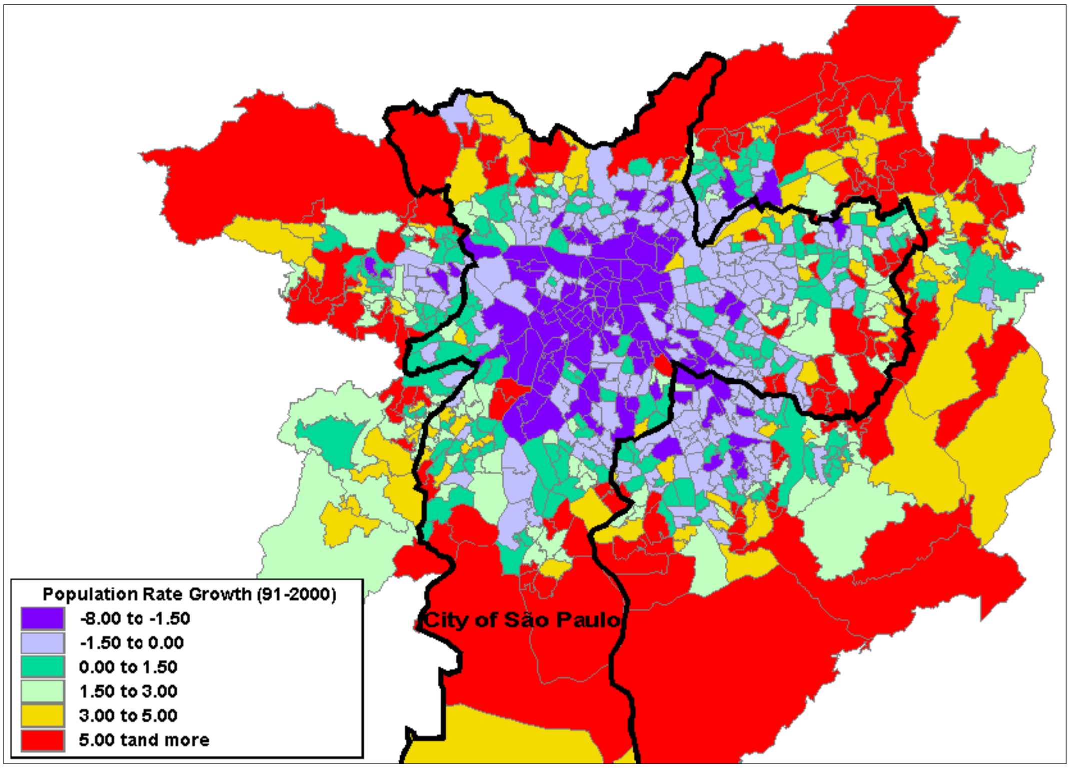
[1] Most of those analyses benefit from the GIS database developed at the Center for Metropolitan Studies (CEM-Cebrap), where census data (1991, 2000), satellite images, real state data, etc. are all available in GIS format. The authors used Maptitude, Envi and Arcview as their GIS software. See, www.centrodametropole.org.br

[2] APA (A*rea de Proteção Ambiental*) are environmental protected areas. APM (*Área de Proteção de Mananciais*) area water sources protected areas. Those are mainly private land with strong usage restrictions. The Atlantic Forest Biosphere Reserve, the Billings/Guarapiranga Water Reservoirs and the Serra da Cantareira's APA are the most important examples.

[3] The Metropolitan Area of São Paulo is an official definition that includes 39 municipalities. The 21 municipalities considered here are the ones that form a continuous urban area with 92% of the total population of the Metro region. The Census Survey Areas are the spatial units of the 2000 Census that allow tabulations for the Census Survey.

areas of the most important municipalities of the region – including São Paulo (Expanded Downtown Area) Guarulhos (Northeast), ABC (Southest) and Osasco (West) – have lost population in absolute terms, some areas located in the outskirts of the city that grown very fast.

Map 1
Rate of Population Growth of Census Survey Areas (1991-2000). São Paulo Urbanized Area.



Source: IBGE, 1991 and 2000 Census.

The areas located in the external ring of the region have presented a significant growth rate, often higher than 5% a year. We can also observe that there are practically no census areas in the expanded downtown part of the city that present positive growth. The only exceptions refer to the areas in which the shantytowns of Paraisópolis and Heliópolis – the largest of São Paulo - are located.

Contrary to the American medium-high income urban sprawl (Duany, Zyberk and Speck 2000), the demographic growth of the Brazilian peri-urban region occurs due to the extension of existing poor areas, almost all located in the suburbs in the case of São Paulo (Torres, 2002). As to the high and medium income areas of the city, almost all are losing population, the only exceptions being Alphaville and Vila Andrade - both in the western part of the region.

In aggregate terms, the recent demographic change of São Paulo may be considered rather unsettling. While the region as a whole was growing in moderate terms (1.5% a year in the 1990s), the central negative-growth areas lost population quite fast (-2.1% a year). In contrast, peri-urban fast-growth areas were growing at the impressive rate of 8.1% (Table 1 and Map 1).

Table 1
Population and Rate of Population Growth According to Groups of Areas. São Paulo Urbanized area, 1991-2000

Groups of areas according to population growth rate, 1991-2000	Population		Population growth rate 1991-2000
	1991	2000	
-8 to -1.5	2316493	1916522	-2.08
-1.5 to 0	4401256	4130804	-0.70
0 to 1.5	3076605	3299875	0.78
1.5 to 3	1844554	2246932	2.22
3 to 5	1259512	1772233	3.87
5 and more	1534626	3102189	8.13
Total	14433045	16468555	1.48

Source: IBGE, Demographic Census, 1991 and 2000.

As a consequence, the population in negative-growth areas has decreased from 6.7 to 6 million inhabitants between 1991 and 2000. In slow growth areas (less then 3% a year), it has increased from 4.9 to 5.5 millions while in the peri-urban fast-growth areas (more than 3% a year) it raised in 2.1 million inhabitants (from 2.8 to 4.9). In 2000, this area represented 30% of the total population of the region. Without such contribution, the urbanized region of São Paulo would have kept its population stable in the 1990s.

Intense demographic variations of this kind have important consequences for public policies. The expectation that a slower population growth rate would reduce the pressure over the offer of public services is only partially true. In the new peri-urban areas, the state must build new infrastructure – i.e., streets, schools, healthcare facilities and basic sanitation. The persistent horizontal growth of the city requires a continuous extension of the network of public services to the peri-urban areas, even when the equipment located in the central areas are is not being used to its full potential. It is also important to notice that this region corresponds to an average extension of 70x60 km, and that the transportation system is crowded and expensive. In other words, it is not realistic to imagine that peri-urban residents would easily access services only available in central areas (Torres, 2002a).

Besides having the highest population growth rates of the city, the peri-urban areas also unsurprisingly show the worst socioeconomic indicators, with high levels of poverty, illiteracy and unemployment. Table 2 shows that per capita family income in very negative growth areas (8.1 minimum wages) is almost five times the one observed in fastest growing peri-urban areas (1.7 minimum wages). This table also shows that such income differentials are associated with high levels of unemployment and illiteracy and are additionally expressed in terms of sanitation indicators, such as water supply, garbage and sewage collection. This poor and illiterate peri-urban region also concentrates the largest proportion of black population (45%).

Table 2
Socioeconomic and sanitation indicators of the Urbanized Area of São Paulo, 1991-2000

	Groups of areas according to population growth rate, 1991-2000						
	-8 to -1.5	**-1.5 to 0**	**0 to 1.5**	**1.5 to 3**	**3 to 5**	**5 and more**	**Total**
Per capita family income (*)	8.11	4.75	3.26	2.70	1.87	1.66	3.86
Average years of schooling of head of households	9.89	8.14	7.08	6.44	5.89	5.55	7.27
Unemployment rate (**)	13.13	16.32	19.31	21.68	23.72	24.93	19.32
Proportion of blacks (%)	13.87	20.88	31.12	37.30	41.85	44.99	30.12
Proportion of children 0-4 years (%)	5.39	6.95	8.74	9.86	10.73	11.68	8.82
Water (%)	99.86	99.79	99.41	97.99	95.39	92.00	97.69
Sewage (%)	97.94	94.84	87.64	80.11	74.66	59.46	83.74
Household density	2.92	3.36	3.56	3.69	3.77	3.83	3.50

Source: IBGE, Demographic Census de 2000.
Notes: (*) In minimum wages (~US$100 in 2005).
(**) It does not correspond to the official unemployment estimates, due to a different methodology adopted by Brazilian Census.

