GREEN-INFRASTRUCTURE
A STRATEGY OF LANDSCAPE CONNECTIONS FOR LONDRINA-PR

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ABSTRACT

In the quest for environmental sustainability, much has been researched on Landscape Ecology. For some decades, several researches have defined strategies for implementing green infrastructures to improve the integration between green and urban areas. This paper presents a proposal for an urban open space system structured by four main elements located on the hydrographic micro-basin from the Ribeirão Cambé, in the city of Londrina -PR. Through a connexion between the Arthur Thomas Park, Igapó I Lake, Tucanos stream and Capivara stream, the presented system aims to play multiple roles relating to the hydrologic / ecologic balance of the basin and the forested lands. The integration would form a connection of public spaces destined for leisure and social interaction, establishing a relationship between nature and local urban landscape.

Keywords

Green Infrastructure. Greenways. Open Space Systems. Ecological Restoration. Landscape Ecology.

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INFRAESTRUTURA VERDE: *UMA ESTRATÉGIA DE CONEXÕES DA PAISAGEM EM LONDRINA (PR)*

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RESUMO

Na busca de sustentabilidade ambiental, muito tem se falado a respeito da ecologia da paisagem. Já há algumas décadas, diversas pesquisas têm definido estratégias de implementação de infraestruturas verdes com o objetivo de melhorar a integração entre áreas verdes e urbanizadas. Este artigo propõe um sistema de espaços livres urbanos estruturados por quatro elementos principais localizados na Microbacia do Ribeirão Cambé, na cidade de Londrina (PR). Por meio de uma conexão entre o parque Arthur Thomas, o lago Igapó I, o córrego Tucanos e o córrego Capivara, o sistema proposto busca desempenhar múltiplas funções relativas ao equilíbrio hidrológico/ecológico da bacia e das áreas florestadas. A integração formaria um conjunto de espaços públicos destinados ao lazer e ao convívio social, estabelecendo uma relação da natureza com a paisagem urbana local.

Palavras-chave

Infraestrutura Verde. Corredores Ecológicos. Sistemas de Espaços Livres. Restauração Ecológica. Ecologia da Paisagem.

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INTRODUCTION

Land use and urban planning strategies of our century have changed both the natural and urban landscapes. Although these changes vary geographically, with intensive land use, they increase landscape heterogeneity and fragmentation (AHERN, 1995). To mitigate these effects, ecological landscape planning is required, which must fully integrate society and nature (MCHARG, 1992) through sustainable strategies for clearing and planning guidelines for city living (PELLEGRINO, 2000).

The landscape, besides being a physical result of a social process of occupation and management of a given territory, is considered a system that when undergoing any action changes morphologically (MACEDO et al., 2012). According to Spirn (1998, apud MENEGUETTI 2007), the landscape context is complex and dynamic, woven of many threads in multiple directions. Meneguetti (2007) also adds that the idea of landscape provides an ideal space for the relations between nature, economy and culture to be analyzed. From a more pragmatic point of view, the landscape is considered an interactive set of spots, corridors and matrices (PELLEGRINO et al., 2006).

According to Forman (2005), "matrix" would be "the element that exerts the greatest influence on landscape processes and changes" - for example, the urban fabric of a city. Already "spots" are defined by Meneguetti (2007) as relatively homogeneous elements that differ from the surroundings, and may vary in shapes and patterns. And finally, the same author defines "corridors" as linear strips of earth that differ from their surroundings on all sides.

According to Pellegrino et al. (2006), landscape ecology is characterized as the science that studies the processes of fragmentation, isolation and connectivity, conducted by humans in natural ecosystems, seeking to investigate the influence of spatial patterns on ecological processes. Such an ecology would study the structure, function and change of heterogeneous areas of land, considering their development and spatial dynamics. The present work has the ecology of the landscape as a guide considering that its concepts have great application potential.

The discussion of current landscapes has inspired a dialogue between ecologists and landscape planners in search of a more "sustainable" condition that meets the needs of the present without compromising the future (AHERN, 1995). Ecological infrastructures are needed to achieve a sustainable urban landscape through elements that connect isolated landscapes and mitigate the effects of fragmentation (FORMAN; GODRON, 1996).

According to Meneguetti (2009), the term "green infrastructure" has

been increasingly used in discussions of this nature. Despite the different meanings associated with the term, according to Benedict and McMahon (2006, apud MENEGUETTI, 2009, p. 60) it is "an interconnected network of natural areas and other open spaces that conserves values and functions of the natural ecosystem". From this concept, an urban ecological structure (UES) is a planned green infrastructure (TZOULAS et al. 2007) aiming to promote a natural and continuous system of green spaces, preserving native species in urbanized areas.

In Brazil it is observed that the rapid urban growth, especially from the second half of the twentieth century, did not value the preservation of green spaces. The current challenge is to develop urban planning that alters areas already consolidated by human occupation. Thus, studies of green infrastructure deployment in Brazilian cities are important ways to contribute to changes in this paradigm.

BACKGROUND

The quality of urban space is influenced by the physical configuration of their open spaces. Open spaces are all open spaces of building, whether vegetated or paved, public or private (MENEGUETTI, 2007). Thus, the study of open space systems goes far beyond green areas, vegetated or public spaces. Therefore, it is assumed that every city has these systems (MAGNOLI, 2006).

The permeable and vegetated areas of a city may or may not be connected. Connectivity is the ability of a landscape to facilitate flows between its biotic elements. Green infrastructures can be characterized as tapestries formed by a variety of open spaces within or around a city. At the regional scale this network of spaces is composed of parks, green corridors and preserved natural spaces, connected or not (CORMIER; PELLEGRINO, 2008).

