Multiscale Planning Approach in the Analysis and Proposition of Ecosystem Services

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Abstract. In the Brazilian context, urban regulations prioritize built environment guidelines over the management – in terms of conservation, creation and optimization – of open green areas. Based on the characterization, analysis, and proposition of possible strategies, this paper discusses the importance and the usage potentialities of the vegetation cover in cities, as well as the repercussions of its absence. The study considered three landscape planning scales (regional, urban, and local) in order to comprehend their relation, and to present possibilities for the enhancement of environmental quality from a large to a day-to-day perspective. The investigation results in a summary of green-sensitive design strategies, as well as in urban instruments, interventions, and parameters at the local scale; all likely to improve urban characteristics regarding green infrastructure.

Keywords: Urban green areas · Green infrastructure · Urban and environmental planning

1 Introduction

The identification and the management of the Ecosystem Services (ES) are few of the greatest challenges in contemporary urban planning [1]. The ES correspond to the functions, processes, and benefits related to ecological resources. They are essential to human well-being, to productive regimes, and for climate regulation [2]. To deal with collateral effects of urban growth and protect ecological resources, systemic evaluations, coordinated efforts, and tangible measures are demanded [3]. Hence, biodiversity richness can be assessed in cities, since it can provide a great range of opportunities, and services [4].

Another fundamental concept is known as Green Infrastructure (GI), and regards the vegetation cover – especially in the urban context. It comes from a holistic perspective of the landscape elements, based on landscape ecology principles, such as structure, function, and change [5]. GI consists in the connection of permeable and multifunctional vegetated fragments – preferably arboreal, that restructures the landscape mosaic. It allows the maintenance or restoration of natural and cultural processes, and the achievement of a dynamic, sustainable and resilient balance of the urban ecosystem [6–8].

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However, it needs to be critically planned, implemented, and monitored. Effective planning depends on a systemic, and transdisciplinary approach, based on the consideration of abiotic, biotic, and cultural aspects and conditions of the place [9].

The concept can also be applied at different scales. At the private scale (individual urban lots), it occurs as the green-design strategies, such as green roofs, gardens, rainwater retention etc.; At the local scale (neighborhoods), as road afforestation of roadsides, rain gardens etc.; at the urban scale (municipality), through ecological corridors that connect existent parks or rainwater-related structures, draining paving; And at the regional scale (landscape and territories), with the conservation and maintenance of forests and other ecological elements [8, 10].

In terms of planning, the landscapes of the Brazilian cities are limited to morphometric guidelines, such as Floor Area Ratio, Maximum Heights, Setbacks and Land Use Ratio[1] [11]. From the beginning of the 20th Century, the Brazilian urban parameterization associated with land zoning has been used as the main planning instruments [12]. What is done in a segmented, individual way at the lot scale, constitutes the urban landscape as it is reproduced all over the cities. This process generates massified and meaningless landscapes [13]. Beyond that, the urban legal instruments created in big cities are remarkably copied to smaller places, with few or no adaptation to the local specificities. Since generally there is a lack of regulations that consider environmental-related aspects even in metropolises, it can be said that, ultimately, green areas are not considered in planning strategies.

The private sector maximizes the occupation of urban settlements. These actions, associated with the neglect of the environmental quality at the urban scape, the lack of monitoring, and the low government budget destined to the creation, conservation and qualification of open green areas, enhance the situation [14].

In this sense, this paper argues about the importance of the creation and adequate distribution of green areas in the Brazilian urban context, which can result in more resilient, equilibrated and qualified spaces. The improvement of the urban normative linked to urban development, and the consideration of the existence of functional typologies and providers of ES are, then, essential. The aim of the investigation was to discuss the importance of the vegetation cover in urban landscapes based on the characterization, analysis, and proposition of green strategies, by considering its usage potentialities at different planning scales.

