Article

A framework of indicators to support urban green area planning: a Brazilian case study

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Abstract

Green areas must be planned along with other city policies because they are important spaces that maintain the quality of the urban environment. The pattern of urbanization, especially with cities in the developing world, has negatively influenced green areas and, as a consequence, reduced the environmental benefits provided by them. São Paulo is one of the world's biggest cities in terms of territorial occupation and population, but its unplanned development has led to serious impacts on its green areas. As a result, this has caused many worsening social and environmental problems, such as flooding and bad air quality. Considering that information is a central factor in the planning process of these areas and that São Paulo has an environmental quality report, the Global Environmental Outlook (GEO) of São Paulo, the purpose of this paper is to analyze the potential of this report to support the planning process of São Paulo's green area system. An indicator framework was described to help the planning of these areas. The indicators presented in Geo São Paulo were selected to create a framework for the policy support. The indicators were selected by their relationship with the green areas directives shown in the city master plan. The indicators were also analyzed by technical and policy relevance criteria.

Keywords green areas; urban planning; indicators; São Paulo.

1 Introduction

According to the Worldwatch Institute (2007), half of the world's population is now living in cities, and in the recent past, the main increase of the urban population occurred in underdeveloped and developing countries.

These countries are becoming more urbanized through a process that has not been used by the developed countries since the 1970s (Tucci, 2003). The large- and medium-sized cities in developing countries are following a pattern of centric-periphery expansion, causing the phenomena called urban sprawl, which can be defined as sparse and disconnected urban growth that leaves empty spaces inside the urban space (Brueckner, 2000).

According to Grimm et al. (2008), cities such as São Paulo, Mumbai, Laos and Mexico City have the highest growth in terms of population and territorial expansion. This phenomenon is associated with several social and environmental impacts that have led to environmental degradation (Grimmond, 2007; Parnell et al., 2007). Despite this, subjects such as sustainability and quality of life have never been so discussed. The unorganized development of cities, especially in developing countries, occurs in the opposite way of what is needed, which is a process that incorporates environmental values into the development of the urban spaces.

The pattern of growth induced in the urban regions of the developing countries has been characterized as disorganized and fragmented and has caused the formation of several isolated cores inside the cities (Parnell et al., 2007). According to Alberti et al. (2007), the effects of this urbanization are manifested because of the physical alterations to the landscape, such as changes to the drainage system and the intense construction of infrastructure. The conversion of natural land cover to impermeable surfaces substantially reduces the infiltration of rainwater, and as a consequence of this, rainwater runoff tends to increase, which results in hydrological responses such as floods (Alebrti et al., 2007). Also, the removal of natural areas for city infrastructure construction, such as roads and housing, increases the temperature of the urban centers, causing the island heat phenomenon (Weng et al., 2004).

Therefore, the process of greening cities can be used to attenuate the effects of urbanization (Baycan-Levent et al., 2009). According to Chiesura (2004), urban green areas are strategic to the quality of life in cities. The author states that the empirical evidence of the benefits and importance of these areas is increasing, especially for the environmental benefits associated with them, such as air and water purification, wind filtration, noise pollution mitigation and microclimate regulation, besides the social services such as socialization and recreation.

São Paulo is a classic example of how serious an unplanned urban development can be. Every year, the city suffers not only in the rainy season with floods and landslides but also in the dry season with air pollution, due to the vehicles mainly. According to the city atlas, the temperature of the city center and the densest regions varies by more than 5°C degrees from the surrounding areas. There are a few districts in the city where the vegetation index per habitant is 0 (Takiya, 2002).

Thus, urban green areas should be an important element in the urban planning. These areas must be planned together with the other cities policies, such as transportation, housing and sanitation. The indicators are important instruments that can provide support to policy formulation for these areas in an urban planning context because they can provide information for all phases of the planning.

Therefore, the purpose of this paper is to analyze how well suited the indicators that were presented in the Global Environmental Outlook of São Paulo city are to support the planning process of urban green areas.