Green corridors are linear open spaces that connect large nonlinear areas or large spots of natural spaces. These sets constitute systems of spaces planned, designed and managed for multiple purposes, including ecological, recreational, cultural, aesthetic and productive objectives, compatible with the concept of sustainability (FÁBOS, 2004). Green corridors can be deployed along rivers and other linear paths, connecting spaces characterized by intense landscape performance. A network of green corridors safeguards natural resources, making them compatible with human activities, contributes to improving the quality of the landscape and the population's life and is an alternative to the current trends in land use planning (RIBEIRO; VAZQUEZ; MIGUEZ, 2012) . The characteristics of the corridors are: facilitating water and biological flows in the landscape; reduce the risks of local extinction and favor recolonizations, increasing the survival of populations; act as

a habitat supplement in the landscape; provide refuge for wildlife when disturbances occur; and hinder the spread of some disturbances, such as fires or certain diseases (PELLEGRINO et al., 2006).

As habitat loss and fragmentation threaten biodiversity, creating and maintaining connectivity of wildlife populations is an important goal. To adapt to climate change, it is essential to increase connectivity and conserve species and ecosystem capacity (LACHER; WILKERSON, 2014). In this context, creating connections for fauna, supporting wildlife movement and sustaining ecological processes, is an alternative. Gomes et al. (2011) state that maintaining and restoring habitat connectivity is critical to the living of species. The isolation can reduce genetic diversity of populations, increase extinction levels, and decrease recolonization capacity. Thus, green corridors support native species populations and connect isolated spots of habitats (HAMMAN, 2017).

By connecting spaces, green infrastructures increase species' survival prospects, allowing some species to migrate, disperse, and repopulate spots in heterogeneous landscapes that may be unoccupied and empty. The spatial concept of linking adequate portions of habitat to a network is a strategy for achieving a sustainable condition in terms of biodiversity and environmental sustainability (AHERN, 1995).

OBJECTIVES

This research aims to identify areas with great ecological potential, but segregated due to inadequate urban actions, proposing a strategy of sustainable connection between these open spaces to preserve nature and unite it to human experience. From this, the ecological fragmentation of the urban landscape is analyzed and strategies for connection of open spaces are proposed that expand the dimension and quality of natural spaces in the urban environment, in an integrated and open spaces' system.

METHODOLOGY

To achieve its objectives, this research applies the concepts of landscape ecology (PELLEGRINO et al., 2006), green infrastructure (BENEDICT; MCMAHON, 2006 apud MENEGUETTI, 2009), open space systems (MENEGUETTI, 2007) and urban ecological structure (TZOULAS et al., 2007) in a case study.

According to Yin (2001), the essence of a case study is to employ an empirical research strategy, investigating a phenomenon in its real context, to explain similar situations. Therefore, subsidies and solutions can be extracted from other case studies applied in similar realities.

To better understand the place of interference and later to propose satisfactory landscape connections to the urban context, this paper chose Londrina (PR) as a place for case study. The municipality was analyzed at three scales, macro, meso and micro, and from these analyses and prior knowledge of the region were adopted criteria to choose the areas of implementation of the connections.

At first, within the macroscale, we tried to analyze how the free spots of urbanization behaved over the years. Then, within the mesoscale, we identified which remnants were the most significant and potentially connected wooded free areas, but which for some reason had no connection to each other. In the third and last step, one of these areas analyzed was selected for interconnection through a system of urban open spaces, aiming at the conservation of local biodiversity and the quality of life of the population.

CASE STUDY

Located in the north of the state of Paraná, Londrina has its urban area located between the parallels 223°10'17" and 23°51'10" S and meridians 50°52'11 "and 51°14'35" (Figure 1), with a territorial area of 1,650,809 km^2. According to data from the last demographic census of the Brazilian Institute of Geography and Statistics (IBGE), 2010, the municipality has a population of 506,701 inhabitants, with a demographic density of 306.52 inhabitants / km^2.

The municipality's system of wooded open areas (Figure 2) includes squares, toilets, valley bottoms, parks and permanent preservation areas (PPA).

During the periods of 1995 (A), 2000 (B) and 2010 (C) (Figure 3), Londrina showed a significant territorial growth. Concomitantly, the urban vegetation was being reduced, giving rise to constructions and soil sealing, that is, the green spots were fragmented and gave way to the urban spot (JESUS; SILVA; BATISTA, 2011).

The reduction of urban vegetation negatively affects urban socioenvironmental quality, so the conservation and expansion of these open wooded areas are of paramount importance for sustainable development and quality of life in the city.

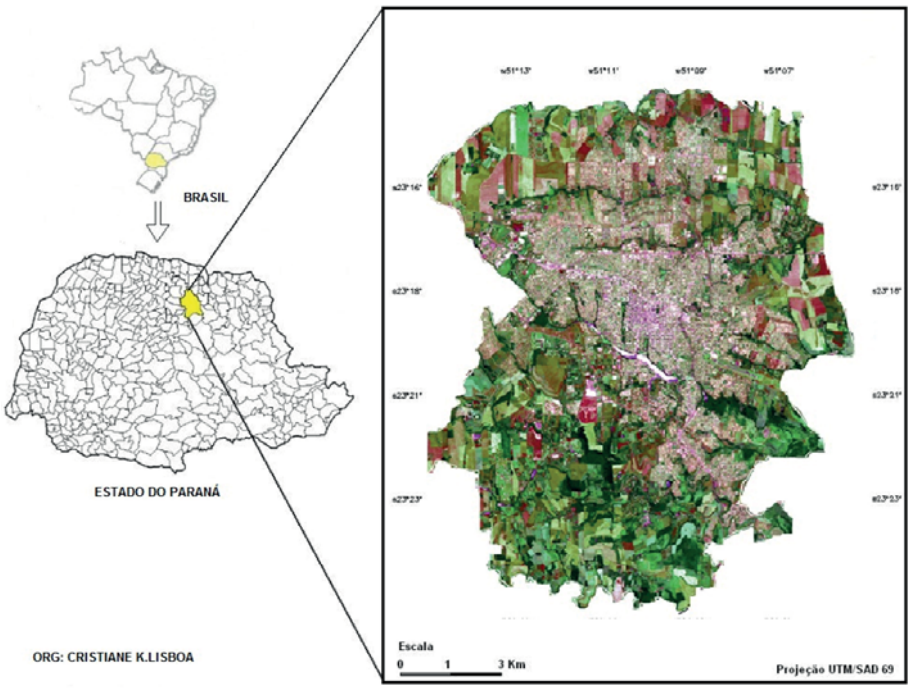


FIGURE 1.
Location of the municipality of Londrina. Source: Barros et al. (2008).