2 Methodology

The conceptual approach of the study is aligned with the UN's Sustainable Development Goals (SDGs), especially the SDGs 6, 13, 14, 15 – related to the biosphere (regarding land and water ecosystems, hydrology and climate systems); and the SDGs 11 and 17, related to sustainable cities and partnerships. Those are goals objectively linked to environmental quality enhancement, carbon sequestration, and the promotion of green areas. At the regional scale, the concept is addressed in a broad perspective, and the main goal is to enhance environmental quality in general. At the urban and local scales,

[1] Known as Utilization Coefficient in literal translation, it is a Brazilian building guideline that limits the constructed area to the area of the urban lot in which it will be settled.

the chosen concept regards ecological, landscape, and recreational processes, aiming at the aesthetic, functional and environmental quality of the open green spaces.

The methodology is supported by a contemporary trend of planning, that parts from the macroscale – from a context analysis, to the main object of study. Although the database used, and consequently the results achieved, present different temporal-spatial cutouts, the articulation of these landscape[2] scales is relevant since each of them is related to specific planning mechanisms and attributes.

The case study areas are placed in the Minas Gerais State, Brazil. It starts in from Iron Quadrangle region (regional scale approach), passes through Belo Horizonte city (urban scale), and finally gets to the Centro-Sul administrative unit (local scale) (Fig. 1). In this paper, the study is presented briefly, and the third step – which consists in the local scale investigations, is highlighted, due to the proposed strategies related to ES.

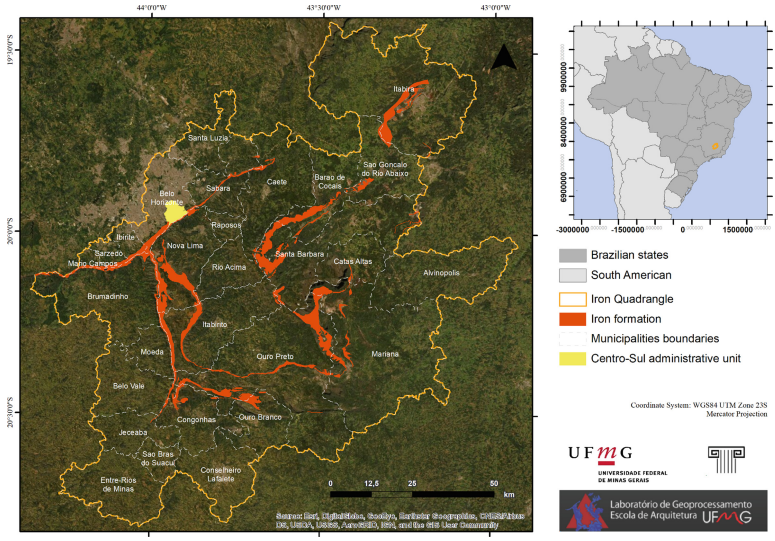


Fig. 1. Iron quadrangle area. Source: the authors.

The Iron Quadrangle is extremely expressive in terms of environmental quality, and is characterized by the presence of physical, cultural, and natural resources – such as geological and geomorphological features, hydrological potential, paleontological and historical sites etc. Classified as Special Biological Importance Area [15], the region is considered a priority in terms of biodiversity conservation in Minas Gerais State. The local attributes of its forests and natural fields are relevant for the protection of the wild life, especially the endemic species – rare and endangered [16].

Belo Horizonte city is the capital of the Minas Gerais State and one of the biggest metropolises in Brazil. In general, the largest cities' decisions in terms of planning tend to impact smaller settlements guidelines [13]. In this sense, studying this area is strategically

[2] In this study, landscape is understood as the result of human and natural interactions; where cultural expressions are produced.

interesting in terms of technical repercussions. Moreover, the comprehension of the urban environment is essential for local scale propositions.

The Belo Horizonte's Centro-Sul Administrative Unit is the sector of the city with the most evident integration with the Iron Quadrangle landscape. Beyond that, it was a methodological strategy to propose green parameters for a context already consolidated in terms of human transformation, as it has the potential of being placed as a reference for other studies in Brazil.

