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Sustainable Occupation of Valley Bottom Areas in Urban En-Vironments: Recommendations for Socioenvironmental Re-generation

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Sustainable Occupation of Valley Bottom Areas in Urban Environments: Recommendations for Socioenvironmental Regeneration

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Abstract: This article addresses the urbanization model in valley bottom areas in the city of São Paulo, analyzed in its urban planning and socio-environmental aspects, and examines the hydrological impacts triggered by its implementation. It argues that sustainable occupation of urbanized hydrographic basins should be based on environmental criteria in order to attain a sustainable water management regime that can ensure urban and environmental resilience. In the "Introduction," the article emphasizes that urbanization in São Paulo has neglected the natural features of river basins, promoting the channeling of watercourses, which resulted in floods and inundations. "Theoretical Basics" brings in key concepts related to the environmental approach of drainage infrastructure with gray and green-blue systems. "Methods" details our qualitative research, bibliographical analyzes, referential case studies, and cartographical analyzes (geoprocessing), focusing on a case study in the Jaguaré creek basin. "Results" includes guidelines and recommendations for an urbanization model adjusted to valley bottom areas, applicable to new patterns of urban occupation or to the adjustment of existing patterns. "Discussion" explores the concept of "local sustainable self-development," and "Conclusions" highlights the importance of an integrated, multisectoral, and sustainable planning, adjusted to the characteristics of river basins in valley bottom areas, promoting a socially responsible urban occupation, especially in the face of climate change.

Keywords: valley bottom; urban sustainability; green-blue infrastructure; São Paulo; Brazil

1. Introduction

The UN Sixth Report of the Intergovernmental Panel on Climate Changes (IPCC-AR6) evinces that global climate change and extreme events such as heat waves, intense rainfalls, downpours, and droughts are undeniably influenced by human activity (IPCC, 2021).

The relationship between climate change and urban occupation constitutes today one of the major challenges in the development of public policies, requiring systemic, transdisciplinary, and multisectoral approaches in different scales, as well as examining the effects of anthropic actions on natural resources (Nobre & Young, 2011; Hulme et al., 2011 *apud* Jahsen, 2021) and on the worsening of social disparities, with an emphasis on less favored populations (Marengo et al, 2021; Dodman et al, 2022).

In Brazilian cities, facing this challenge requires confronting several sectoral and technocratic public policies implemented over a century, as well as proposing solutions that integrate the city, the society, and the environment.

Nobre (2011) reinforces the direct relationship between urban land occupation and the urbanization process of Brazilian cities. This rapport affects and has been affected by climate extremes with intense rainfalls, periods of drought, and rising temperatures, among other things. Highly impermeable areas – densely built and paved – contribute to excessive heat and the formation of

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rapid high-intensity storms and are those that suffer the most from the formation of heat islands, recurrent floods, inundations, and consequent flooding[1].

In valley bottom areas, frequent flooding resulting from the overflow of rivers during periods of more intense rain could be normal if floodable areas remained preserved – permeable and vegetated. However, the urbanization model of several Brazilian cities has taken up space in river floodplain areas for a much-desired "urban development." In several cities, the management of urban waters throughout the 20th century has adopted a purely "technocratic" approach, focusing on the construction of large infrastructure works for the rapid drainage of rainwater, river covering and/or channeling, and road construction on valley bottoms. Thus, greater water flow and the mobility of people and goods were prioritized over environmental quality.

In São Paulo, the largest and most populated Brazilian city,[2] main rivers have had their geomorphologies deeply altered to control flooding and quickly remove wastewater, according to a model that constituted an urban and infrastructure solution at the same time (Travassos 2010; Alencar, 2017). Channeling riverbeds and building riverside avenues, or even "erasing" several watercourses and replacing them with road systems, were predominant solutions in valley bottoms, turning rivers into elements of urban infrastructure. Combined with this model, "urban voids" that result from the straightening of riverbeds were occupied by precarious settlements in many places, contributing to the recurrent worsening of inundations, causing hydrological disasters with major impacts.

Such procedures are seen as structural in nature and are part of technical solutions with heavy infrastructure artifacts – termed gray infrastructure by many authors – and have not solved the conflict between urbanization and floods in the medium and long term.

Due to the limitations and inefficiency of the current model, scholars and creators of public policies have been advocating for a "non-conventional" approach with a focus on regeneration, preservation, environmental conservation, and sustainable managing of water and river landscapes in valley bottom areas. This concept of integrated management of water resources (GIRH) allows the city infrastructure to develop in a sustainable and environmentally adapted way (TUCCI, 2008). It is a model that pursues urban and environmental resilience from a perspective that integrates the population, rivers, and floodable areas (Travassos, 2010; Tucci, 2012; Anelli, 2007).

In general, such an approach regards the hydrographical basin as a planning and management unit, combining structural measures and infrastructural engineering solutions with non-structural measures, when necessary, the implementation of nature-based solutions (SbN) and short- and long-term institutional preventive actions – environmental monitoring, regulation, control, and education (Tucci, 2005, SuDS, 2015). In other words, it is an approach that conciliates "gray and green-blue infrastructures."

This article reflects on the urbanization model of valley bottom areas, with an emphasis on the case study of Jaguaré Creek, located on the southwest zone of the city of São Paulo. From a series of reference plans and successful projects, we seek to build a set of guidelines and recommendations for implementing an environmental approach.