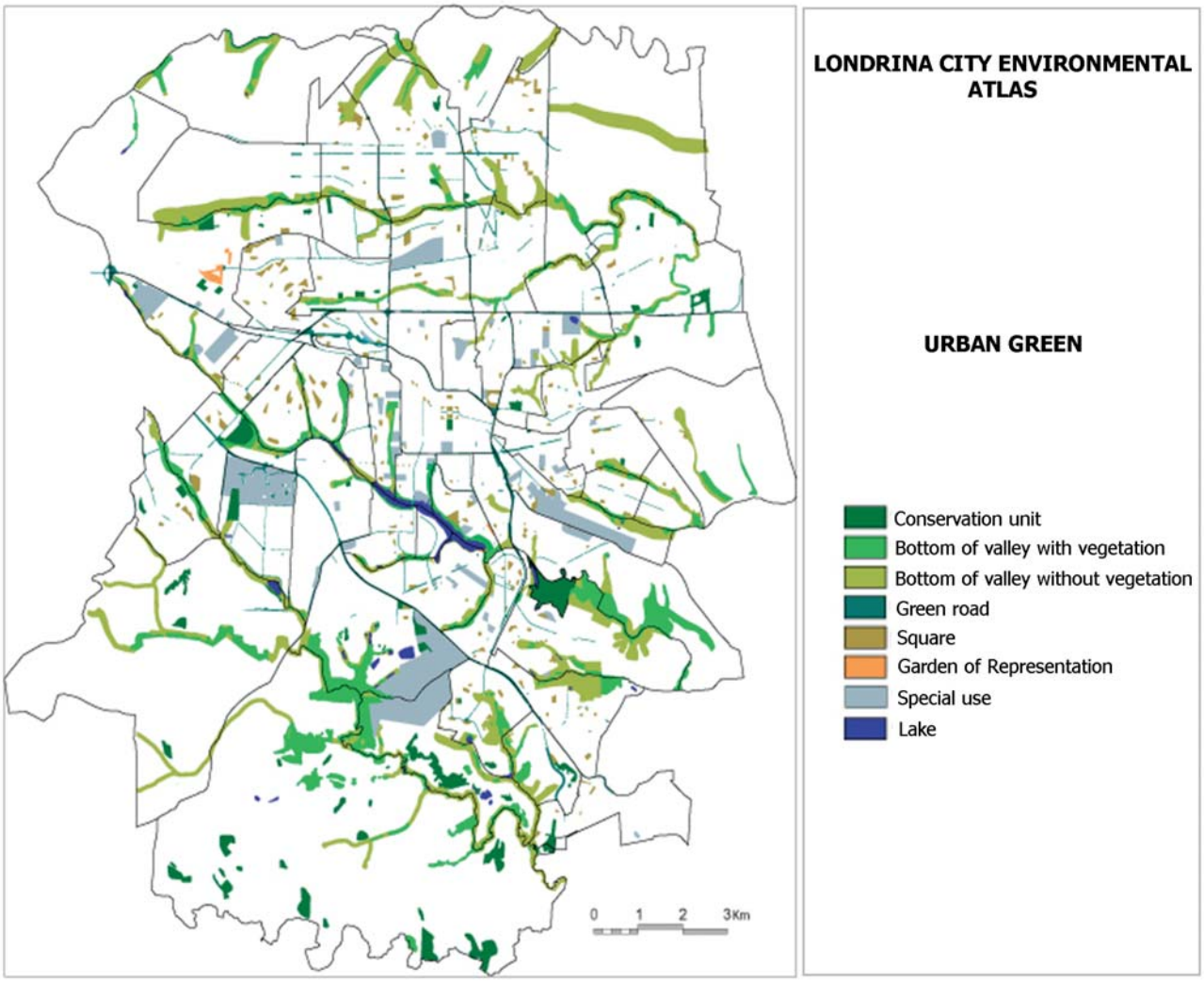


FIGURE 2. Urban greens in Londrina. Source: Barros et al. (2008).