Such an urban sprawl has also significant environmental consequences in terms of transportation and pollution. On the one hand, peri-urban housing means longer journeys and increase in air pollution; on the other, poor peri-urban areas not only mean lack of sanitation and pollution of river and streams (Torres, 2002a) but also deforestation and destruction of natural landscapes that still surround São Paulo.[4]

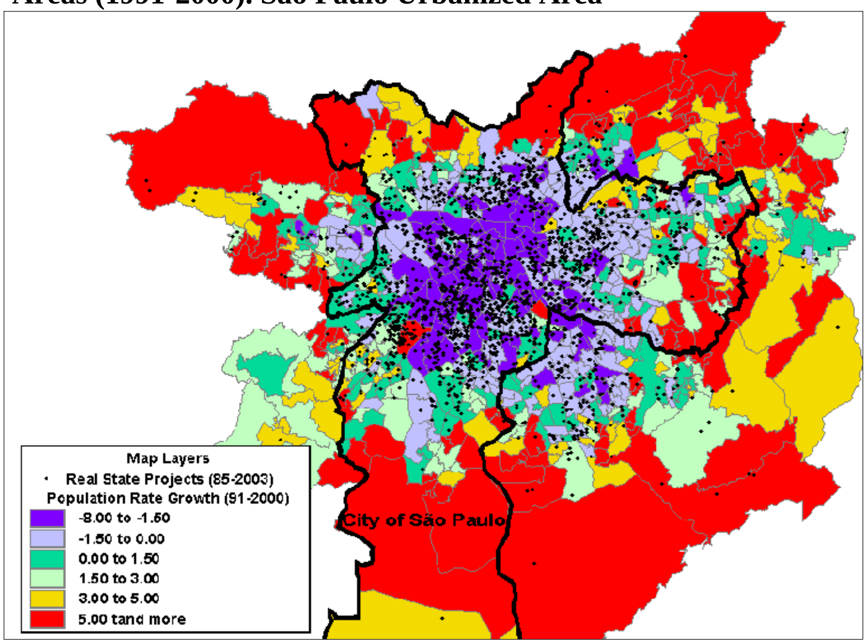
[4] We further discuss this issue in Section 3.

2. Urban sprawl and land markets

Between 1995 and 2003, there was a significant residential real state investment in São Paulo, with private companies launching more than 7.5 thousand residential projects, including nearly 400 thousand residential units, 3 million square meters of area and almost 10 billion dollars in private investments.[5] Such projects refer to those by private companies only, and not include the investment made by families and individuals themselves. Surprisingly, the bulk of such investment happened in areas that lost significant amount of population between 1991 and 2000. Evidence of this argument is presented in Map 2.

Map 2

Real State Investment (1985-2003) and Rate of Population Growth of Census Survey Areas (1991-2000). São Paulo Urbanized Area



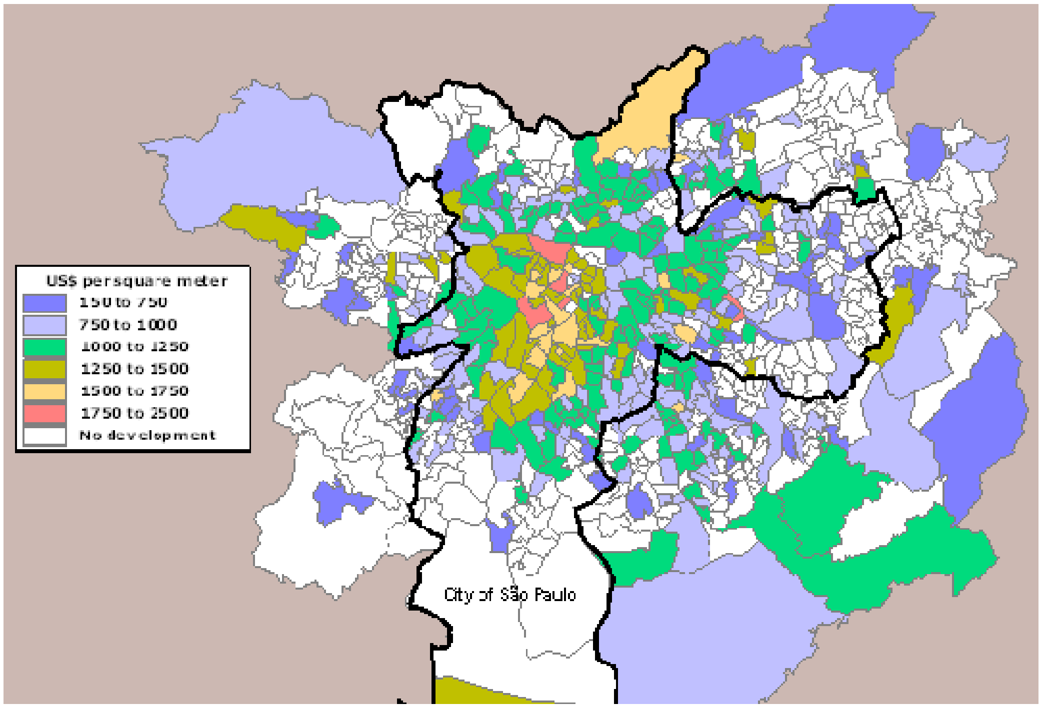
Sources: IBGE, 1991 and 2000; Embraesp, 1985-2003.

In other words, there seems to be limited connections between private companies housing production and the strong dynamic of population growth in the far suburbs. The housing built by private companies has been almost exclusively offered for high and medium income families,[6] with only 11% of such projects referring to houses or apartments of less than 50 square meters of residential area, considered to be more cost effective for low-income families. Even in this case, most small apartment

[5] See Embraesp 1985-2003, which register all new real state investments advertised in newspapers.

projects were located in rich areas, and sold as residencial-hotels, not affordable for the poor. Overall, private companies has never intended to sell housing projects to poor dwellers, since their income levels made such housing units unaffordable for either acquisition or rental purposes. This dynamic is strongly associated with real state prices. In Map 3 we present the average distribution of land prices in metropolitan area of São Paulo.

Map 3
Average Square Meter Price of New Real State Investment (1985-2003). São Paulo Urbanized Area.



Sources: Embraesp, 1985-2003.

By comparing Maps 1 and 3, it is possible to observe that there seems to be a significant correlation between high land prices and negative population growth. Areas with strong population growth presented mostly low land prices or no real state development in the last two decades. Although we have few individual data to support such an argument, the ecological presented here also works as evidence in this case, as almost no private companies invest in the fast-growing poor suburbs. Table 3 summarizes the data available on this issue.

[6] This process has been described in the urban planning literature as "gentrification" (Smith, 1996).

Table 3
Total Population and Growth Rate for Areas Classified According to its Average Square Meter Price of New Real State Investment. São Paulo Urbanized Area.

US$ per square meter (1985-2003)	Population 1991	Population 2000	Growth Rate 1991-2000
No development	5794062	7462966	2.85
Less than 1000	4131638	4590084	1.18
1000 to 1500	4004931	3962867	-0.12
1500 and more	502645	452638	-1.16

Sources: IBGE, 1991 and 2000 and Embraesp, 1985-2003.

In fact, the data shows that the areas with high land prices (and strong real state investment) are loosing population.[7] On the other hand, those areas with no development and probably low land prices are the ones growing faster. Self-construction houses in areas with low land price or in illegal settlements explain poor suburbs growth. By analyzing the available information, we also conclude that no private investment exist in poor areas. These trends also indicate an increasing of the already high level of residential segregation (Torres, 2004).