The study is the product of an academic research. It advocates for an integrated and systemic urban planning process, considering the hydrological and socio-environmental characteristic of river basins, aiming to promote their sustainability and regenerate watercourses as structural elements of the landscape. It proposes to adopt a mixed system with gray and green-blue infrastructures, starting

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[1] A Flood (*enchente* in Portuguese) is part of the natural cycle and occurs when water overflows from rivers and canals due to intense rain. Inundation (*inundação* in Portuguese) involves the overflow of water from rivers or lakes into an occupied territory (river flooding), causing impacts and losses and generally resulting from a process of unsuitable occupation of floodplains. Flood or flooding (*alagamento* in Portuguese) is the accumulation of water in urban areas, often linked to mobility problems.

[2] With an urbanized area of 914.56 km², a population of 11,451,245 inhabitants and a demographic density around 7,527.76 inhabitants/km² (IBGE, 2022).

from four dimensions of sustainability: the environmental, political-administrative, urbanistic, and infrastructure dimensions.

The text is organized in five parts besides this Introduction: 1) Theoretical Framework, a brief revision of literature, highlighting concepts, theories, and studies; 2) Methodology, describing the methodological procedures of the study that gave origin to the article, considering its replicability; 3) Results – discussion of the study's main results, highlighting the case study of the Jaguaré Creek, in São Paulo; 4) Synthesis of the main recommendations that can be applied to other valley bottom areas with similar characteristics; 5) Discussion, presenting the concept of "local sustainable self-development" supported by society participation and citizenship principles. 6) Conclusions, which sums up the major features of the article, reinforcing the need to build sustainable paths that promote an engagement between the population and urban rivers.

2. Theoretical Framework

The hydrological cycle has an impact on water availability and purity, which is a major resource to society sustainability. River basins are mainly stocked through precipitation. Part of the rain that falls on a river basin can be retained by vegetation, returning to the atmosphere through evapotranspiration; another part reaches the ground and slowly infiltrates until it reaches the groundwater, and then rivers and seas. Rainwater contributes to the increase of this precious resource for cities and therefore must be duly taken account of and managed. When well-managed, treated, and conserved, it has the capacity to feed water tables, enrich biodiversity, enhance beauty, and compose agreeable places and landscapes.

Traditional infrastructural drainage systems based on the quick removal of rainwater consider this precious resource as a mere residue. They aim to reduce the impacts of water runoff with structural measures composed of robust elements to conduct rainwater, applied in predominantly local solutions. Although they do reduce conflicts between drainage and urbanization in affected areas, they often transfer floods to downstream areas. These problems are worsened by the occupation of originally floodable areas, in a strategy of "space allocation" (Canholi, 2015) quite common in urbanization processes. The occupation of floodplains and the inappropriate densification of valley bottom areas, supported by the installation of large infrastructures, jeopardize the natural capacity of retaining rainwater, making it necessary to find other places to this end.

In general, these built systems are considered a kind of defense against risks, but they do not consider the complexities of rapid urbanization and the several socioeconomic and biophysical processes involved (Bai et al., 2015 e 2016; McPhearson, 2016). They include physical infrastructures, management, and urban services, which are subject to external governance and whose interactions can encompass different areas in local and remote operations, often leading to unintended consequences due to a lack of understanding of systemic connections. The ability to plan and govern with a systemic, intersectoral, and multi-scaled approach is of major importance to deal with this complexity (Bai et al, 2016; Alvim, 2003) and to reach the desired urban sustainability.

Flood control exclusively by means of local structural measures fails and is easily overcome by trying to change rivers' natural state to reduce flooding. This control requires huge investments in ever larger works that are never successful (Marengo, 2008; Arkansas, 2010; Christofoletti, 1999; Costanza,1998; Gorski, 2010; Petts, 2007; Riley, 1998).

Actually, urban rainwater management has become more and more complex in recent decades, evolving from flood control and risk reduction to consider rainwaters as a resource subject to quality control and capable of restoring flow regimes and promoting microclimatic resilience in the current context of climate change (Fletcher et al, 2015)

This way, methods and strategies that adopt nature conservation and adaptation of urban areas to flooding as a principle, establishing parameters of coexistence with flooding situations, of evaluating and managing risks, and of recovering after extreme events have been emerging as much more resilient and efficient (Wang et al, 2022).

They include approaches that adopt adaptability and resilience to floods as a paradigm to reduce their adverse consequences, adapting cities and buildings to flooding events in view of the regime of climate change and extreme meteorological phenomena (Wang et al, 2022; Rosseto and Travassos, 2023). Such changes include the integration of naturally floodable areas as a premise, as well as guidelines for planning urban land use and occupation; they unfold in projects for the recovery of waterfronts, implementation of linear parks (Demantova, 2009, Burkhard et al, 2012, Cengiz, 2013; Naeem et al, 1999, Costanza, R. d'Arge R. De Groot et al,1997), and other strategies that value "nature-based solutions."

As for the environmental approach, urban drainage unfolds into two systems that operate in an integrated and simultaneous way: the gray and the green-blue systems. The former is constituted by networks of traditional heavy infrastructure artifacts – reservoirs, dikes, and watercourse channels – and the latter is formed by natural drainage and infiltration systems – natural riverbeds, floodable floodplains, green and permeable areas (Maranhão, 2020, SUDS, 2015).