The goal was to propose ecosystems services (instruments, parameters and design interventions) to the study area, considering some SDG (Sustainable Development Goals) and working in multiscale approach (Fig. 2).

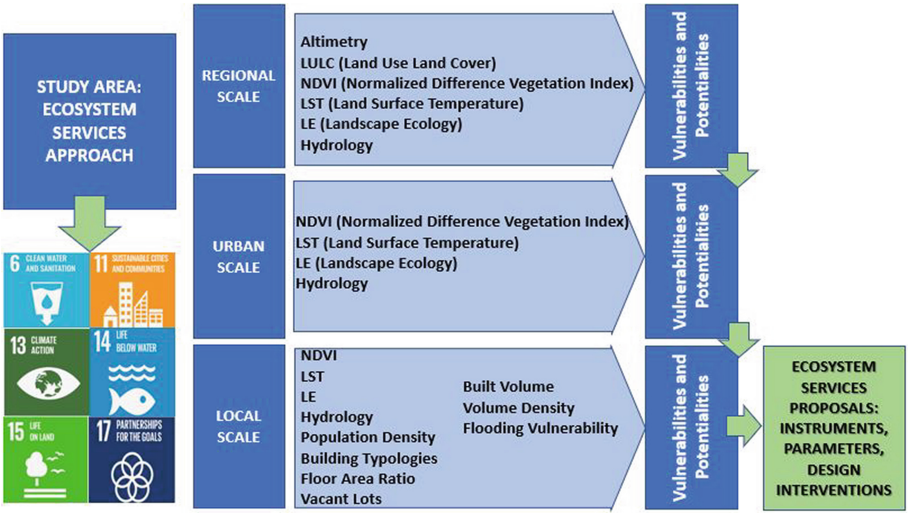
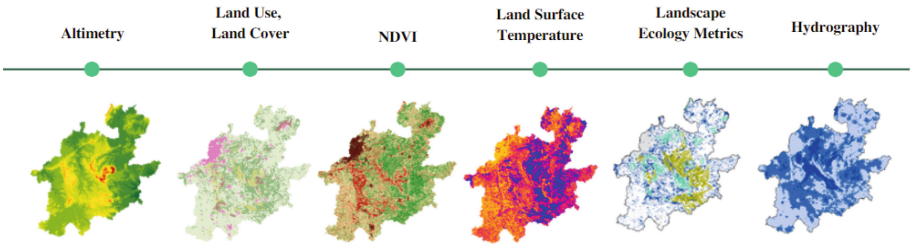
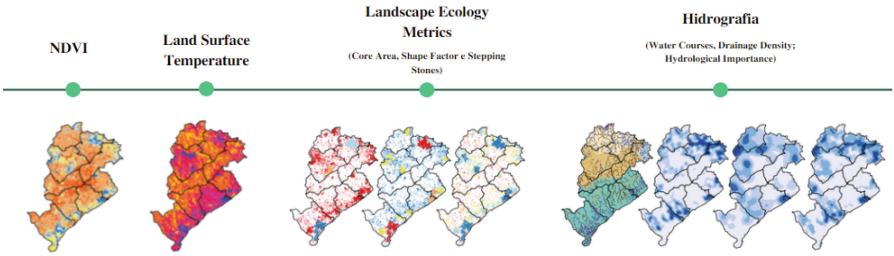


Fig. 2. Framework of the process. Source: the authors, 2022.