In summary, we can say that, in the 90s, the Metro Area received additional 96 thousand households every year.[8] On average, the investment provided by private companies as presented above was responsible for only 23% of such increase. Public housing projects were almost insignificant,[9] indicationg that most of the new housing has been built by families and individuals in very far suburbs, which explains the significant peri-urban demographic growth. This also shows that the general pattern described in the 70s - of poor urban dwellers living in self-constructed houses in the so-called "peripheries" of the city - is still true for São Paulo in the 90s (Kowarick, 1979).

2.1 The Role of the Informal Markets

Informal settlements are yet another important dimension of this process. Due to the lack of affordable housing, the poor population ends up living in different types of

[7] The negative growth areas received the largest amount of private investment (70%), while the fast growth areas (growing at more than 3% a year) received only 6% of the total investment between 1985 and 2003.
[8] The total number of households (occupied or not) reached 3.8 million in 1991 and 4.7 million in 2000 in the 21 municipalities considered in this analysis. It represents an yearly growth rate of 2.3%.
[9] The data available is quite controversial and incomplete. Considering only the City of São Paulo (that accounts for 60% of the population of the Metro Area), the average production of new households by the

informal settlements, such as slums, irregular developments and shantytowns. A recent study by the Secretariat for Housing of the city of São Paulo estimates that at least 25% of the city's households are either in shantytowns or in illegal developments (Sehab, 2003). However, illegality and/or informality in São Paulo should be even higher since it also refers to a more complex arrangement of land use regulations: building norms, environmental constrains for land occupation, infrastructure regulation on neighborhood development, zoning, and property rights (Figure 1).

FIGURE 1: Forms of regulation and of housing occupation in São Paulo

		REGULATIONS ON PROPERTY RIGHTS	
		Legal	***Illegal***
REGULATIONS ON LAND USE, ENVIRONMENT AND INFRAESTRUCTURE	***Legal***	A Regular housing areas	B
	Illegal	C Slums Irregular developments	D Shantytowns

Source: Adapted from Lim (1995: 525). See also Torres (2002b).

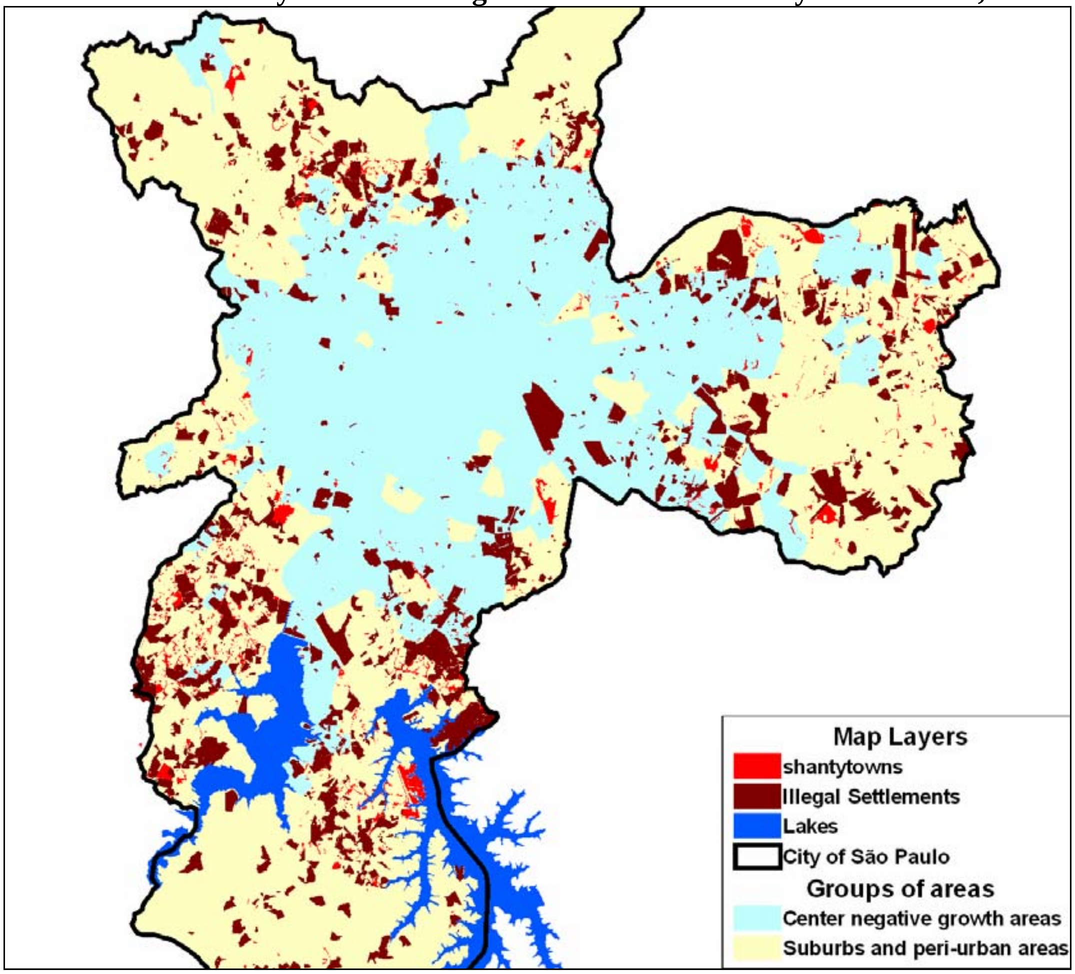
As a consequence, only a small part of the city - which has also been called "the legal city" (Situation A in Figure 1) - can be to some extent comparable to a city of a developed country (Grostein, 1987). Private investments usually happen in such legal city such as the central areas of São Paulo. Most shantytowns and illegal settlements are located in poor suburbs and in peri-urban areas (Map 4 and Table 4).[10]

One can see that shantytowns are much more frequent in the peri-urban areas (19.3% of the local population) than in the central negative growth areas (4.3%). The same pattern occurs with illegal settlements, which represent almost 24% of the population of peri-urban areas while only 10% of the population of central areas. In the poor slow growth areas (less than 3% a year), the percentage of population living in shantytowns and illegal settlements is 15.5% and 17.4% respectively.

city government was less than 4 thousand per year between 1989 and 2003 (Marques and Saraiva, 2004). This amount does not include the investment in urban regularization and shantytown urbanization.

[10] Unfortunately, we only have data for the city of São Paulo to support this argument.

Map 4
Distribution of Shantytowns and Illegal Settlements in the City of São Paulo, 2000



Source: Secretariat for Housing of the City of São Paulo, 2002.

Table 4
Population living in shantytowns and illegal settlements. City of São Paulo , 2000.

	Groups of Areas			
	Negative growth areas	Slow growth areas > 0 & < 3%	Fast growth areas > 3% a year	Total
Population living in shantytowns	208,478	527,462	430,283	1,166,223
Population living in illegal settlements	470,112	591,009	529,862	1,590,983
Total	678,590	1,118,471	960,145	2,757,206
% Population living in shantytowns (*)	4.34	15.50	19.27	11.18
% Population living in illegal settlements (*)	9.80	17.37	23.72	15.25
Total (%)	14.14	32.87	42.99	26.43

Source: IBGE, 2000 and Secretariat for Housing of the City of São Paulo, 2002.
Note: (*) Percentage of population living in shantytowns or illegal settlements in relation to the total population of the group area.

Illegal occupation accounts for 43% of the population living in fast growing peri-urban areas of the city of São Paulo. Such illegal occupation of the poor peri-urban areas seems to be part of the same process that induces the strong rate of population growth in poor areas. In the case of São Paulo, there are diverse institutional barriers for the provision of proper infrastructure and social services in irregular and/or invaded areas. This high level of irregularity "justifies" the non-provision of social services, or the limits imposed upon their potential availability.