These operations are developed through mixed systems of gray infrastructure – channels, pipes, reservoirs – and blue-green infrastructure – beds and ditches, lakes and buffering areas, and vegetated floodplains. By superficially conducing or damming rainwaters in an association with green spaces, natural drainage networks, buried and hidden by traditional systems, are made visible and tangible in urban environments.

Gray infrastructure networks are usually located and concentrated on valley bottom areas, while green-blue infrastructure networks are spread throughout the whole river basin surface. In this way, to create resilient, low-maintenance, and failure-resistant systems, it is advisable to explore the qualities and characteristics of both and, if necessary, to combine their possibilities.

Promoting a systemic approach is crucial to face up to socio-environmental conflicts generated by urbanization processes, which do not manifest in the same way throughout the territory. This implies understanding the origin of the current systems structure – social, economic, ecological, and political – within and beyond the city, exploring new arrangements and new forms for a possible future.

The environmental strategy approach for urban infrastructure consists in promoting a co-design and co-production process that presents innovative ideas and solutions, combined with collective adherence to goals shared by a wide range of decision-makers and other interested parties regarding urban planning and management, either in the public, private, or community sectors (Bai et al, 2016; McPhearson et al 2016). An effective systemic approach can empower disadvantaged groups by addressing the causes of inequalities and disparities.

In regard to issues related to drainage management in cities, the environmental infrastructural approach has advanced towards a view that aims to coordinate environmental, social, and economic development by adopting strategies and solutions to reach a sustainable development that includes green-blue infrastructures (Ying et al, 2021; Rosseto e Travassos, 2023).

These strategies comprise interventions that unfold in many scales, define river basins as planning and management units, and adopt macro and micro drainage solutions combined with patterns of land occupation and mixed systems of drainage infrastructure (Arkansas, 2010; Poleto, 2011). Generally, they integrate social housing, sanitation, drainage, and green areas plans and designs, treating valley bottom areas as systems of green-blue parks with leisure and outdoor activities, so they can be fully occupied, accepted, and cared for by riverside communities. (Cengiz, 2013; Travassos, 2010: Alencar, 2017; Castro, 2020).

3. Materials and Methods

The main methodology was qualitative research based on bibliographical analysis related to indirect sources, reference cases, and cartographical studies (geoprocessing) to promote a territorial reading of the issues related to the main case study.

Some experiences in North American cities have been taken as references in adopting measures to restore the relationship between watercourses and the urban environment, incorporating plans with a systemic environmental approach (Cengiz, 2013). It is worth highlighting cities situated along the Mississippi river, such as Baton Rouge and New Orleans, which adopted river basins as planning and management units and defined distinct parameters for the occupation of the territory, aiming to establish a more balanced relationship between hydrography, relief, and built environment. In Brazil, few experiences point the way towards adapting urbanization in valley bottom areas.

Among the case set, two were considered important references to guide this research: Blumenau in Santa Catarina, Brazil, and New York in the United States (NYC, 2019). Analyzing these two cases, we sought to recognize the main parameters that conciliate urbanization and natural dynamics of river edges in valley bottom regions. These studies subsidized the bibliographical qualitative research that investigated implantation models of traditional and green-blue infrastructures, or the Low Impact Development (LID) that was the reference adopted in NY.

The case study of the Jaguaré Creek river basin, in the western zone of the municipality of São Paulo, started with a historical study on São Paulo City urban planning. Then, understanding of the empirical object was deepened by a study carried out by Fundação Centro Tecnológico de Hidráulica (FCTH) (Hydraulic Technological Center Foundation) from the Politécnica School (Poli-USP) and the School of Architecture and Urbanism of the University of São Paulo (FCTH, 2017). We sought to understand the processes of land occupation, the decisions of planned sectoral works and their impact in flooding events. To this end, cartographical databases were built. Through the map overlay method, with layers of specific information, it was possible to understand the characteristics of the territory and the environment, in particular the hydrological dynamics, as well as the development of urbanization processes in the basin area.

Lastly, starting from the environmental and urban sustainability parameters extracted from the two reference cases, combined with deepened LID techniques and environmental zoning applied to the physical and hydrological characteristics of the Jaguaré basin, a set of recommendations was defined along its valley bottom. Such recommendations have been organized in four categories: urbanistic, environmental, infrastructural, and political-institutional (Alvim e Rubio, 2020).

The urbanistic dimension considers how the analyzes of the features of land use and occupation have an impact on issues regarding drainage and water quality in valley bottom areas. Those features are street layout (streets, sidewalks, and type of paving); buildings, considering their location and the activities developed there (land use and occupation); the existence or absence of trees and other sets of green areas; free spaces such as squares and (public or private) gardens, linear parks and Permanent Protection Areas, and geologically vulnerable areas (slopes and hillsides).

The environmental dimension looks at the natural elements that form the natural environment in valley bottom areas: watercourses, beds and banks, the river flora in its physiographic aspects, considering the different degrees of anthropic change to which these elements are subjected in urbanization processes.

The infrastructural dimension analyzes the elements of basic environmental sanitation systems (water supply and sewage collection networks), drainage systems, solid waste collection, and sweeping systems.