2 Materials and Methods

The report Global Environmental Outlook of São Paulo (UNEP, 2004) was used to identify all the environment indicators that provide information about the quality of the city environment. To coordinate the indicators with the city green space, the São Paulo green areas policy, which was established in the city master plan, was analyzed. With the master plan, all the directives associated with the establishment and management of the urban green areas were identified. The framework was elaborated by matching all the environmental indicators to all the identified directives related to the green area system. For this, a matrix was built that could relate the aggregated indicators to the directives. The indicators with the highest relationships with the directives were selected first and then analyzed according to the criteria of their technical and policy relevance based on OECD (1994) and Winograd (1995).

3 São Paulo's Green Area System

São Paulo's green area system was established in the city master plan. The current plan, instituted in September of 2002, shows several actions for the expansion and improvement of the urban green areas. These actions are oriented especially for the protection of the water resources and the fauna and flora as well as to increase the number of protected areas (UNEP, 2004).

The need to make the municipality's green area system stronger is due to the effects of the unplanned urbanization process to which the city has been subjected. Yli-Pelkonen and Niemelä (2006) stated that the consequences of the physical structure changes to the green areas remnants are the loss and fragmentation of these areas, ecosystem functions changes and biodiversity loss. These changes also impact the human quality of life because of the negative effects from loss of the environmental benefits.

Therefore, concern about the recovery and creation of new green spaces inside the city is important for the promotion of the environmental benefits, especially those associated with temperature moderation, control of air quality and visual and sound amenities. These areas can also be used as spaces for recreational activities and social interaction (Bolund, 1999; Yli-Pelkonen and Niemelä, 2006).

According to Oliveira (2005), in São Paulo, the natural landscape changed to an urbanized landscape in an intense and unorganized way, commonly without respect to the zoning and environmental protection laws. The horizontal expansion of the city from the unplanned process of urbanization has had serious consequences over the green areas and also on their distribution throughout the city's territory. According to Takiya (2002), their distribution is punctual and isolated, with the worse index values of green acreage per habitants in the periphery.

There is limited information about the green spaces to support the formulation and planning process of these areas inside the city dynamics (Baycant-Levent et al., 2009). The authors confirmed that usually there is lack of information about the quantity and quality of the urban green areas, and thus improvement is needed especially about the information acquisition.

Indicators are an important instrument for the management of urban green areas that can provide information not only to support the policy formulation for these areas but also to ensure the effectiveness of the implementation process and in the monitoring phases inside a policy cycle. According to Smith (1998), the use of indicators is also associated with an easier comprehension of the real problems and needs, a better flow of information and an increase in the local support that improves the policy implementation. These indicators allow for the identification of changes in the implementation and can improve public participation and the ability to identify and correct mistakes.

The use of indicators as an instrument of policy and planning support for the valuation of urban policies has been applied in several countries, for example with the implementation of the Global Environmental Outlook (GEO) developed by the United Nations Environmental Program. The methodology allows for the elaboration of reports about the state of the environment. Although it was initially developed for the national and regional scales, in the last five years, it has started to be developed for a local scale, as with the GEO of São Paulo city (UNEP, 2004).

The GEO for cities shows a series of indicators that synthesize a great amount of information that is produced about the environmental quality of the cities to evaluate the socio environmental conditions in the cities. The use of this report is associated with a better understanding of the cities dynamics, especially with the availability of information that can be used as instruments to support decision making with respect to the urban planning policy and actions.

The indicators have a great potential to guide urban management, especially by allowing the integration of the many phases of the planning process (Bossel, 1999; OECD, 1994). The indicators favor not only the elaboration of policies and actions, but they also help to monitor results obtained from the implementation. Considering the need of the city of São Paulo to strengthen the urban green areas policy and the important role that the indicators can play, the way that the indicators presented GEO São Paulo could help to plan the green area system of the city was analyzed. A framework was created with the main important indicators that are related to the directives defined in these areas in the city master plan. The indicators to be presented in the following discussion were also the indicators with the best association with the technical and policy relevance criteria.