Even when the State decides to invest in irregular settlements, it is more difficult to find proper site location for social equipment in irregular or illegal land. Moreover, the State must follow complex legal procedures in order to appropriate private land, and also takes more time to find proper land for public equipment close to illegal developments and shantytowns. Sometimes the State decides not to invest in such areas due to the risk of losing public investments made in those places – which may be later incorporated by their private owners. Lawsuits against public administrators that do not follow the complex set of standard procedures may also happen in regard to land use regulations (Maricato, 1996; Torres, 2002).

Different authors have argued that informal land use is a major issue for developing countries. Some defend the regularization of land property and the simplification of norms and regulation as important preconditions for further social and economic development in this kind of urban area (World Bank, 1999).[11] However, the links between land use and social policies need to be addressed more extensively, since public services must be present even when land regularization is not in force. In the case of Brazil, some of these services are even considered to be constitutional rights.

In summary, in the case of São Paulo, it seems quite clear that the urban sprawl shows a stronger relation to land market dynamics (and the role of the government) than to the demographic dynamics *per se*. Quoting Sabatini (2001), who studies the segregation patterns in Chile, we can also say for São Paulo that "the land market is in the eye of the storm".

[11] "Only well functioning land markets can provide an adequate supply of housing, and maintaining these markets is another task that deserves attention from the public sector. Providing universal registration and establishing clear property rights to all urban land will require strengthening existing institutions. Ill-defined land rights render land useless and discourage the redevelopment of entire portions of a city. But simply providing security of tenure creates incentives to improve housing and infrastructure dramatically. To avoid adding to the backlog of problem housing and neighborhoods, new development must meet basic – but not excessive – compliance standards**"** (World Bank, 1999: 146)

3. Urban Sprawl and Environmental Degradation

One of the most significant environmental impacts of the urban sprawl of São Paulo seems to be the massive destruction of the green belt of Atlantic Rainforest surrounding the city. The Atlantic Rainforest is one of the most endangered eco-systems in the world. Different studies on deforestation estimate that less than 10% of the original forest remnants are preserved in Brazil, and the rate of destruction is still high (Fundação SOS Mata Atlântica, 1998).

São Paulo's Atlantic Rainforest greenbelt has been partially preserved – especially on its Northern and Southern parts - mainly because the topography of remaining areas does not allow for its agricultural exploitation. The South Region is part of the water sources protection area, and has intensified its already high population growth in the last decade. More recently, the North of São Paulo has also been growing fast around the fringes of the Cantareira mountain range.

A recent green coverage study conducted by the government of the city of São Paulo using satellite images has indicated that the city lost 53.4 square km of of green coverage in the last decade (PMSP, 2002). The greatest part of this deforestation (56%) was concentrated in only 10 of a total of 96 districts, all located in the poor suburbs, in which there has also been high rate of population growth.[12]

In other words, the urban sprawl was followed by a significant destruction of the remaining forests in the metro area, with little respect for the restrictive environmental legislation that forbids any deforestation of the Atlantic Rainforest – Bylaw 750/93 (Marcondes, 1999). Those green areas are part of the so-called Atlantic Forest Biosphere Reserve, an UN initiative, and are key for different ecological dynamics, since they serve as ecological corridors and routes for migratory species (Lino, 1992). They also play a fundamental role in the conservation of water sources.

Not surprisingly, the city has an important deficit of public spaces and green areas, a situation unlikely to be reversed since in the most consolidated portions of the city there are very few public areas available for building new parks. The available maps of green coverage show that half of the city districts present no significant forest coverage in terms of both the trees planted along the street network and parks or squares

[12] Districts include Jardim Ângela, Parelheiros and Grajaú in the South; Tremembé, Perus, Anhanguera and Jaraguá in the North; and Iguatemi, Cidade Tiradentes and São Rafael in the East.

(PMSP, 2002). In poor suburbs several public areas were invaded and turned into shantytowns and illegal settlements.[13]

In 1991, the municipalities of the Metropolitan Area considered in our study still presented a forest coverage of 1.23 thousand square kilometers, representing 35.7% of the Metropolitan Area, mostly located in preserved areas and strategic sites for the protection of water reservoirs. By 2000, the remaining forest in the same municipalities equaled 1.17 thousand square kilometers (34% of the region). Such figures are nevertheless good news, indicating that the São Paulo Metropolitan Area still possess substantial forest coverage.

However, this data also indicates an important net loss of forest cover (57.2 square kilometers) during the 90s, at a rate of 4.7 in nine years.[14] Although such deforestation could not be considered very high when compared with the rate of destruction of other Brazilian areas such as the Amazon Rainforest (PRODES-INPE, 2004), it is quite damaging for São Paulo both because of previous loss and the strategic services it provides for the metropolis in terms of protection of water sources and reduction of air pollution.

In Map 5 we present the distribution of forested areas in São Paulo in 2000 according to our own estimates, highlighting the areas that suffered higher levels of deforestation during the 90s (more than 2% of its area within the decade). In geographic terms, most of the deforestation took place in some of the far suburbs that had grown significantly in the 90s.

One can see that the center of the city is almost completely deforested. On the other hand, large parts of the suburbs are still covered with their original vegetation. We did not considered in this account pasture or grassland, although secondary forest succession and reforestation areas are also included in this estimate.

Additionally, Map 5 shows that the region in which the most important water sources for São Paulo are located – the reservoirs of Billings and Guarapiranga in the South of the city – present not only significant deforestation but also rapid population growth. The consequences of such dynamics are of concern and subject to extensive debate by the local press. The annual investment needed to preserve such reservoirs is

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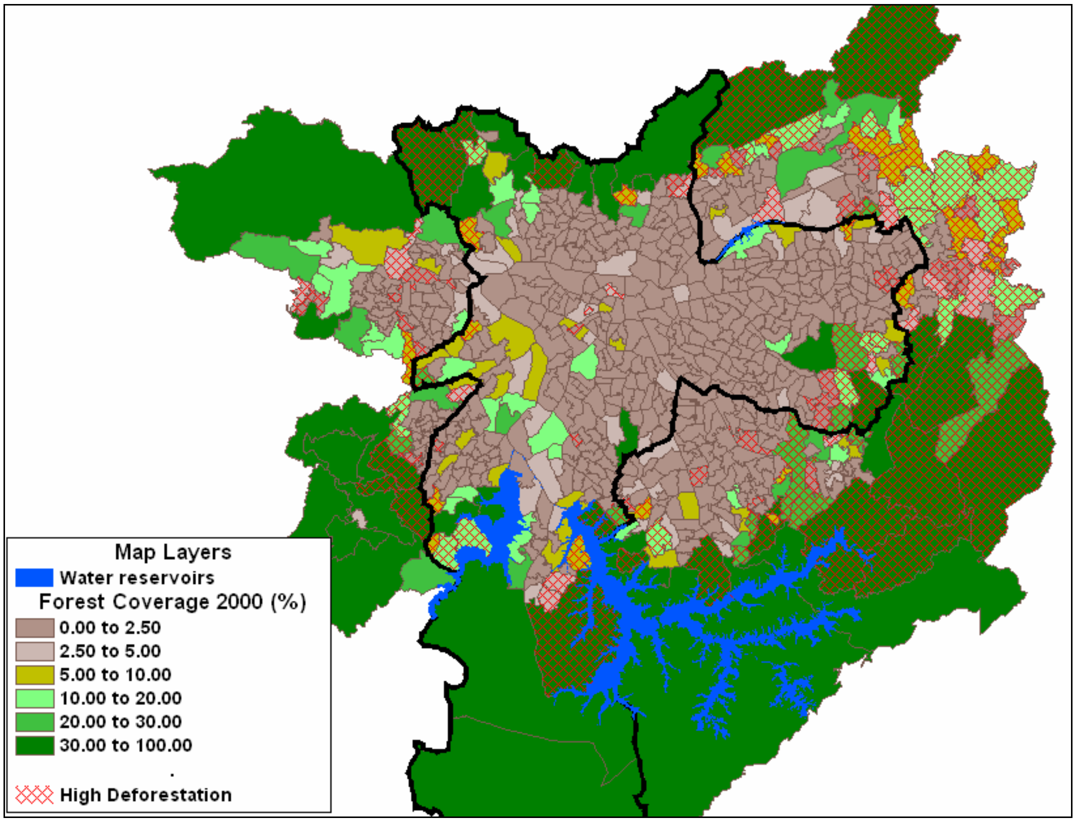
[13] See section 2.