The political-institutional dimension considered in its analyzes the laws and standards regulating land use and occupation, water use, and conservation issues in the three federative tiers Brazil is organized into: federal, state, and municipal entities. They represent the set of federal and state laws that regulate and protect rivers, watercourses, and protection areas (Water and Forest Codes), federal and state agency standards (National Agency of Water-ANA – and the São Paulo State Sanitation and Energy Regulation Agency – ARSESP), and the standards defined by companies and authorities that operate basic infrastructure services (Municipal Water and Sewage Service – SEMAE and São Paulo State Basic Sanitation Authority – SABESP). Regarding these laws and regulations, the proposals aim to define their jurisdictions, mainly with reference to the application and enforcement of this legal framework.

The circular diagram represents each dimension and the whole set of elements and/or actions that allow the river basin context to be analyzed. The circular format reinforces the systemic and multidimensional approach of these analyzes. (Diagram 1).

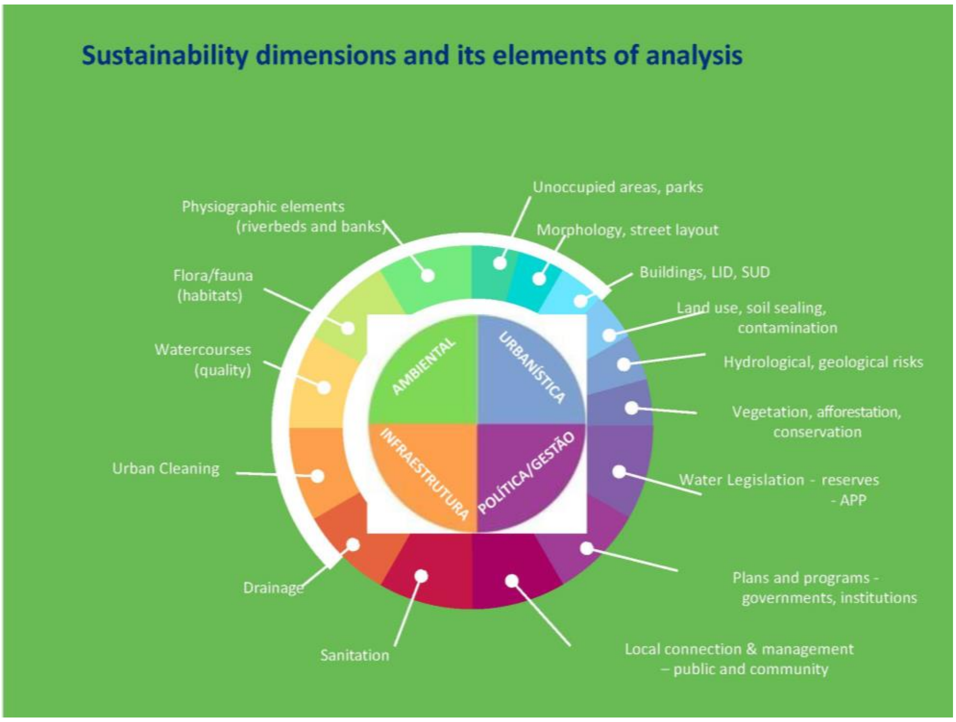

Diagram 1. The dimensions of sustainability. Source: Prepared by the authors.

4. Results

4.1. On reference cases: the plans of Blumenau (BR) and New York (USA)

In analyzing successful experiences, that the adopted parameters consider the systemic character of sustainability, as pointed out by several authors (HOUGH, 2004; SCHUTZER, 2012; HIGUERAS, 2006; PALOMO, 2003; CAPRA, 1982; SACHS, 1995; ALVIM et al, 2019), through different disciplines and indicating new paths for urban planning and land use in cities. The reference plans have respected and incorporated the natural dynamics in a synergy with the design of the landscapes and the city.

The parameters listed in each case were organized in line with the four dimensions described in the methodology, which Alvim and Rubio (2022) consider essential to understanding the sustainability of river basins: a) urbanistic dimension; b) urban infrastructural dimension; c) political-institutional dimension; d) environmental dimension. (Table 1).

It should be noted that both cases involve a systemic approach, adopt river basins as planning units, are developed in several scales, and adopt infrastructure solutions combined with patterns of land occupation in mixed systems that integrate plans and designs for housing, sanitation, drainage, and green areas.

Demarcating risk areas, along with specific rules for land use and occupation as determined by a risk zoning, is an important common procedure. Both plans emphasize that prevention, control, and risk reduction should be based on a consideration of flooding as a permanent condition, not an unpredictable event.

Measures of protection and recovery linked to extreme events have been included in both plans, highlighting the need to integrate urban planning, risk management, and land use. Such plans include nonstructural prevention or correction measures, requiring the contribution not only of public officers, but also of the population in vulnerable areas.

It is important to note that the plans were produced at different times. New York's was launched in 2018, whereas Blumenau's was launched ten years before, in 2008. This time gap entailed differences in their conceptual approaches. The Blumenau plan includes several traditional hydraulic engineering structural measures (dams, widening channels, floodgates), while the New York plan

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prioritizes nonstructural measures, incorporating concepts of sustainable drainage (LID, SuDS), such as the adjustement of existing urban structures, land use control, and financial and technical support. Although the Blumenau plan has been updated in 2022, notions regarding the impact of urban-environmental measures remained largely the same as they were in the 2008 Plan.