4 Results and Discussion

In São Paulo's master is established and defined all the policy guidelines for the urban green area system. However, as the basis of the management and planning of the urban green areas, the city also uses a report on the environment quality made with indicators from the GEO São Paulo. Therefore, these environment indicators were analyzed for their ability to support the planning process of the municipality's green area system. The analysis was performed in a way that could demonstrate if there is a group of indicators that allow for the elaboration of policies and actions related to these aspects as well as that could allow for the monitoring of the planning process of the green area system of São Paulo. This ability was analyzed by matching all the indicators presented in the GEO with the directives of the green area system defined in the São Paulo master plan, both the current one and the one under review.

Table 1 The 16 directives of the São Paulo green area system identified in the plans.

A.	To create cultural and tourist activities and sports uses, all compatible with the character of the green areas
B.	To establish a permeability rate
C.	To make the uses of these spaces compatible with their preservation
D.	To allow for the adequate treatment of the vegetation
E.	To establish a shared management of the public green areas
F.	To incorporate the private green areas into the green area system
G.	To expand and maintain the green paths for the interconnection of the green areas
H.	To restore the degraded green areas
I.	To create programs for new green areas implementation
J.	To create green areas in the drainage headwaters
K.	To establish recovery programs
L.	To increase the green area per capita index
M.	To establish interconnections between the regions of environmental importance
N.	To stimulate tree planting in the public schools
O.	To create forest areas in remnants from expropriations
P.	To ensure biodiversity conservation

The analyses were centered on how the indicators responded to the green area system directives and on the possibility of using these indicators as instruments to support the formulation and evaluation of the execution of the master plan policies that are related to the green areas. A matrix was made to allow the identification of the relationship between the indicators and the directives and goals of the green area system. The matrix was created by two sources of information: the aggregated GEO São Paulo indicators and all 16 directives from the green area system, identified in the city master plan, the current one and in the proposed one under review. Table 1 shows the 16 directives identified in the plans.

Table 2 The relationship between the green area system's directives and the indicators presented in GEO São Paulo.

Indicators	Green Areas System's Directives															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1. Growth and population density			■			■										
2. Authorized and unauthorized Settlements			■													
3. Expansion of the urban area	■	■	■			■	■	■				■	■			
4. Vertical properties		■				■										
5. Reduction of vegetation cover				■			■		■	■	■	■	■			■
6. Disposal of wastewater and rainwater													■			
7. Atmospheric emissions									■						■	■
8. Potentially polluting activities			■	■				■				■				
9. Occurrences involving wildlife												■				
10. Air quality									■						■	■
11. Areas of flood and slip risk		■						■			■	■				
12. Areas of erosion and siltation			■				■				■	■				
13. Vegetation cover			■	■			■	■	■		■		■	■	■	■
14. Species diversity							■		■					■		
15. Protected areas	■		■		■	■			■				■			
16. Urban afforestation	■		■	■		■	■		■				■		■	■
17. Preservation of historical, environmental and archaeological areas	■		■													
18. Biodiversity loss							■	■				■		■	■	■
19. Microclimatic changes				■			■		■		■				■	■
20. Occurrences of floods and landslides											■	■				
21. Lowering of underground water table		■						■			■	■				
22. Legislation of watershed protection			■	■							■					
23. Establishment and management of protected areas			■		■	■			■	■	■		■	■		
24. Environmental education	■		■		■											
25. Areas at risk of flood slip recovered			■	■			■	■			■		■	■		
26. Areas of erosion and sedimentation recovered			■	■				■			■	■	■			
27. Recovery of degraded areas			■	■		■		■		■		■	■			■
28. Expansion of vegetation cover	■		■	■			■		■	■			■	■	■	■
29. Rehabilitation and release of wild animals												■				

Table 2 shows all 29 aggregated indicators where at least one of the variables has shown a relationship to at least one of the directives established. Therefore, primaries were selected in which the indicators have at least one relationship with one of the directives, creating a group of indicators with the potential to describe the policy of São Paulo green area system.

Using this matrix, it was possible to select the potential key indicators to support the planning process of the urban green areas of São Paulo. A preliminary group of indicators was selected by establishing a minimum necessary correlation among the indicator and the directives. Because the indicator that showed correlations to the largest number of directives was *expansion of urban area*, which was related to 12 directives, the minimum established was half that amount or 6. With this, 12 indicators were selected. However, this does not imply that the others 17 indicators were not important. They should also be used when working with the São Paulo urban green areas, but there was a group of indicators that were more related to the directives established in the master plan, so these indicators were considered first. The 12 indicators are presented in Fig. 1.