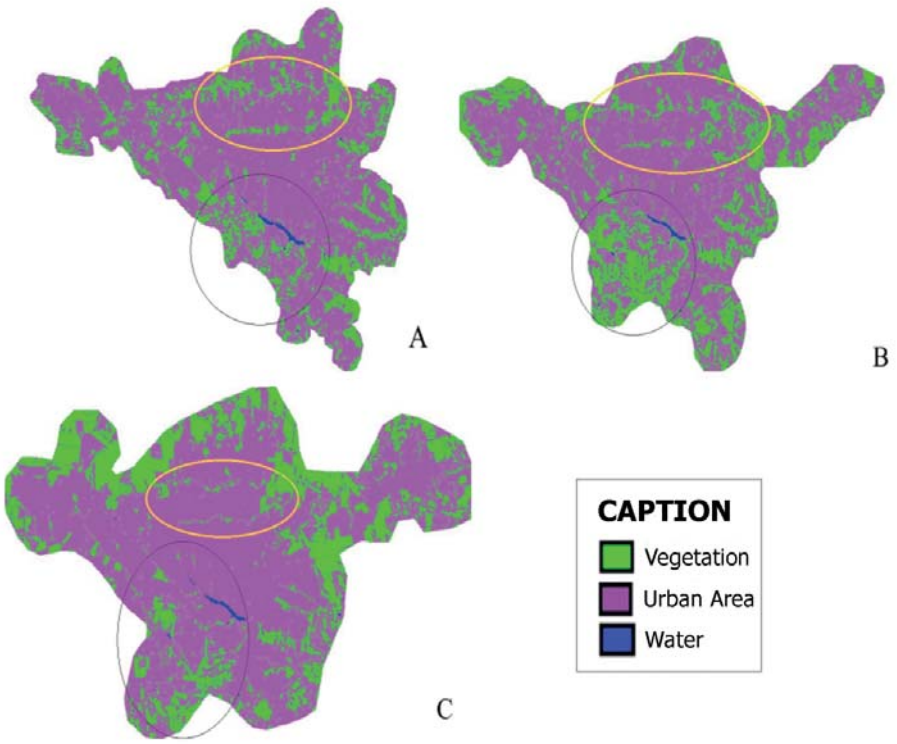


FIGURE 3.
Territorial growth and vegetation decline (A: 1995; B: 2000; C: 2010). Source: elaborated by the authors based on Jesus, Silva and Batista (2011, p. 1071).

In the mesoscale, Londrina was analyzed from the point of view of its micro-basin (Figure 4), as this is an element of integration between nature and society increasingly used as a reference for planners (ARAUJO, 2004). These are environmentally important areas, but often threatened by the urbanization process. Among the four basins involving the municipality of Londrina, the micro-basin of Ribeirão Cambé was chosen because it encompasses the central area of the city and has characteristics that link the urban system between its southeast / northwest peripheral areas. The stream has its headwater in the municipality of Cambé, near the Ney Braga Exhibition Park in Londrina, and is responsible for the formation of the Igapó I, II, III and VI lakes. These lakes are located in the urban area of Londrina and are tourist and leisure places.

The selected micro-basin is born to the west of Londrina (PR), has an area of 77.20 km^2 and a delimitation of 48 km; its main water course is 25 km long. Spikes of elongated shape delimit the area, where pass the highways BR 369 and PR 455, which join in the road clover near the headwater (ARAUJO, 2004).

Analyzing the use and occupation of the micro-basin of Ribeirão Cambé (Figure 5), we notice the large existing vegetation corridor, as well as its interruption in the Igapó dam area. To the south, two valley bottoms (valley bottoms of Capivara stream and Tucanos stream) are inserted from the headwater in the urban context. The rest of the basin, howe-

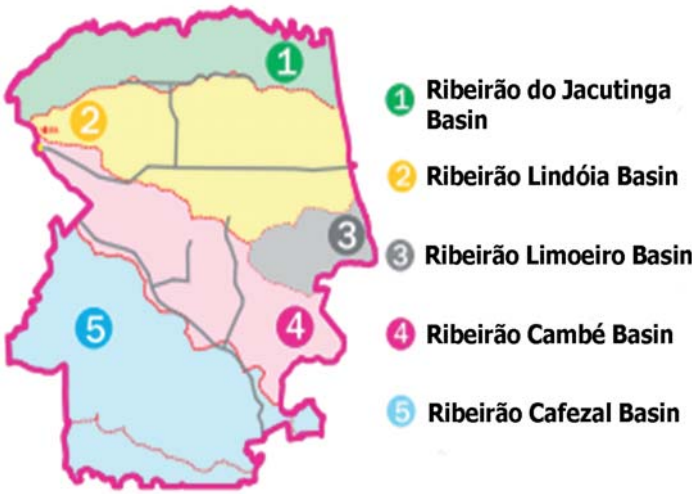


FIGURE 4.
Urban perimeter micro-basins.
Source: prepared by the authors based on Londrina City Hall (2017).

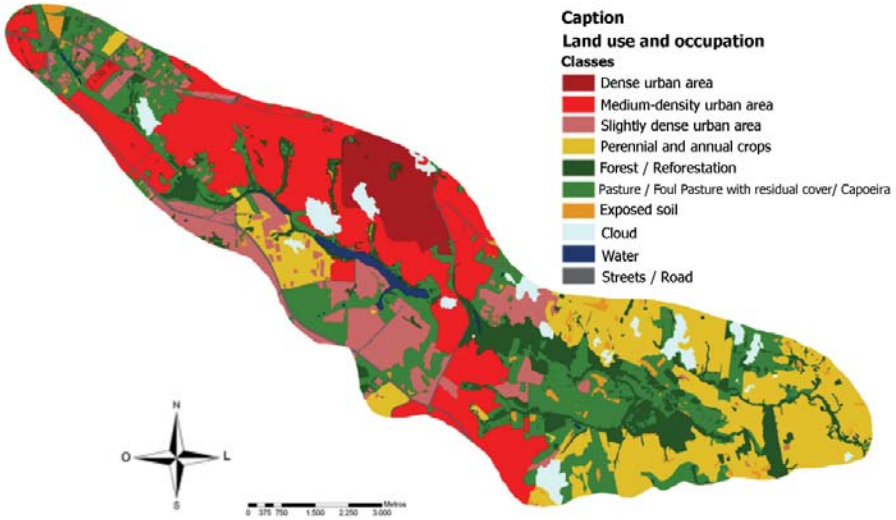


FIGURE 5.
Map of use and occupation of the micro-basin of Ribeirão Cambé.
Source: elaborated by the authors based on Araujo (2004).

ver, connects with these areas only fluvially, with no direct connection to the vegetation that borders the valley bottoms. The largest green area observed in the microscale analysis is that of Arthur Thomas Municipal Park, which directly connects the northern part of the Ribeirão Cambé basin (contained in the urban area of Londrina) with the southern part. The park is characterized by its vast vegetated area and great biodiversity. In the center, there is also the Igapó lake, located between a highly dense area (to the north) and a slightly dense area (to the south) but with a large density potential. This situation exerts a pressure of intense occupation and urbanization on the green areas, generating fragilities in the ecosystem.