Anyway, despite being distinct and specific, the urbanistic parameters defined for each city are largely seen as instruments for sustainable territorial organization of the river basins and thus contribute to building a portrait of balance and harmony in urban river landscapes that may restore the possibility of an interaction between the population and the watercourses.

Table 1. – Measures proposed by the New York and Blumenau Plans of Risk Reduction, organized according to the four analytical dimensions proposed by the research.

DIMENSION	STRUCTURAL AND NON-STRUCTURAL PROPOSED MEASURES	NEW YORK	BLUMENAU
URBANISTIC	RISK ZONING FOR FLOODABLE AREAS	X	X
	LAND USE CONTROL RELATED TO CONTAMINATION AND PERMEABILITY	X	X
	SETTING FLOOD WATER LEVEL FOR INDUSTRIAL PROPERTIES IN RISK AREAS	X	X
	ADJUSTMENT OF AREAS SITUATED BELOW THESE LEVELS	X	X
	ZONING AND BUILDING LEGISLATION ADJUSTMENT TO ALLOW ADAPTATION OF EXISTING PROPERTIES, OR CONSTRUCTION OF NEW ONES LOCATED IN RISK AREAS	X	X
	FLEXIBILIZATION OF EXISTING ZONING RULES FOR ADAPTATION OF PROPERTIES IN RISK AREAS	X	
	ENCOURAGE PROACTIVE INVESTMENT FOR SMALL CHANGES THAT INCREASE RESILIENCE OF EXISTING BUILDINGS	X	
	GRANT SPECIAL PERMITS FOR COMMERCIAL AND TOURIST ACTIVITIES LOCATED IN RISK AREAS TO ENCOURAGE MIXED ACTIVITIES	X	
	LIMIT THE STAY OF VULNERABLE POPULATION IN RISK AREAS (THE ELDERLY, PRECARIOUS SETTLEMENTS)	X	X
	CONTINGENCY PLAN AGAINST FLOODS AND SLIDES		X
	MUNICIPAL LEGISLATION ENCOURAGING NON-STRUCTURAL MEASURES (restriction to waterproofed areas, incentive to rainwater collection and integration of risk zones into land subdivisions)		X
	INSTITUTION OF ECOLOGICAL ECONOMIC ZONING		X
	CREATION OF RIPARIAN PARKS		
	WATER RESOURCES MUNICIPAL PLAN (quality of water)		X
INFRASTRUCTURE	CONSTRUCTION OF PROTECTION AND FLOOD CONTENTION DEVICES IN RISK AREAS		X
	DAM CONSTRUCTION		X
	AQUISITION OF WHEATER RADAR		X
	SLIDING PREVENTION WORKS ON ROADS; FLOODGATE CONSTRUCTION AND CHANNEL IMPROVEMENT		X
	WIDENING OF THE CANAL RIVER ITAJAÍ-AÇU		X
POLITICAL-ADMINISTRATIVE	PUBLIC POLICY OR PLAN FOR DISASTER PREVENTION OR DAMAGE MITIGATION	X	X
	PREVENTION AND RECOVERY INITIATIVES	X	X
	FLOOD INSURANCE PLAN OR SYSTEM	X	
	OPERATION OF DIFFERENT DEPARTMENTS/SECRETARIATS IN MANAGING CONTROL OVER OCCUPATION OF FLOOD AREAS	X	X
	SETTING AIMS AND DEADLINES FOR URBANISTIC AND BUILDING ADJUSTMENTS IN RISK AREAS	X	
	CREATION OF A RESILIENCE LAW FOR EXISTING PROPERTIES AND OTHERS TO BE CONSTRUCTED	X	
	TECHNICAL AND FINANCIAL SUPPORT FOR ADAPTATION OF PROPERTIES IN RISK AREAS.	X	
	FACILITATE PERMITS FOR RECONSTRUCTION OF AREAS AND BUILDINGS HIT BY STORMS OR OTHER DISASTERS WHEN A STATE OF EMERGENCY IS DECREED	X	
	FEDERAL GOVERNMENT FINANCIAL SUPPORT FOR RECONSTRUCTION AFTER EXTREME EVENTS	X	X
	MUNICIPAL CIVIL DEFENSE PLAN INTEGRATED WITH SANITATION, HOUSING, ENVIRONMENT, WATER RESOURCES AND TERRITORIAL PLANNING WITH PREPARATION PROGRAMS; ALERT; MOBILIZATION FOR RESILIENCE; RISK EVALUATION AND REDUCTION, AND RECOVERY OF AFFECTED AREAS		X
	CREATION OF A HOUSING POLICY ENSURING THAT LOW-INCOME POPULATION DO NOT LIVE IN RISK AREAS		X
	IMPLEMENT PAYMENT FOR ENVIRONMENTAL SERVICES		X
	MATER PLAN FOR PREVENTION OF NATURAL DISASTERS (PDPDN) four principles: i) preserve biodiversity and the inhabitants' relocation in risk areas; ii) avoid procedures that increase downstream speed of water flow or flooding; iii) ensure delay in the flow of water from tributaries of the itajaí-açu river; vi) multiple use of the river basin installations and spaces.		X
ENVIRONMENTAL	ADOPTION OF THE RESILIENCE CONCEPT TO SUSTAINABILITY	X	
	ENVIRONMENTAL PLANNING COMBINED WITH HYDROLOGICAL ISSUES	X	X
	URBANISTIC PATTERNS ADJUSTEMENT TO CLIMATE CHANGE.	X	

Source: Prepared by the authors.