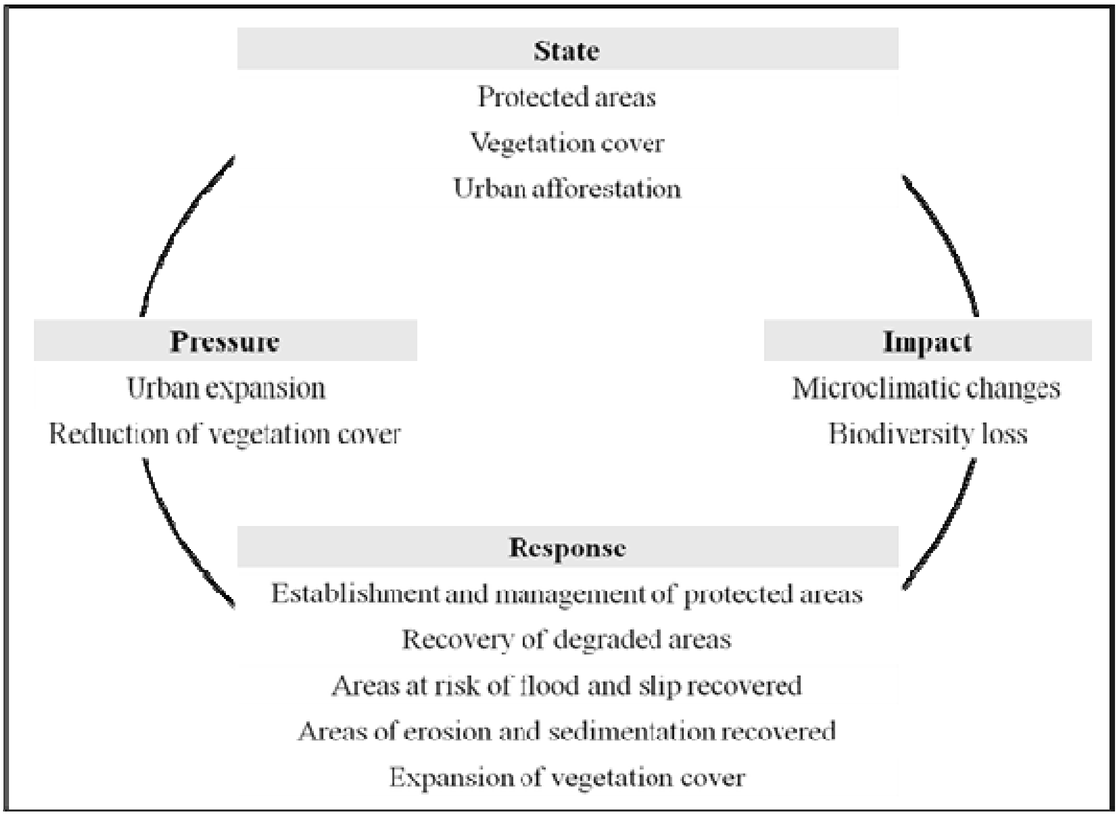

Fig. 1 Framework of indicators.

The indicators of the GEO were formulated according to the model Pressure-State-Impact-Response (UNEP, 2004). This set of indicators represented the main information synthesized to support the planning process of actions and policies related to the green area system of the city of São Paulo. These are the indicators that directly relate to the directives established for the green areas in the city master plan. Despite the direct correlation and relevance of these 12 indicators, consideration should be given to determine if the information provided was according to the principles of policy relevance and technical procedures of constructing an indicator.