[14] Such estimate simply subtracts the forested areas accounted for in 1991 from the ones in 2000. Therefore, it also includes forest plantation and forest regeneration.

impressive, and other alternatives would imply, for instance, bringing water from *Vale do Ribeira*, located further down South. Such an expansion of the water network would demand huge public investment due to the distances and topographic difficulties involved.

Map 5
Forest Coverage and Areas with High Level of Deforestation. Urbanized Area of São Paulo, 2000



Source: CEM-CEBRAP. Satellite images (LANDSAT TM 1991 and LANDSAT ETM 2000).See Annex 1.

It is also important to notice in Map 5 that the areas highlighted - with more than 2% of deforestation in the 90s - showed a total population of 1.7 million in 1991 and 2.8 million in 2000, a rate of growth of 5.3% a year. Considering this evidence, we try to interpret this forest data by employing the same geographic divisions previously used for analyzing these demographic trends (Table 5 and Figure 2).

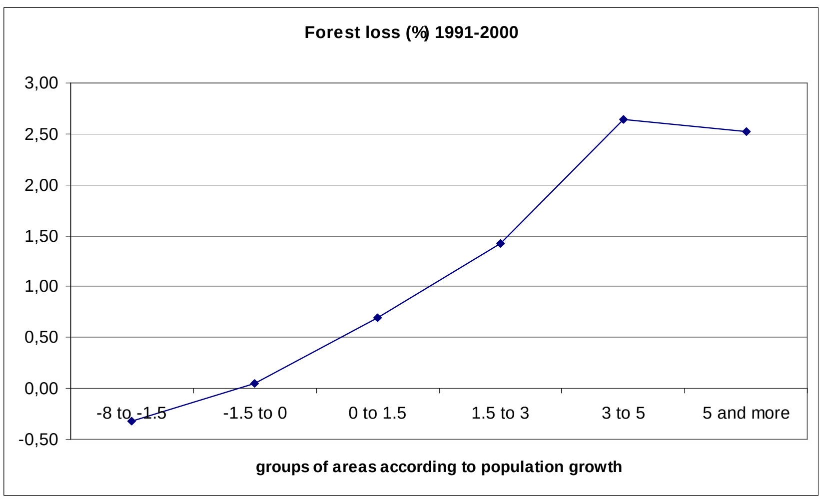
Table 5
Changes in forest cover between 1991 and 2000. Urbanized Area of São Paulo.

	Groups of areas according to population growth rate, 1991-2000						
	-8 to -1.5	1.5 to 0	0 to 1.5	1.5 to 3	3 to 5	5 and more	Total
Total Area (km2)	255.46	383.35	323.71	434.31	650.90	1542.43	3590.16
Forest coverage 1991 (km2)	9.37	13.13	26.36	129.84	313.20	751.28	1243.19
Proportion of forested land 1991 (%)	3.67	3.43	8.14	29.90	48.12	48.71	34.63
Forest coverage 2000 (km2)	10.18	12.94	24.10	123.67	295.99	712.34	1179.22
Proportion of forested land 2000 (%)	3.99	3.37	7.44	28.48	45.47	46.18	32.85
Change in forested area 1991-2000 (km2)	0.82	-0.20	-2.27	-6.17	-17.21	-38.95	-63.97
Change in forested area 1991-2000 (%)	0.32	-0.05	-0.70	-1.42	-2.64	-2.53	-1.78
Spatial distribution of deforestation	-1.27	0.31	3.54	9.64	26.91	60.88	100.00

Source CEM-Cebrap. Satellite images (Landsat TM 1991, Landsat ETM 2000).[15]

Figure 2

Deforestation and rate of population growth between 1991 and 2000. Urbanized Area of São Paulo.



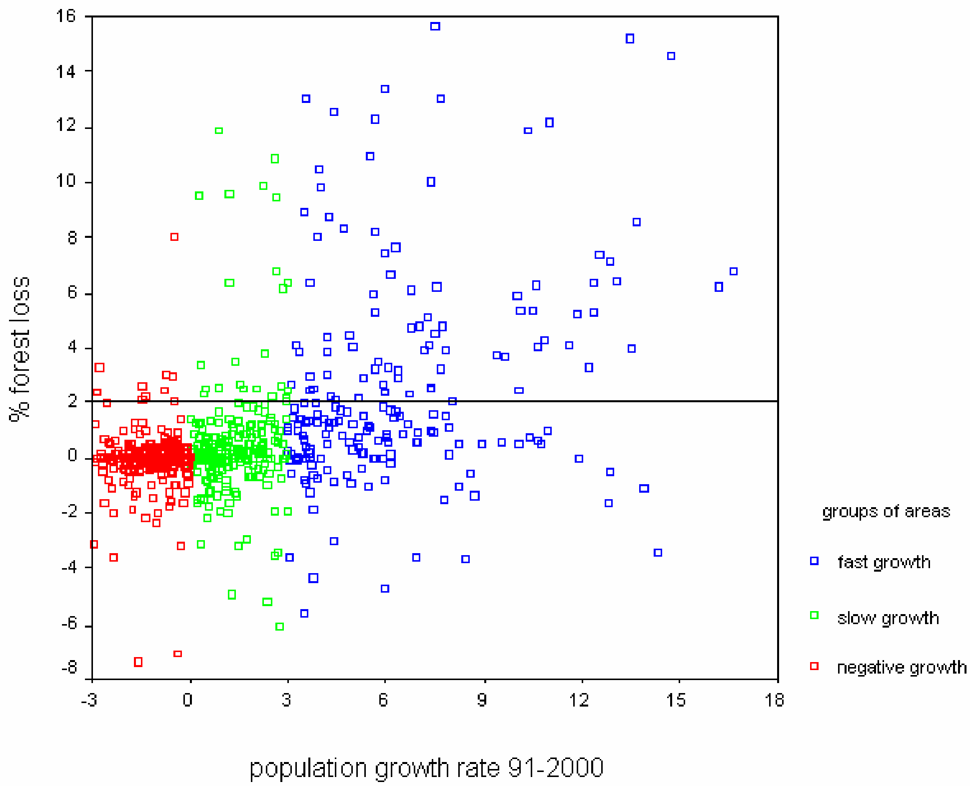
Source CEM-Cebrap. Satellite images (Landsat TM 1991, Landsat ETM 2000) and IBGE, 1991 and 2000.

In 2000, almost 50% of the fast growing (peri-urban) areas were still forested, particularly in the North and the South. In slow growth areas, 20% of the territory presented forest coverage, while negative growth areas showed a forest coverage of only 4%. Ironically, the rate of population growth is strongly positive in forested areas and negative in denser urban ones. Additionally, over 85% of all forest coverage of São Paulo's Urbanized Area are located in peri-urban areas, totalling more than one thousand square kilometers. On the whole, almost 5% of the forest coverage that existed in 1991 was destroyed by 2000, a trend that will most likely continue in the near future.

Available data shows that fast growing areas (more than 3% of population increase a year) presented a net loss of almost 50 km2 of forest coverage between 1991 and 2000, i.e. a reduction of 5% of their original 1991 coverage. In other parts of the city, such loss was less significant, and even includes a small grow in the forested area of the central parts of the city (in which population is negatively growing).

However, this kind of ecological data may not precisely establish the connections between population growth and deforestation. While it is clear that most of the deforestation occurs in areas with very fast population growth, it is not an exclusive feature of such areas. We present evidence of this argument in figure 3, below.

Figure 3
Relationship between population growth and forest loss in the Urbanized Area of São Paulo, 1991 and 2000.