Arthur Thomas Municipal Park, initially created and intended for the establishment of a leisure area in Londrina, is today one of the few permanent preservation areas in the urban area of the city. In addition, the extension of the park makes up a system that regulates the dynamic

balance of water resources of the micro-basin of Ribeirão Cambé due to the amount of streams within it. The park (Figure 6) has an estimated area of 85.47 hectares and was transformed into a conservation unit through Official Letter No. 376 of April 26, 1994.

Only after the analysis of the mesoscale can we define at the microscale level which would be the areas from which suggestions can be made to mitigate environmental impacts and ensure the sustainable use of natural resources.

Figure 7 shows the points of interest for the interventions that will be suggested. They are large areas, free of construction, with great ecological potential, and often vulnerable to urban, social, economic and speculative processes. As far as Arthur Thomas Park is concerned, municipal legislation is directly related to its buffer zone, which offers it relative and fragile protection.

Londrina has characteristics in common with other cities in the north of the state of Parana, which, on the one hand, have relatively well preserved hydrographic basin and valley bottoms in remnants of green spots and, on the other hand, urban sprawl in recent decades which, despite not advancing over these protected areas, have diminished the green spots around them and contributed to the physical disconnect between them.

However, the environmental weaknesses imposed by the urban sprawl of recent decades can still be reversed by appropriate projects of green infrastructure.

Criteria for establish guidelines

Observing the global context of the city of Londrina and its physical characteristics, the potential of ecological restoration was analyzed and, afterwards, an area was selected to illustrate the applicability of the concepts of an urban ecological structure (UES) in the city.

It is remarkable, in the global context of the city, the highlight of the hydrographic basins as catalysts of the vegetated areas in the landscape. This is due to the characteristics of urban planning since the initial plan of Londrina, which preserved the valley bottom areas and the riparian forest of the streams.

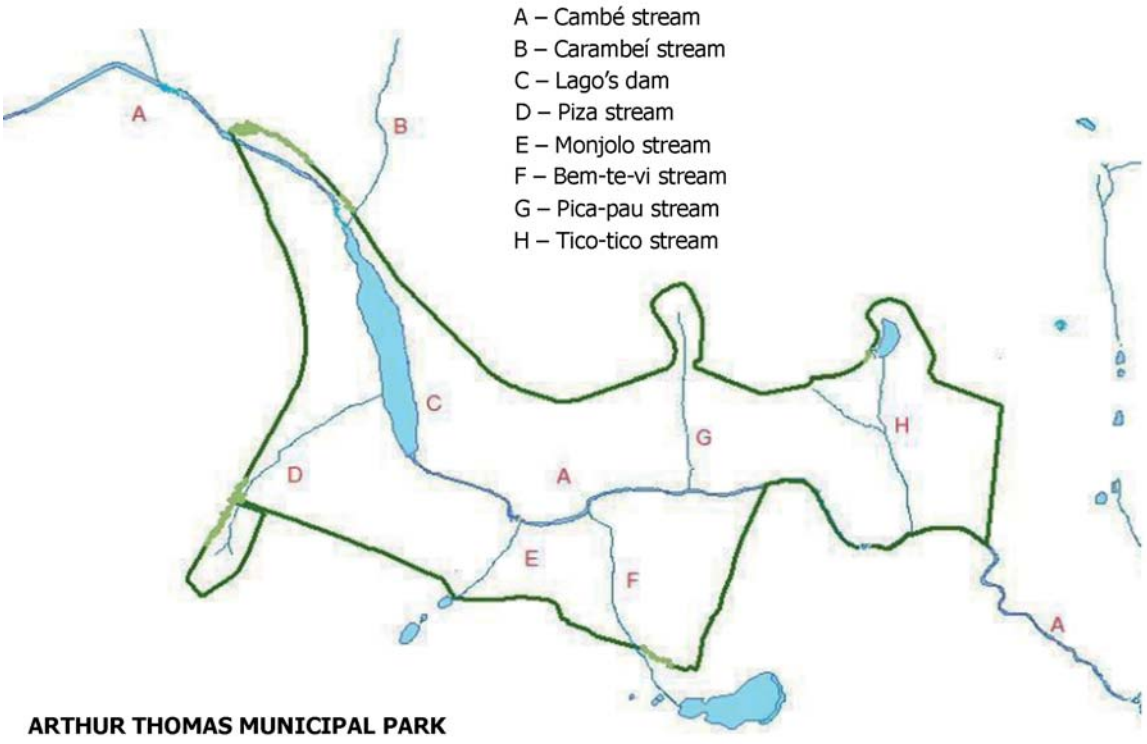


FIGURE 6. Arthur Thomas Municipal Park. Source: elaborated by the authors based on Ballarotti (2010).

FIGURE 7. Microscale space. Source: prepared by the authors based in Londrina (2017).

In this first moment, we analyze the potentialities of intervention in the macroscale of the urbanized area of Londrina (Figure 8), in search of vegetated spaces that can connect. It is observed that the vegetated area, corresponding to the valley bottom of the micro-basin of Ribeirão Cambé, has great potential for interconnection, besides physical characteristics that favor the implementation of connecting corridors.

From the guidelines defined in the macroscale observation, some initial objectives are established to implement an UES in this area (Figure 9). Noteworthy is the large extent of this basin, largely contained in densely urbanized areas of the city, and the sudden disconnection of the southern part from the rest of the basin, caused by intense urbanization and road connections.

Problematic

From the observation of the main characteristics of the study region microscale, the challenges to implement an UES were identified. The study area covers four segments disconnected from each other by the urban network (Figure 10). The overall goal of the project is to connect these areas in the formatting of an UES. The physical connection of vegetated spaces around the river network aims to maintain local biodiversity and preserve these spaces in connection with the urban context.