The indicators of pressure are used to express which human activities may influence the environment (OECD, 1994). Of all the indicators of pressure presented in Geo São Paulo, there were two that indicate activities that cause more pressure over green areas. The expansion of the São Paulo urban area is directly associated with the loss of green areas, due to the characteristics of the urbanization process (Cohen, 2004). The city development policy has led to a horizontal expansion. Therefore, this indicator signifies the increase of pressure, for example, over the vegetation cover. The territorial expansion of urbanization, in the way that has been happening in São Paulo, tends to eliminate the green areas for the construction of roads and housing (Jacobi, 1997). This conclusion can be verified in the city master plan, which defines a recovery of all valley bottoms and floodplain, through the implementation of linear parks. As these specific areas are commonly not regularly occupied, there is another policy that remains for these areas, and it is a housing policy. A percentage of these areas are classified as areas of special social interests, where the main actions are related to the regularization through a process of urbanization. The channeling of watercourses and then the construction of infrastructure occurs there, instead of the recovery of the riparian vegetation of the watercourses and the establishment of green ways.

The other indicator of pressure selected was the reduction of the natural land cover. In São Paulo, the reduction of the green areas is primarily related to the unplanned expansion of the urban area and the consequences of this process that substitutes the natural land cover with urban infrastructure. The lack of natural land cover in the urban green areas is associated with several disturbances to the environment, such as the island heat phenomena, the intensification of floods, climate changes and the increase in the vulnerability of certain areas to slip and erosion (Chiesura, 2004; Yli-Pelkonen and Niemelä, 2006; Niemelä et al., 2010).

The indicators classified in the state category are supposed to report the actual conditions of the environment (OECD, 1994), and the indicatorsselected are associated especially with the land use theme. The main important indicators in the state category are associated with the presence of green areas in the city, such as parks, green ways, protected areas, natural land cover and urban afforestation. According to Chiesura (2004), these areas have an important role in regulating the city climate and also in promoting social interaction. According to Niemelä et al. (2010), easy access and good quality of the urban green spaces are important to achieve a high-quality living environment, which has a direct consequence on public health.

From the state indicators, it is possible to know the vegetation cover conditions of the city landscape, which is an important aspect that is directly related to the directives presented in the master plan. The information provided by this category can help to understand the consequences of certain environmental conditions and the impacts resulted from these conditions.

The impact indicators that showed more relevance to the green area system planning were the changes in the microclimate and the loss of biodiversity. Many studies have shown the relationship between the lack of green areas and the increase in the temperature in cities, especially due to the absorption of heat by the city buildings and the urban surface (Souch and Drimmond, 2006; Weng et al., 2004). The presence of green areas can help to ease the effects of urbanization by controlling the air temperature by evapotranspiration, by controlling the wind and also by the shadow effect. The proper planning and management of these areas are also potentially associated with the biodiversity preservation, especially by promoting the connections and allowing flow through other important natural areas inside the city or surrounding area (Niemelä et al., 2010; Weng et al., 2004; Bolund, 1999).

The response indicators represent the adoption of public and government actions to improve, attenuate or avoid the pressures and impacts on the environment (OECD, 1994). The indicators selected were associated with the recovery of areas that have been degraded due to the impacts that result from the main pressure activities. The unplanned expansion of the city over areas with high environmental vulnerability demands actions to reverse the situations with high risk to society, such as the flooding areas (Jacobi, 1997).

One of the main criticisms of the Pressure-State-Impact-Response (PSIR) model is related to the idea of simplification. According to Bossel (1999), this model is restricted to a linear idea of a cause and effect relationship, and relationships that are not linear among the components of the system chain cannot be considered by this model, which leads to actions in response that are correctives and not preventives. This picture can be shown by the indicators related to the recovery of areas that are degraded and at risk of flood, slip, sedimentation and erosion. These are actions taken after a certain state of degradation. Despite the criticism of the model, the responses to one of the city’s main problems, which is related to the drainage and has serious consequences and is the main reason for the risk areas, is associated with corrective actions. According to Tucci (2003), the Brazilian policy to deal with the drainage impacts derived from urbanization is associated with the idea of letting the water escape as fast as possible. The author states that it is a principle that has been abandoned by the developed countries since 1970, and the immediate consequences of this kind of action are increasing the flooding in other parts of the city due to the canals, which put more areas at risk.