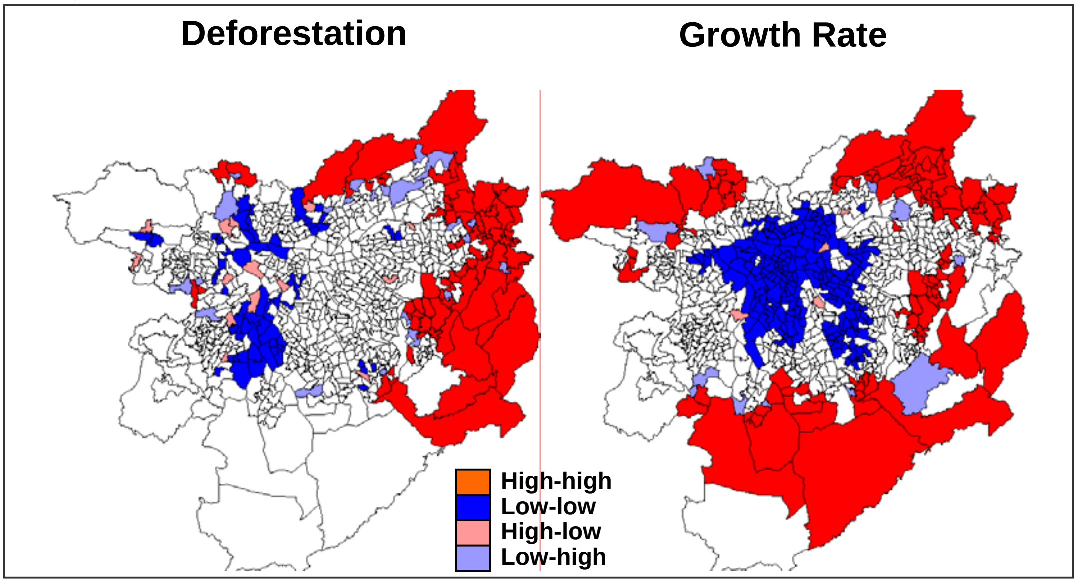
Source: IBGE, Demographic Census of 1991 and 2000 and Satellite Images.
Notes: 1) Each point refers to a census survey area.
2) The percentage of forest loss was calculated for each area.
3) Pearson correlation coefficient $r = 0.426$

[15] See Annex 1.

This figure shows that there are very few situations in which high rate of deforestation occurs in the negative and slow growth areas, and that almost all deforestation has happened in the fast growth (peri-urban) areas. However, it is also important to consider that not all peri-urban areas present high rates of deforestation, with some of them even showing forest regeneration. In this context, public intervention should consider a targeted pproach, focusing on the Eastern portion of the city, for instance, which concentrates an important share of forest loss.

Considering theses problems, we have tried to test such arguments through different statistical Models. First, we tested a space regression model (Anselin, 1996), presented in Annex 3. Besides a significant heteroskedasticity, the regression did not presented a strong correlation between population growth rate and deforestation. The R2 achieved was 36%, even when using controls for other variables, such as 1991 forest coverage. Secondly, we used Moran techniques (LISA map) to try to observe the relationships between clusters of deforestation and clusters of population growth.[16] Those maps were produced with Geoda software; final results are in map 6, below.

Map 6:
Clusters of Deforestation and Growth Rate (LISA map). Urbanized Area of São Paulo, 1991-2000.



Source CEM-Cebrap. Satellite images (Landsat TM 1991, Landsat ETM 2000) and IBGE, 1991 and 2000.

[16] Moran and LISA are techniques to measure and locate cluster occurrences.

What those maps show is that deforestation is highly concentrated in the Eastern part of the Metropolitan Area, while the cluster of high rate of population growth is spread across the suburban area. The Eastern cluster of high deforestation alone is responsible for 71% of all forest loss observed in the region. This area presented a significant deforestation rate (5.8%), which reduced its forest cover to 44.8% in 2000.[17]

The data indicates that although population growth and deforestation seem to be connected in some regions, this cannot be perceived as a general rule to understand deforestation dynamics. The Eastern cluster could also be explained by additional elements such as agricultural activities and land use regulation, although those are note necessarily valid for other suburban areas. We do not have much information on metropolitan agricultural activities, but we will try to further discuss land regulation by exploring the connections between deforestation and environmental regulation in the following section.

3.1. Deforestation and Environmental Regulation

Green areas and water sources are protected in São Paulo by national, state and local legislation. Such laws define different types of protected areas. For the case of São Paulo, the most important are the following:

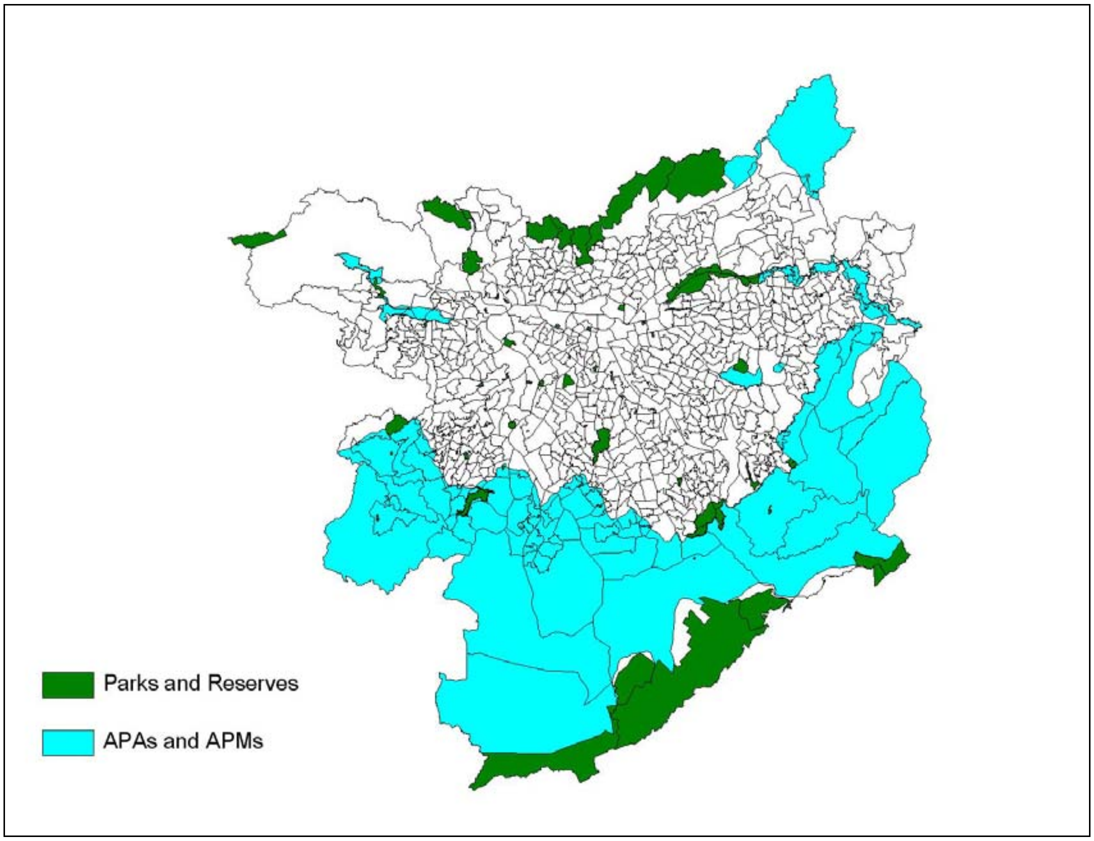
- Areas of Environmental Protection (Áreas de Proteção Ambiental - APAs). This type of conservation area allows for private use of natural resources, according to the limitations of the law. Land use is enforced by the federal government agency (IBAMA);
- Areas of Water Source Preservation (Áreas de Proteção de Manancial - APMs). This form of conservation area was regulated by the São Paulo state legislation (9.866/97) that establish a policy for water sources areas, including the metropolitan reservoirs of Billings and Guarapiranga. It also allows private use of land. As mentioned before, the enforcement of this legislation is quite inefficient. There is 1.8 million people living in such areas, and 17 out of the 39 municipalities in the Metropolitan Area of São Paulo have more than 50% of their area protected by this regulation.