Guidelines for implementing an urban ecological structure

The major action of the project is to connect these vegetated areas to each other as well as to the urban network of the city. From the project action strategies defined by Tardin (2010) (Figure 11), guidelines were proposed to achieve the project objectives.

In this understanding, main and secondary intervention proposals were established to establish an UES:

(1) Connection of vegetated permeable areas of the Capivara stream with those of Igapó Lake.

> (a) Expropriation of 60 meters from the shore of Igapó Lake as a permanent preservation area, as provided for by Federal Law 6,766 / 1979.
>
> (b) Opening of the valley bottom road, provided for by the municipal law of land use and occupation.

(2) Connection of the permeable vegetated areas of the Tucanos stream with those of Igapó Lake.

> (a) Extension of the vegetated area at the northern end of the stream.

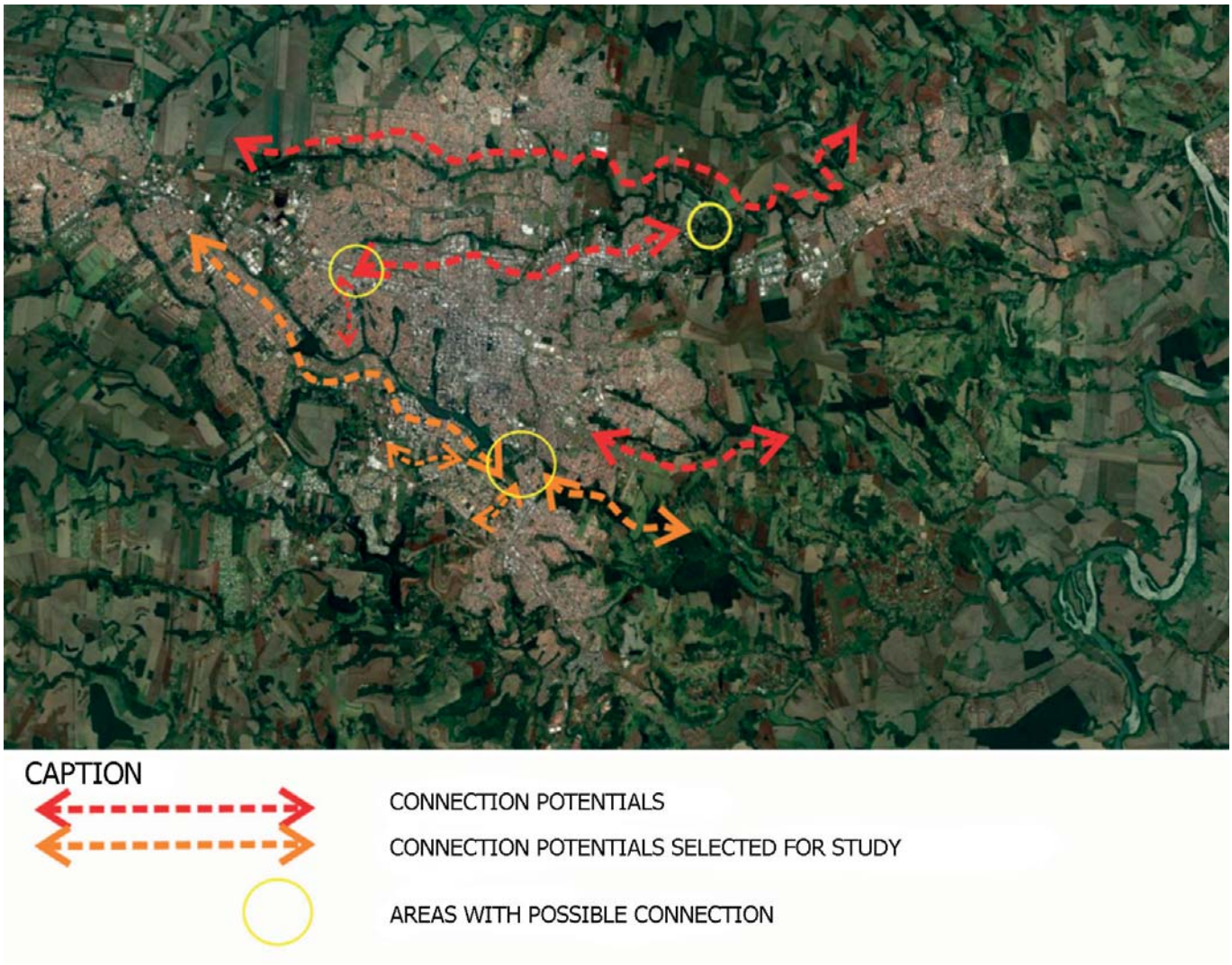


FIGURE 8. Potentialities of the urban ecological structure in macroscale of the city of Londrina. Source: prepared by the authors based in Londrina (2017).

FIGURE 9. Potentialities of the urban ecological structure in macroscale of the Ribeirão Cambé basin. Fonte: prepared by the authors based in Londrina (2017).

(3) Connection of the permeable vegetated areas of Igapó Lake with those of Arthur Thomas Park.

(a) Expropriation of allotted urban areas at the southern end of the stream.

(b) Elevation of the existing roads at the points of conflict that cross the vegetated region, with the implementation of fauna connection structures.

FIGURE 10. Segmented areas of intervention. Source: prepared by the authors based in Londrina (2017).