4.2. The Jaguaré Creek river basin in São Paulo: sustainable urbanistic guidelines for valley bottom regions

Integrating the environmental dimension in planning valley bottom areas represents a fundamental change that overcomes the functionalistic paradigm. According to the latter, these areas

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corresponded to the locations of traffic, sanitation, and drainage infrastructures which, being subject to "hydrological disturbances," are subject to adjustment.

Given the morphological characteristics of the main rivers in São Paulo as "lowland rivers," these basins contain vast flat areas in their larger flood beds and floodplains. The rectification and channeling of riverbeds made it possible to occupy these floodable areas, turning them into focuses of urbanization with an intense variety of uses, such as housing, industries, shops, and public facilities. However, in as much as they changed the regimes of these rivers by directing and accelerating flows and containment works, these interventions augmented the impacts of the natural regime of floods, transferring and increasing their energy.

The Jaguaré Creek hydrographic basin is situated in the western zone of the municipality of São Paulo, with an area of 28.2 km², corresponding to 1.9% of the total area of the city (FCTH, 2016). After the confluence with the Itaim creek, the bed of the Jaguaré creek runs along the bottom of the valley, under Escola Politécnica Avenue, up to its mouth in the Pinheiros River, of which it is a tributary on the left bank (Figure 1).

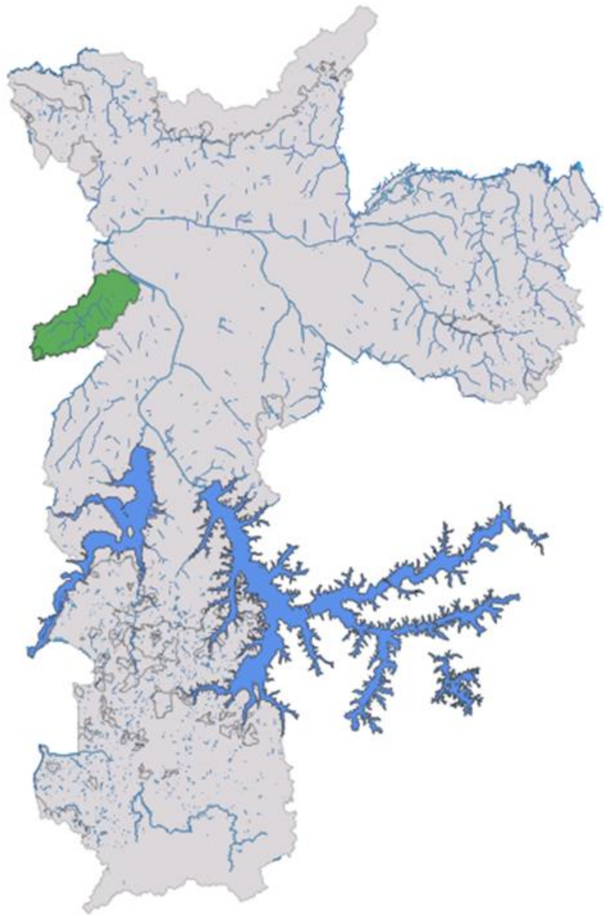

Figure 1. – Placement of the Jaguaré Creek hydrographical basin in the municipality of São Paulo.

This region of the city of São Paulo is called the southwestern vector. Historically, it has been an area of intensive industrial and residential use, but which has currently become an important financial hub in the global market, offering great employability and high land value. As such, it has become a subject of disputes in the context of a metropolis marked by great socio-spatial inequalities (Iglecias, 2001, Pasternak & D'Ottaviano, 2016).

The study of the Jaguaré Creek hydrographic basin is justified due to the following factors: i) it is completely situated within the limits of the city of São Paulo; ii) its diversity of occupation has allowed for studies in different urbanization scenarios with conservation areas in the headwaters and natural beds protected by vegetation in the main contributors; with low- and medium-density neighborhoods made up of single-family and multi-family homes in the middle portion of the basin, which coexist with preserved natural beds and sections occupied by precarious settlements; with industrial occupation, which has been changing due to the construction of vertical residential condominiums and the presence of institutions such as the University of São Paulo – USP and the Institute of Technological Research – IPT, in its lower region next to the river mouth; iii) because the basin had been the subject of interventions in order to protect and restore environmental quality with the implementation of some stretches of linear parks and environmental sanitation programs (Córrego Limpo) [Clean Creek] promoted by the Water Supply and Sanitation Services Company (Sabesp) and by state and municipal governments.

Investigating whether the historical process of this basin's urbanization was shaped by a valley bottom model was the starting point of the empirical study. Therefore, it was necessary to establish a methodological approach that allowed for reflection and were recorded by means of a procedure subject to verification and analyzes – therefore, an evolutionary procedure. The aim was to build a methodology that, in parallel with the research progress, could also encompass the multi-dimensionality and interdisciplinarity related to urban sustainability studies (Farias, 2022).

To this end, analytical maps were produced from historical and official cartographic bases in three different periods: 1933 1981 and 2007. The first two had to be vectorized and georeferenced with the use of QGis; the 2007 base was already vectorized. Natural elements (water courses, masses of vegetation or even agricultural areas, in green and orange colors on the maps) and urban morphological elements (roads, avenues, and land parcels, in lilac colors on the maps) were then analyzed and juxtaposed in the three periods.