[17] This area also presented a significant rate of population growth (5.4% a year).

- Parks, forest reserves and urban parks, under local or state jurisdiction.[18] Those areas are basically government property and their occupation by private dwellers is forbidden. The most important and preserved remnants of the Atlantic Rainforest are located in parks in the farthest Southern portion of the Metro Area. In the North, the public parks of Cantareira and Jaraguá - sponsored by the State government - also include important remnants of native forest with medium to advanced stages of forest succession. Both the Western and Eastern areas of the city are less protected by the presence of parks and reserves.

Map 7 and Table 6 present the spatial distribution of these environmental protected areas within the urbanized area of São Paulo.

Map 7
Distribution of Environmental Protected Areas. Urbanized Area of São Paulo.



Source: CEM/CEBRAP, 2004

[18] The State Parks in the metropolitan area are the following: Cantareira, Alberto Löefgren, Jaraguá, Juquery, Jurupará, Várzea do Embu-Guaçu, Guarapiranga e Estação Ecológica de Itapeti. See: www.if.sp.gov.br

For analytical purposes, we have aggregated APAs and APMs in a single category due the similarity of their legal characteristics, i.e. land property status (private) and the possibility of land use under the terms of the environmental regulations. Together, they correspond to 40.8% of the total Metropolitan Area and 61.5% of its forest coverage. Parks and reserves account for 7.8% of the total area and 19.4% of the forest coverage. The areas under now environmental protection aggregate 51.4% of the territory and only 19.1% of its forest coverage.

Table 6
Changes in the forest cover between 1991 and 2000 according to land use status. Urbanized Area of São Paulo.

	Parks and Reserves	**APMs and APAs**	**No protection**	**Total**
Total Area (km2)	279,01	1465,02	1846,13	3590,16
Urban area 1991 (km2)	15,57	142,24	1005,56	1163,37
Forest coverage 1991 (km2)	224,10	769,04	250,06	1243,19
Urban area 2000 (km2)	12,05	159,82	1152,17	1324,04
Forest coverage 2000 (km2)	228,65	725,29	225,28	1179,22
Proportion of forested land 2000 (%)	81,95	49,51	12,20	32,85
Change in forested area 1991-2000 (km2)	4,55	-43,74	-24,79	-63,97
Change in forested area 1991-2000 (%)	**1,63**	**-2,99**	**-1,34**	**-1,78**

Source: **Source** CEM-Cebrap. Satellite images (Landsat TM 1991, Landsat ETM 2000) .

Considering deforestation data regarding the land use status, we find some surprising results. While non-protected areas have lost some of their remaining forest between 1991 and 2000 (1.,3%), and parks and reserves presented some level of forest regeneration (1,6%) – which was to be expected, the other protected areas (APAs and APMs) presented a significant forest loss, corresponding to 3.,0% of their territory, or 43.7 square km. Such unexpected data strongly suggest that this form of environmental legislation is not working as planned.

In general terms, this data indicates that part of the environmental legislation (APAs and APMs) is not being able to controll land occupation, population growth and forest loss. The so-called “law of protection of water sources” has not been able to limit urban expansion around major lakes and forest remains in the Southern part of the metropolis. On the contrary, the law has produced a reduction in land prices, which led to expanded in illegal occupation and the consequent pollution of the water sources and deforestation (Marcondes, 1996). For instance, in a buffer of 1km around the two major reservoirs (Guarapiranga and Billings), for instance, the population has grown from 554 thousand in 1991 to 881 thousand in 2000, or 4.3% a year.

However it is also important to understand the role played by the deforestation cluster we have previously identified. We present in Table 7, deforestation data according to land use status and the Eastern cluster location.

Table 7
Changes in the forest cover between 1991 and 2000 according to land use status and presence of the Eastern cluster. Urbanized Area of São Paulo.

Types of Area	Forest coverage 2000 (km2)	Change in forested area 1991-2000 (km2)	Change in forested area 1991-2000 (%)
Parks and Reserves	228.65	4.55	1.63
APAs and APMs that belong to the Eastern cluster	229.45	-29.1	-6.58
APAs and APMs outside the Eastern cluster	495.84	-14.65	-1.43
Eastern Cluster without APAs and APMs	54.77	-15.61	-5.75
Other areas	170.51	-9.17	-0.58
Total	1179.22	-63.98	-1.78

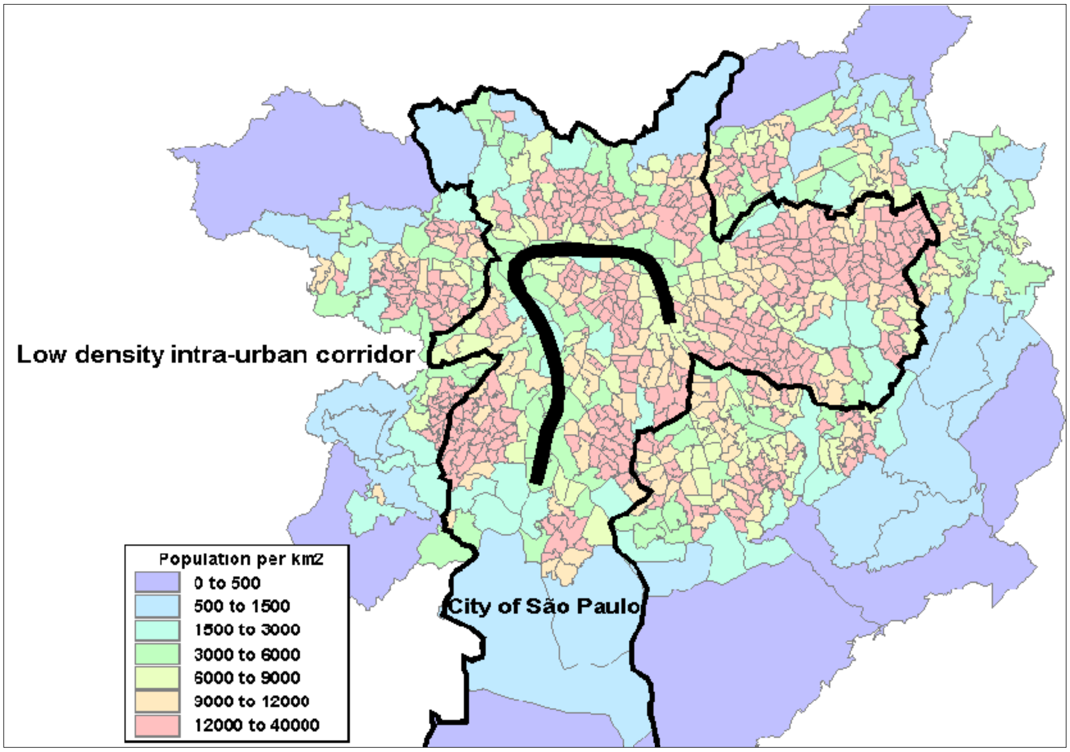
Source: CEM-Cebrap. Satellite images (Landsat TM 1991, Landsat ETM 2000) .

One can see that although deforestation happens in all areas, with the exception of parks and reserves, it is much more significant in the areas - be them protected or not - that belong to the Eastern cluster. Such result points to the need of a better understanding of this particular region of the Metropolitan Area. However, it is also important notice that deforestation in APAs and APMs are significant even outside such cluster.

5. Conclusion

This paper has first shown that the demographic growth of the city is very uneven. While the center of the city is losing population, its farthest suburbs are growing fast. Associated to this observation, we have also noted that those areas are the poorest and with less infrastructure of the region within the Metro Area and that they present high levels of deforestation and informality in terms of land use. The high concentration of social, environmental, and legal problems in the far suburbs makes them very ill suited for population growth, which ironically persists to expand. However, it is not necessarily true that this pattern of growth – all city growth focused on the “periphery” – must continue. There is right now a significant amount of nonoccupied land in central parts of the Metro Area – especially in the old industrial belt and along some railroad corridors, as shown in Map 8.