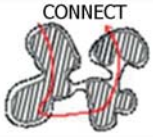
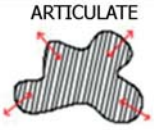
PROJECT ACTIONS	CONCEPT	SITUATION	DESIGN STRATEGY
DEMARK 	SET LIMIT WHERE THERE IS NO LIMIT SET	OPEN SPACES WITHOUT REFERENCES OF PROTECTED AREAS AROUND	LEGISLATION AND ROUTE
CONNECT 	JOIN SPACES ALREADY PROTECTED AND ADD TO SPACES TO BE MARKED	CONTINUOUS SURFACES BETWEEN PROTECTED AREAS OR TO BE PROTECTED	CONTINUOUS CORRIDOR
ARTICULATE 	RELATE THE URBAN TISSUES, OR PART OF TISSUES, WHICH HAVE NO INTERACTION BETWEEN EACH OTHER	OPEN SPACES BETWEEN URBAN FABRICS OR WITHIN THE FABRICS	WILDLIFE CROSSING

FIGURE 11.
Design Guidelines. Source: elaborated by the authors based on Tardin (2010).

It is difficult to transform urban structures and their morphological features. Implementing projects of this size requires political planning and complex works. In this understanding, the project was planned in two stages: the first with 10 and the second with 27 years from the initial date. In the first stage (Figure 12), three elements would be connected: (Capivara stream, Tucanos stream and Igapó Lake).

In the second stage (Figure 13), the largest connection with the fauna structures will be established between the three elements already connected and the Arthur Thomas park.

Ecological restoration in an urban context presents difficulties for spatial reorganization. To connect segmented spaces, it would be necessary to expropriate allotment areas. The connection between the Capivara stream and Igapó Lake would have the effect of the valley bottom law provided for in the municipal legislation. This law establishes a vegetated margin of at least 60 meters wide at each end of the river and a pathway permeating the valley bottom. Thus, the restoration of riparian forest around Igapó Lake will serve as a connecting corridor between these two elements.

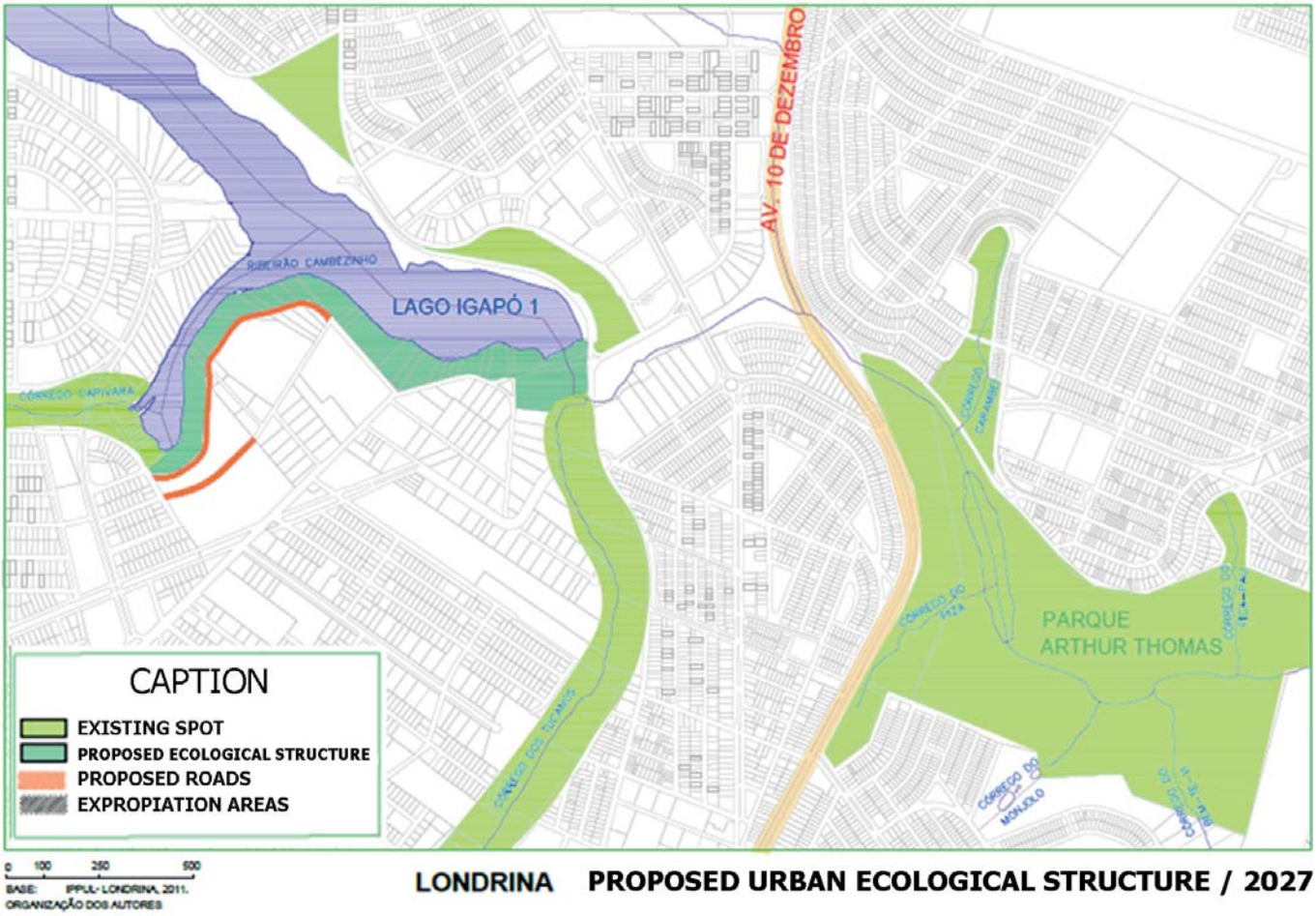


FIGURE 12. Proposed Urban Ecological Structure 2027. Source: prepared by the authors based on Londrina (2017).