The 1933 map shows the existence of an important regional road (São Paulo-Paraná), the natural bed of the Jaguaré creek in the bottom of the valley, and an incipient urbanization in the river mouth and in the middle portion of the basin. The 1981 and 2007 maps, in turn, present a picture of expanded urbanization all over the basin, with the conservation of a few areas without urban occupation in the headwaters of the creek; just the uses have changed in this interval, with the strengthening of the conservation areas recorded on the 2007 map (Figure 2).

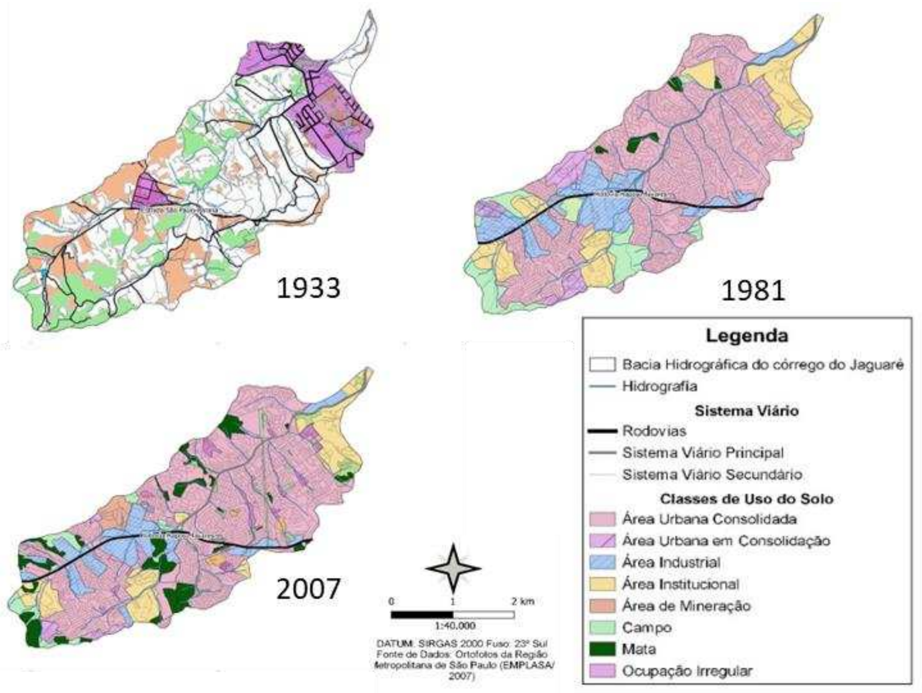

Figure 2. Maps of land use and occupation in the Jaguaré Creek basin, SP (1933, 1981, 2007).

It has been concluded that this basin's urbanization process occurred in the northeast-southwest axis and was determined by the canalization of the stream bed and the construction of riverside avenues, as well as induced by the establishment of important institutions (Butantã Institute and USP) in its low portion.

From a methodological point of view, the simplification of the adopted criteria in two groups – natural and anthropized elements – would not include the existing multiplicities in the complex scenario of a contemporary city.

In the following stage, the analyzes of the "Jaguaré Project" (FCTH, 2017) developed by the Hydraulic and Technological Center of the University of São Paulo, was key to understanding the possibilities of this basin. The Jaguaré Project established guidelines for socio-environmental and infrastructure restoration projects in the river basin, based on socio-economic, political, and environmental data, including georeferenced data, measurements, and biochemical analyzes, as well as hydrological models. The central idea includes urban quality via restoration of physiographical and environmental elements, guiding infrastructure, and land organization policies in the basin. The same methodology was adopted by the São Paulo municipal government to produce Drainage Workbooks and in developing a Drainage Master Plan for the city (FCTH-SIURB, 2023).

Areas subject to floods were analyzed based on hydrological and socio-environmental studies on the Jaguaré basin and considering urbanistic and infrastructure aspects. The goal was to propose solutions to make urban structures and buildings safer, adjusting them to environmental features, and evaluating the need for adjustment to existing legal standards and urban plans.

The amount of data created for the analyzes of the Jaguaré Project, by means of surveys and on-site visits from aerial photos, allowed for a necessary systemic approach to evaluate the multiple dimensions and relationships in the region of the Jaguaré creek basin.

After that, the data were organized according to the four dimensions of sustainability, which structured the final stage of the research. Parameters were selected to compose analytical tables by topics and organize the recording of the communications in a direct way.

Matrix diagrams of each component, identifying key issues to be pondered and evaluated, were also drawn For the purposes of this research, which aimed to present a set of rec-ommendations, we opted for a qualitative interpretation, rather than for measurements

After the matrix diagrams were read and analyzed, recommendations were proposed that cover structural and non-structural measures, i.e. the environmental approach, considering occupation patterns that are compatible with the environmental features of the valley bottom areas; participatory management processes; and recasting programs, plans, and specific standards to reduce flood impact and risks in these areas. These recommendations encourage a systemic approach at several scales and promote a collaboration between local authorities (state companies and regional city governments), local communities, and private owners to implement interventions in public spaces and adjustments in private properties, with public technical and financial support. The results are presented in tables and diagrams.