Map 8
Population Density. Urbanized Area of São Paulo, 2000



Source: IBGE, Demographic Census, 2000.

In this sense, such trends seem to be related to the land markets rationales. Should the population growth happen in denser areas, much of the current damage could be reduced. In our point of view, only a significant change in the dynamics of local land markets could allow for a more sustainable pattern of growth.[19] This land has not been occupied because of both their high prices and the lack of public policies that could redirect it to low-income dwellers and housing projects. Taxation, for instance, could be more extensively used to stimulate vertical building and punish vacant lots. Current zoning regulations also prohibit tall buildings in large, high-income, low-density neighborhoods, significantly restricting the possibility of other families to live in areas that have full infrastructure.

[19] In other words, we totally agree with Martine (2001) that density should be stimulated in order to revert such trend.

Secondly, it is important to notice that it is not the case to blame the poor migrants that move to these least structured suburbs. They are the first to be affected by the degradation of the environment, not only through their exposure to environmental hazards and vectors of contagious diseases, but also because their places of residence are less protected in terms of equipment and/or construction patterns that could avoid such hazards.

The logic that produces the urban sprawl in metropolitan areas such as São Paulo is quite complex, and related to the role of different branches of the government (regulation, taxation, infrastructure, housing policy, etc.) and private companies. Most likely, this sprawl would be happening even with a zero population growth scenario.[20]

Therefore, the most significant issue here is how to change such unfortunate trends. The idea that general land use (and environment) regulation could cope with such problems is quite naïve, since it has not been able so far to properly regulate illegal settlements in São Paulo. Urban environmental legislation, for instance, often falls victim of such logic. The example of the "law of water sources protection" in stimulating land occupation is just one tragic example of the failure of a series of attempts to enforce land regulation.

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[20] In fact, it is already the case of the city of São Paulo that is growing quite slowly (0.8% a year between 1991 and 2000).

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Annex 1- Procedures for generating land cover estimates

In order to produce land cover indicators, we used the following satellite images for the Metropolitan Area of São Paulo:

1. Landsat 5 TM (Thematic Mapper), orbit point 219/076 – October 23, 1991
2. Landsat 7 ETM+ (Enhanced Thematic Mapper Plus), orbit point 219/076 - September 21, 2000.[21]

We adopted the software ENVI 4.0 to process such images and initially registered the 1991 image, procedure later applied to 2000. These images were geometrically corrected and registered with reference to the vector cartography of rivers and streams for the region (scale 1:10,000).

We used different digital image processing procedures to enhance the images regarding its vegetation, i.e., contrast enhancing, color composites, filters for special frequencies and mathematic operations for image classification. The color images that have presented the best results for visual interpretation were the ones produced with the TM4, TM5 and TM3 bands and channels red (R), green (G) and blue (B). We produced the color composites in 1991 and 2000, keeping the same contrast for both of them.

Since the main objective was to identify basic green coverage, we chose not to use NDVI (Normalized Vegetation Index). The classification were based on TM4, TM5 and TM3 bands for 1991, which guided the mapping classes adopted here. We have produced the following classes: urban areas, water, exposed soil, grassland (pasture, etc.) and forest. We have made no attempt to discriminate primary forest, secondary forest of planted vegetation, since it was not the paper's objective.

Having produced such classes, we started the classification based on different samples. Our basic source of information has been aerial photographs (scale 1: 8,000) of significant targets. Based on the largest sample possible (at least 5,000 pixels) in the two color composites (1991 and 2000), we started the process of supervised classification.

We used the classification algorithm known as Maxver (maximum likelihood), following Richards (1986). After such initial classification, we used different filters

[21] These dates refer approximately to the 1991 and 2000 census reference dates.

such as “clump” and “sieve”. Such procedures were adopted for the images of both 1991 and 2000.

In order to test classification accuracy, we used a confusion matrix generating a Kappa coefficient of 0.9466 in 1991 and 0.9442 in 2000. Such coefficient varies between 0 and 1, and the best classifications are those closest to 1. The Kappa coefficients we have obtained are satisfactory, and we accepted the classification (Richards, 1996). The classified images were transferred to the ArcGis 8.1 where the images were converted to a grid format and than analyzed for each census survey area for 2000.

Annex 2 – Land Market indicators

Table 8
Indicators on Private Companies` Housing Investment (1985-2003) According to Groups of Census Survey Areas, Classified Based on Their Population Growth Rate (1991-2000). Urbanized Area of São Paulo.

Groups of areas according to population growth rate, 1991-2000	Number of occupied households 2000	Population density (Pop./km2)	Average family income (1)	New private investment in residential area per household (2)	New investment per household (3)	Investment per group of areas (%)
-8 to -1.5%	622918	7484	22.90	12.84	5.55	37.51
1.5 to 0%	1213558	10749	15.15	7.17	2.49	32.80
0 to 1.5%	916966	10836	11.17	7.09	1.63	16.19
1.5 to 3%	605315	10943	9.54	3.57	1.16	7.60
3 to 5%	466761	7961	6.97	3.26	0.60	3.04
5% and more	801623	8715	6.23	1.98	0.33	2.86
Total	4627141	9526	12.42	6.16	1.99	100.00

Sources: IBGE, 1991 and 2000; Embraesp, 1985-2003.

Notes: (1) Expressed in number of monthly minimum wages of 2000. In 2004, one minimum wage corresponded to approximately 90 dollars.

(2) Total residential area (square meters) produced between 1987 and 2003 divided by the number of households in 2000.

(3) Total investment (US$) between 1987 and 2003 divided by the number of households in 2000.

Annex 3: Space Regression Model

Dependent Variable:

- PDVARBUST9 Deforestation between 1991 and 2000 (%)

Explanatory variables:

W_PDVARBUST9	Deforestation in neighborhood areas (Queen Contiguity)
TAXDESEM	Unemployment rate (2000)
PSUBNORM	Population living in shantytowns in 2000 (%)
TAXA91_0	Population rate growth 1991-2000
PVARBUST91	Forest coverage in 1991 (%)

SUMMARY OF OUTPUT: SPATIAL LAG MODEL - MAXIMUM LIKELIHOOD ESTIMATION

Dependent Variable :	**PDVARBUST9**	Number of Observations:	757
Mean dependent var :	-0.861942	Number of Variables :	6
S.D. dependent var :	2.70072	Degrees of Freedom :	751
Lag coeff. (Rho) :	0.436037		

R-squared :	0.359094	Log likelihood :	-1671.42
Sq. Correlation : -		Akaike info criterion :	3354.85
Sigma-square :	4.67469	Schwarz criterion :	3382.63
S.E of regression :	2.1621		

Variable	Coefficient	Std.Error	z-value	Probability
W_PDVARBUST9	0.4360368	0.04451628	9.794996	0.0000000
CONSTANT	0.2175727	0.2761531	0.7878698	0.4307727
TAXDESEM	0.01987509	0.01528693	-1.300136	0.1935545
PSUBNORM	-1.296872	0.5664194	2.289596	0.0220447
TAXA91_0	0.1352656	0.020164	-6.708276	0.0000000
PVARBUST91	0.02847819	0.00669473	-4.253822	0.0000210

REGRESSION DIAGNOSTICS
DIAGNOSTICS FOR HETEROSKEDASTICITY
RANDOM COEFFICIENTS

TEST	DF	VALUE	PROB
Breusch-Pagan test	4	481.9144	0.0000000

DIAGNOSTICS FOR SPATIAL DEPENDENCE
SPATIAL LAG DEPENDENCE FOR WEIGHT MATRIX : **pesos_mod1.GAL**

TEST	DF	VALUE	PROB
Likelihood Ratio Test	1	96.99473	0.0000000