However, the other two indicators of response, the establishment and management of protected areas as well as the expansion of vegetative land cover are actions that prevent putting areas at risk, so they are more than responses to the negatives impacts. They are ways to avoid allowing the environment to get worse, and they even attempt to improve it.

Thus, OECD (1994) states that the Pressure-State-Impact-Model is based on causality, where human activities exert pressures on the environment and change the quality and quantity of natural resources, with social responses to these changes through environmental, general economic and sector policies. However, OECD (1994) argues that the selection of the indicators and their classification into pressure and state categories should not obstruct the view of more complex relationships in the ecosystems and in the environment-economy interactions. The model is an attempt to put pressure, state, and response indicators in a systematic context and is created to bring together indicators that address similar problems.

As shown, the set of indicators selected by the relationships with the green area system directives was compounded by the indicators that can provide highly relevant information to support the planning of these areas. Despite its relevance, it is necessary to analyze the quality of the information (Winograd, 1995). Thus, the indicators selected were analyzed according to the criteria defined by OECD (1994) and Winograd (1995). Ten criteria were used to evaluate the indicators: type of indicator as classified by the PSIR model, number of references used to create the aggregated indicator, scientific accurately, directionality, spatial scale, coverage, most recent data, time of actualization, documentation and time comparison.

These criteria allowed an evaluation of the technical characteristics that have been used to describe the indicators and also the policy relevance of each indicator to determine if it could help in a policy planning process.

The results of this analysis showed that the best performances of the indicators were associated with the scale and coverage, and all the indicators selected were made for the municipality scale. The worse criteria analyzed was the time of actualization and a weak directionality.

5 Conclusions

As shown, green areas play an important role in maintaining the quality of urban environments and are associated with benefits to the natural and social environments. Large cities of the developing world are trying a pattern of growth that has not been used by developed countries for a long time, and it is causing the swelling of the cities and horizontal expansion. One of the main consequences of this pattern is the removal of the vegetative land cover and green areas (Grimm et al., 2008).

The establishment and management of these spaces inside the city have to be planned along with the other policies of the cities, especially the policies related to the infrastructure sector because the uncontrolled expansion of the city structures, such as roads and housing, are the main activities that have influenced the state of the urban green areas. All these policies must be created together, so they can be applied in a systemic approach to the urban planning (Grimm et al., 2008).

One of the main difficulties when planning these areas, according to Baycant-Levent et al. (2009), is the lack of information. São Paulo has a report of the urban environmental quality that could help the planning process of these areas. The GEO São Paulo presents a range of indicators that could provide the necessary information to establish and manage the city green area system. From all of the indicators presented in GEO São Paulo, there were 12 that responded directly to the green areas directives, so its use can provide extremely relevant information for the planning.

The Pressure-State-Impact-Response model used in the GEO favors a linear idea that helps to elaborate a framework of themes that are interconnected by a cause-effect relationship. The most important indicators pointed to the urban expansion and the reduction of the natural landscape as the main factors that pressure the urban environment. These two factors have been compromising the state of the city green areas, and as a consequence, they have impacted the microclimate of the city and are potentially associated with the loss of the biodiversity. The main responses identified were the recovery of areas that are already degraded and the attempt to expand the vegetative landscape and the establishment of protected areas in the city's remaining natural areas.

This framework of indicators elucidates the pattern of São Paulo growth and its consequences. As with many cities in the developing world, São Paulo has grown in population and territorial expansion without any concern for the reduction of vegetative land cover (Grimm et al., 2008). These indicators have influenced especially the protected urban areas, as addressed by Oliveira (2005), where the pressures of São Paulo's urbanization over the forest remnants in the city, located in the north and south extremes, and also the natural landscape cover that has been substituted with the urban infrastructure, with serious social and environmental consequences. This framework helps to incorporate this discussion at the policy formulation level, so the planning of green areas can be considered with the urbanization problems of the city.

As shown in many studies (Niemelä et al., 2010; Chiesura, 2004; Bolund and Hunhammar, 1999), strengthening these areas is important to the quality of the urban environment. Due to the current situation of the cities in developing countries, it is necessary to utilize instruments, such as key indicators, to support the planning of green areas to facilitate the implementation of actions related to these areas.

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