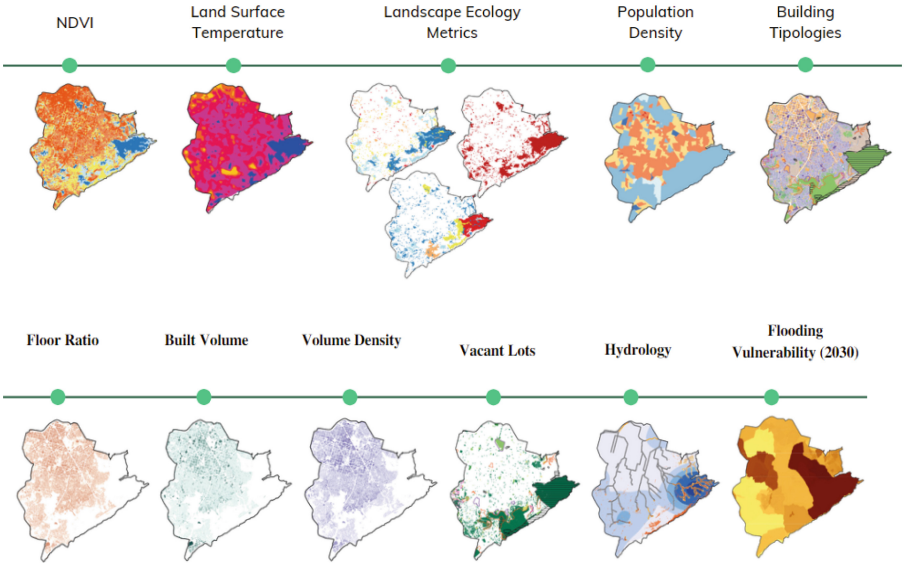
The dataset used at the environmental analysis was related to natural and human aspects and their correlation. To select the variables, principles of potentialities, cultural values and conflicts of interests were considered, since those processes interfere and reproduce in the territory dynamics. In all landscape scales the following information were studied: green cover (NDVI and Landscape Ecology metrics); biomes, protected areas, land use and land cover, hydrology (drainage density, rainwater recharge potential, hydrological importance, and watercourse typologies); land surface temperature; topography; slope; etc. At the local scale only, considering the proposition phase of the investigation, social aspects such as population density, built volume, risks and vulnerabilities etc. were also analyzed. The map set produced did not always follow the color ramp standards commonly adopted in cartography, because it was a methodological choice to use contrasting chromatic patterns to favor the reading of colorblind users (Fig. 3).



Regional Scale: Iron Quadrangle Region



Urban Scale: Belo Horizonte city



Local Scale: Centro-Sul administrative unit

Fig. 3. Landscape scales and the study map collection. Source: the authors, 2022.

The characterization of the vegetation cover was held by calculating NDVI with Landsat-8 v.2's red (B4) and near infrared (B5) registers for 2014 and 2020 scenarios. The Landscape Ecology metrics applied were Core Area, Shape Factor, and Stepping Stones,

aiming at the evaluation of the green fragments in terms of dimensions, density, isolation, distance, connectivity and shape complexity. Both analyses were conducted critically in order to comprehend spatial patterns and recurrent dynamics, since it conditions ecological processes. The main goal was to identify the better conditions to create, increase or conserve green areas at the regional and urban scales [17].

The physical conditions, such as topography, slope and biomes, were investigated with the objective to comprehend their correlation and how they condition or interfere on regional and urban dynamics, i.e., natural limits to urban sprawl; remarkable elements of the landscape; etc. Land use and land cover were analyzed to identify land conflicts in areas of environmental importance. Land Surface Temperature were also investigated in 2014 and 2020 to favor the reading of urban transformations and its consequences over the territory; and of the relation of the arboreal vegetation with thermal load, urban surfaces and urbanization itself.

The hydrology analysis was conducted with the use of different data layers constructed both for this research and on previous studies on the Iron Quadrangle region. The drainage density is considered as an important morphometric parameter of analysis of river basins, once it considers factors such as rainfall regime, relief, rainwater infiltration capacity, erosion resistance and so one [18]. It was modeled by the calculation of hydrology of the area, followed by spatial concentration analysis. The rainwater recharge potential is associated with the likelihood of the land to recharge aquifers by the infiltration of water in general.