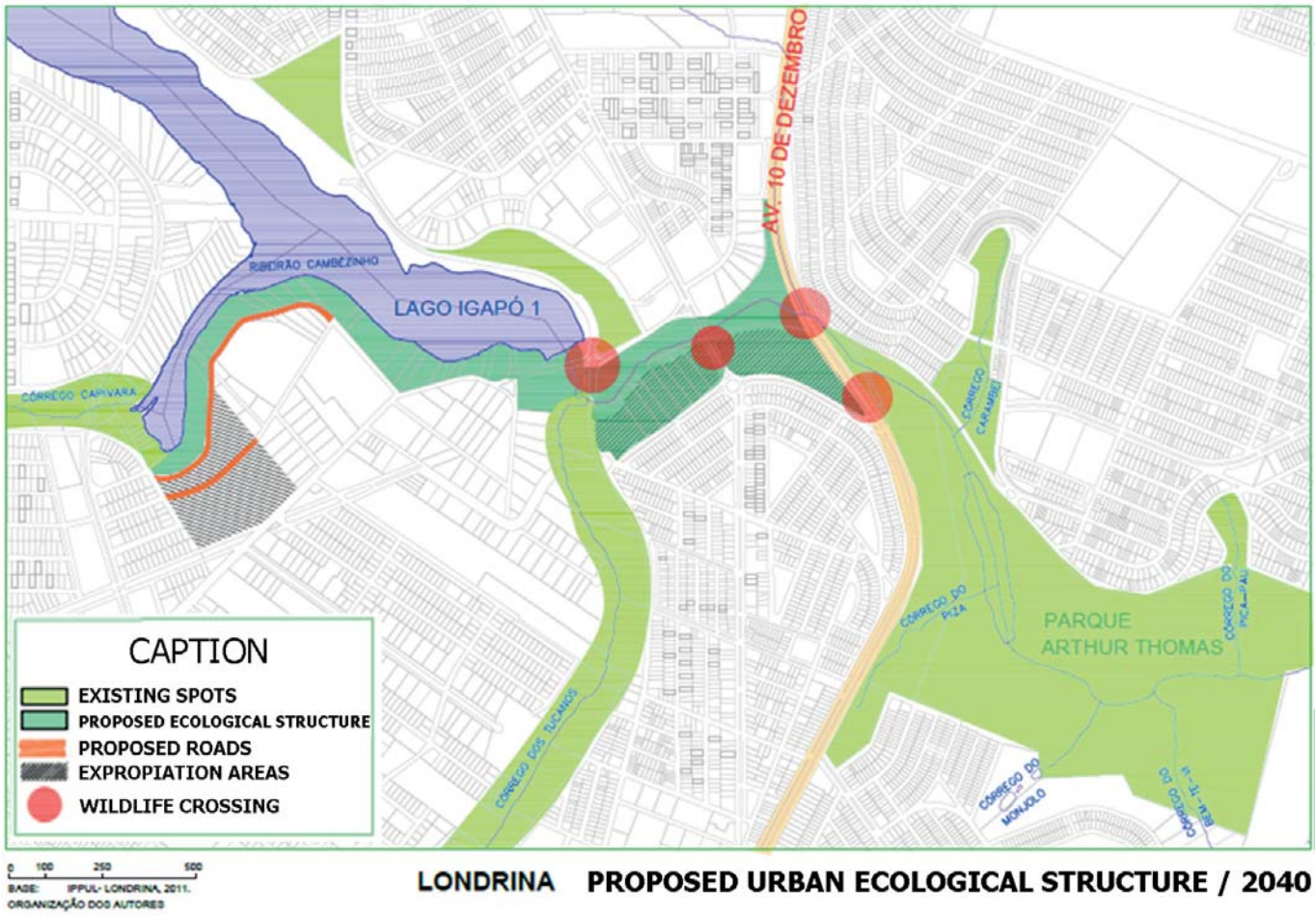


FIGURE 13. Proposed Urban Ecological Structure 2040. Source: prepared by the authors based on Londrina (2017).

For the connection between Igapó Lake and Arthur Thomas Park, it was also planned to expropriate allotted areas, to ensure the ideal size of the corridor and that the banks of the stream will be back to the width prescribed by law. It was foreseen in the development of this strategy that nearby empty areas could be occupied with the expropriated contingent in the project. This solution, however, is presented as a suggestion. Thus, there is the possibility of relocating the population to nearby area and even zoning.

In the projected connections were also observed four points of conflict between the vegetated areas and important roads that cross the region in the north-south direction. According to the initial theoretical research, it was adopted at these points the implementation of fauna connection structures to separate the flow of biotic elements and vehicles, ensuring environmental maintenance and the connection of these areas.

CONCLUSION

Urban ecological structures have as their main objective to promote ecological resources vital for the sustainability of urban space. The co-existence of areas of high concentration of ecological values with the urban space enables the defense of the natural capital of this space (water, air, biotic component) and humanizes it. The conceptual application of an UES in the proposed spatial cut emphasizes that the maintenance of natural processes may be inserted in urban contexts. Land use within the city has a major impact on the existence and survival of unbuilt spots. In this sense, this work has brought to light an unusual reflection on current urban interventions.

It can be observed that the green spots of the city used as a case study are currently disconnected and have greatly decreased in recent decades. Nevertheless, applied urban expansion guidelines, such as the preservation of valley bottoms, make it possible to restructure the landscape through an UES. The same potential is present in other cities of similar context (MENEGUETTI, 2009). Therefore, although urban expansion projects do not include adequate green infrastructure, guidelines such as these may preserve the potential of future projects.

The effort applied to the proposition of a green infrastructure highlights the importance of connectivity between areas with ecological potential, which contributes to the transformation of urban landscapes. This study sought to exemplify a project in the region of the micro-basin of Ribeirão Cambé, in the city of Londrina (PR), studying the applicability and effectiveness of this structure in the global context of the city, where connectivity between areas restructures the natural landscape and maintains ecological functions of the territory. New research could evaluate the possibility of an UES in other cities, as well as regional connections between them.

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