Is considered an important analysis parameter, since the process favors the hydrological cycle – related itself to hydric protection and water availability. The model was constructed by Camargos *et al.* [19] with the use of different variables, such as slope, geology-related contamination risk, land use and land cover, etc. The methodology utilized was a Multicriteria Analysis by Weights of Evidence. The hydrological importance was estimated by using a Combinatory Analysis of the previous datasets – drainage density and rainwater recharge potential. Before the map algebra operation, the spatial model indicated low to high hydrological importance zones in the area. The data were also used to study Belo Horizonte's characteristics in terms of hydrology.

For the local scale, beyond the previous present information, the city hall dataset [20] were also observed i.e., built volume, building typologies, vacancies and flood risk. Geoprocessing methods were also utilized to calculate the Floor Area Ratio and the volumetry of the built environment, which indicated the effect of the current building guidelines over the landscape.

3 Development

The environmental analysis enabled the identification of the potentialities and the vulnerabilities of the study areas, by giving information for planning-related aspects, as well as for the proposition of strategic actions. It was possible to design procedures related to the reduction and contention of environmental threats linked to the characteristics of the place. Since the analysis motivated the survey of proposals, it is a projection of the territory's reality as well as a plan based on the desired landscape. The purposes are linked to the generation of a more sustainable and resilient scenario for the city.

The association or the overlaying of all information were primordial for the identification of the existing conflicts, activities and processes in the Iron Quadrangle in general, and in Belo Horizonte in particular. At the regional context, it was possible to reaffirm the importance of conservation for the management of existing resources, since Federal Protected Areas showed to be located in areas of extreme interest in terms of water availability, for example. At the urban scale, it was also observed that the conservation of open green spaces is not an organic, spontaneous process, since the expressive fragments of arboreal vegetation were generally located in protected areas. These observation enforces the urgency of protecting other zones in the Iron Quadrangle region and in Belo Horizonte, since the natural resources, such as mineral goods and vegetation cover, are under constant pressure from the private sector.

The ideas cited in this study can guarantee the vegetation presence, which are significant for the landscape, for urban ambiance, to achieve climate regulations etc. They can serve as an environment policy guide, as economic, sustainable, risk reduction, and resource protection features were considered. It was also considered that those open green areas need to be connected to a multifunctional net that can integrate leisure, cultural, functional facilities etc., with the potential of improving life-quality of communities. The application of each of the proposals implies the commitment of the understanding of the place in order to comprehend existing capacities. It reinforces the importance and the relevance of the multiscale approach.

The proposed instruments, parameters, and design interventions are present in a summary (Fig. 4), containing information i.e., its name; description; impact; category (traditional or not conventional – in the Brazilian context); involved stakeholders; tax incentive possibilities; known benefits defended by specialists – identified by icons; an illustration in an urban context; and a zoning map indicating the most suitable areas in the

Fig. 4. Summary example – community garden proposition. Source: Morais, 2022.

Centro-Sul administrative unit to receive the intervention. The zoning developments were held by overlaying the most important information – regarding each of the proposals, of the produced map set. Regional, urban and local scale data, its correlations and influences were interpreted and used at this moment (Fig. 5). General information of all proposals is indicated in Table 1 [21].

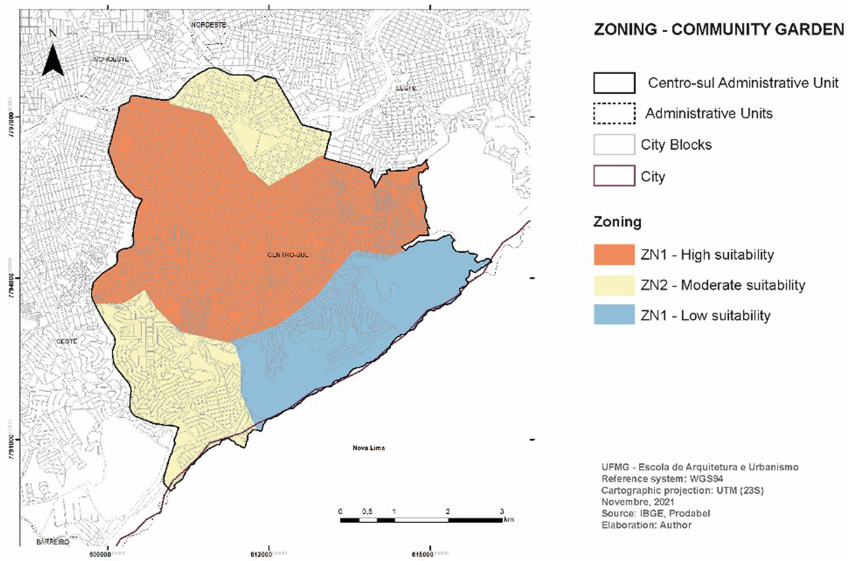


Fig. 5. Zoning example – community parks suitability. Source: Morais, 2022.

Table 1. General information of all proposals.

Instruments, parameter or design intervention	Proposal	Benefits
Vertical gardens	Green structures in building facades	Ecological, microclimate, landscape
Green roofs	Vegetated areas above residential, industrial, commercial or public houses or buildings. Vegetation can be undergrowth, shrub or arboreal. The roof can be adopted in an extensive type (with ecological function); Semi-intensive (green roof with design) and Intensive (garden type park). The implementation of green roofs on existing roofs is important to create ecological green corridors, as the multiplication of these roofs can connect urban centers with natural areas around cities	Ecological, rainwater retention, microclimate, landscape, leisure

(*continued*)

Table 1. (*continued*)

Instruments, parameter or design intervention	Proposal	Benefits
Minimum permeability ratio	Permeable area of urban lots that must be on natural soil and partially vegetated with shrub and/or robust vegetation. The calculation of the Minimum Permeability Ratio must consider not only the size of the lot, but also the drainage capacity of the soil (soil type). In this sense, the most fragile areas in terms of soil typology (less draining) should have a higher permeability rate. For areas where it is not possible to practice permeability, depending on the occupation density and/or infrastructure saturation due to occupation, it is necessary to proportionally add to the permeability rate other forms of capturing rainwater, such as a green roof. Ex: 30% permeability rate + 10% other initiative	Ecological, geological risk, microclimate, landscape, leisure
Community gardens	Creation of a green area on a parcel of urban land that can be shared by a group of people. The owner is allowed to register it with the city hall as a collective space and, in return, receives government incentives to requalify and maintain the space and rent the space for collective use. The group is responsible for the consolidation and maintenance of the space	Ecological, rainwater retention, microclimate, landscape, leisure
Linear parks	Linear areas of vegetation covering rivers and streams, acting as a biological conduit for wildlife, contemplating the function of leisure areas, urban mobility (such as bicycle paths) and still being able to recover and requalify areas of the city, as well as enabling the preservation of cultural heritage	Ecological, geological risk, rainwater retention, microclimate, landscape, leisure
Vegetated volume	Creation of minimum vegetated volume (arboreal vegetation) proportional to the area of the lot and the built volume, implanted in the back of the lots, so that the multiplication in all the backyards creates a kind of green corridor through the city	Ecological, geological risk, rainwater retention, microclimate, landscape

(*continued*)

Table 1. (*continued*)

Instruments, parameter or design intervention	Proposal	Benefits
Urban ecological corridors	Linear open spaces that connect non-linear areas or large patches of natural spaces, constituting systems of spaces planned, designed and managed for multiple purposes, including ecological, recreational, cultural, aesthetic and productive, compatible with the concept of sustainability	Ecological, geological risk, rainwater retention, microclimate, landscape
Green sidewalks	Streets with intense urban afforestation. These would be more restricted streets, favoring the transit of pedestrians and cyclists. Afforestation should give preference to native vegetation that promotes urban biodiversity. The streets must be composed of other resources of green infrastructure, such as rain gardens, porous pavements, vegetated ditches etc	Ecological, rainwater retention, microclimate, landscape
Rainwater reservoirs	Delay in the access of rainwater to the drainage network, making the runoff in and out of the reservoir compatible with the infrastructure capacity. The reservoir dimensioning criterion must consider that the outlet condition cannot be worse than the lot would have in its "natural" condition, that is, before human alterations	Rainwater retention, microclimate
Rain gardens	Rain gardens at lower levels, which can be projected onto streets or buildings, to receive water from surface runoff from impermeable areas	Ecological, geological risk, rainwater retention, microclimate, landscape
Vegetated drainage/runoff ditches	Devices made up of depressions excavated in the ground, whose purpose is to collect rainwater from surface runoff to be temporarily stored. The ditches are vegetated, configuring linear gardens. They can be implemented in common areas along blocks, streets, avenues, roads, parallel to public transport roads/tracks, in parking lots, on property boundaries etc	Ecological, geological risk, rainwater retention, microclimate, landscape
Detention basins	Vegetated depression that receives water during the rainy season, reducing surface runoff and consequently delaying the entry of rainwater into the drainage system	Ecological, rainwater retention, microclimate, landscape, leisure

Source: Morais, 2022.

4 Results and Conclusions

The characterization and environmental analysis at the three landscape scales made it possible to identify the potentialities and vulnerabilities of the study areas and the viability for the implementation and qualification of the green areas. It also served as a subsidy to propose instruments, interventions and urban parameters that generate distributed, and no longer concentrated, environmental quality.

The adopted methodology of environmental analysis in different scales of landscape presented satisfactory results, since it allowed to approach urban planning in an articulated way, integrating and connecting the proposals in the different scales, and understanding the importance of an integrated planning. It also made it possible to think about the most satisfactory and coherent planning actions and proposals for each planning scale, considering the different actors involved and realizing that each scale fulfills specific functions related to planning.

Therefore, the temporal and spatial effects on the urban landscape are different and associated with the nature of the proposals and scales. Actions on a regional scale will be perceived over a longer period of time, as the actions are spatially larger, and therefore will have a broad temporal and spatial effect. On the other hand, at the local scale, actions are spatially more restricted, with more immediate spatial and temporal effects, functioning as "urban surgeries" and acting as mitigating actions for the most urgent processes. Although they present different spatial and temporal results, it is essential that the scales of approach are worked in an articulated way.

The analysis and proposition at different scales also allowed us to understand how actions and legislation related to urban planning need to be integrated, articulated and compatible with the specifics of each landscape scale.

In proposing instruments, interventions and green urban parameters, we sought to give visibility to the possibilities of actions, integrating different functions (principle of multifunctionality), and contemplating the possibility of action for the different actors – public power, private initiative and civil society. The proposals also contemplated short-term and long-term actions and considered the different environmental and social benefits involved, such as improved climate, drainage, leisure areas, etc. The proposals started from the concept of green infrastructure in order to mitigate the problems caused by the traditional urbanization models that, in general, do not contemplate the structure and processes that occur in the landscape.

Regarding the need to improve environmental quality, changes are necessary at different planning scales (regional, urban, and local) to change the current scenario, considering the influencing factors in each of them. The planning and implementation need to occur in an integrated and articulated way, considering actions in different temporal spaces, conditioned and coherent with each planning scale.

The proposal of parameters and the zoning indication for the Centro-Sul administrative unit, based on environmental analysis, can serve as a starting point for future studies in the discussion of the need and strategies for implementation and maintenance of urban green areas.

Investigations with the application of geoprocessing are also methodological contributions, as the study organizer proposes steps, application models, collections and data integrations with reproducible criteria applicable to other areas of study, if these areas

have the same quality of collections of data. All work that involves geoprocessing is a methodological contribution, as it is a set of methods and techniques that will result in the proposition of a framework, whose intention is to collaborate not only with the study itself, but also with the possibility of applicability of the model in other case studies.

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