4.3. Recommendations

The lessons learned through reference cases and the study of the Jaguaré creek in São Paulo have contributed to create a set of general planning principles that can be replicated in valley bottom areas, aiming to promote the regeneration of river landscapes, improve the quality of the water, and establish sustainable balances between society and the environment.

The general principles listed on Table 2 intend to guide the making of urbanistic plans in valley bottom areas. They propose a systemic approach for urban-environmental planning and management, adopting the environmentalist approach in the use of structural and nonstructural drainage, water, and residues management measures; and promoting the participation of all agents involved in the process of land use and occupation: public authorities, public services and infrastructure companies, the community members and residents, and the population in general.

Based on the general principles, a set of recommendations was proposed for each dimension analyzed in the Jaguaré Creek case study. Recommendations considered not only the singularities, nature, and way of operation of each dimension, but also that all of them correspond to actions and to the deployment or adjustment of artifacts and constructions that have impacts on the basin's land use.

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The recommendations – that can be replicated – consider the whole basin as an intervention area and identify elements and actions in public or private realms in each dimension. They take into account existing natural and anthropic contexts so as to reconcile urbanization and the environmental dynamics of the basin, as well as those that determine and guide management and local governance actions. Future action must be based on parameters compatible with the hydrographic basin's hydrological and environmental features, foreseeing public uses, ensuring safety, and adjusting existing structures and buildings in already consolidated floodable areas, provided they present no risk to people's lives.

For the environmental dimension, the recommendation is to implement new sustainable rainwater management systems, which have been adopted in several countries with different names (LID, SUDS, WSUD), but are all based on the same concepts and principles, acknowledging the fundamental importance of restoring and preserving the natural cycles of water and vegetation in urban environments. The need for environmental design for valley bottom areas is reinforced.

Table 2. – General principles for the regeneration and adjustment in urbanized valley bottom areas.

GENERAL PRINCIPLES TO REGENERATE AND ADAPT OCCUPATIONS IN URBANIZED VALLEY BOTTOM AREAS	Assume local scale and river basins which these regions belong to as planning units.
	Integrate environmental and socio-environmental objectives in harmony with urban and economic development goals in valley bottom areas planning.
	Demonstrate that bringing these targets in harmony only causes benefits.
	Protect and restore the characteristics and functions of rivers and creeks natural resources.
	Regenerate, recover and redesign riversides as a territory with environmental qualities for community use.
	Establish a commitment with all players (public authorities, public service companies, and local population) to attain multiple objectives and benefits.
	Encourage and guarantee ample public participation in the planning process, as well as in recovering and regenerating designs of valley bottom areas.

Source: Prepared by the authors.

As far as the political-institutional dimension is concerned, a systemic, multi-scale and participatory model of urban planning and governance is presumed, implying the effective participation of various players – public officers, public service concessionaires, local communities, and the population in general.

For the urbanistic and infrastructure dimensions, the most significant recommendation includes adjustment actions to reduce situations of risk (strictly for public officers) and adjustments in flood and drainage areas in both the public and the private realms. (Table 3a,b).

Table 3a – Regeneration and adjustment recommendations for urbanized valley bottom areas.

ENVIRONMENTAL DIMENSION	PROJECT AND DESIGN RECOMMENDATIONS FOR VALLEY BOTTOM AREAS	PUBLIC	Protect resources and functions of natural rivers
			Create or keep natural flood (and other anthropic impact) buffering areas.
			Restore river and riverfront habitats
			Use nonstructural alternatives to manage water resources (LID, SUDS, WSUDS, Strategies)
			Reduce impervious areas
			Manage rainwater in the area and use nonstructural approaches (LID, SUDS, WSUDS Strategies)
			Balance playful and public access activities with river protection
			Integrate information on rivers' natural resources and environmental role with the cultural importance and history of waterfront projects, public art, and other expressions that show the importance of rivers.
		PRIVATE	Maintenance of land use occupation limits to guarantee permeability and integrate afforested areas (climate improvement, fauna and flora refuge , biodiversity)
			Increase permeability and rainwater retention (reduction of runoff and groundwater replenishment)
POLITICAL-ADMINISTRATIVE DIMENSION	PUBLIC AUTHORITIES RESPONSIBILITIES AND DUTIES	PUBLIC	Demonstrate the importance of maintaining the characteristics of the city's rivers and creeks with the river
			Plan invariably at river basin scale and redesign the waterfront
			Provide the public with access opportunities, connections and inspiring activities in waterfront areas.
			Disseminate the river environmental and cultural history through public education programs, graphic signage and events.
			Create a flood zone map
			Hold Public Authorities responsible for deaths, damages and losses resulting from the floods
			Permanent and preventive integration among sectors of the municipal administration (Flood Prevention Working Group)
			Risk Management Preventive Plan with non-stop update and Preventive Actions Support Fund
			Creation and Permanent Maintenance of Environmental Education Programs and Activities
			Creation of a board to operate and manage risk situations with equal composition between public agents (multisectoral), public service concessionaires, and populations
			Creation of a centralized autonomous administrative unit to plan and manage actions related to risk situations
			Shares of financial participation of concessionaires in the Support Fund (Transportation + Garbage + Sanitation)
			Participation in public consultation processes
			Adherence to and participation in Environmental Education programs
		PRIVATE	Coordination with representatives in public management (councilors, deputy mayors, etc.)
			Organization of residents' and neighborhood associations etc.

Source: Prepared by the authors.

Table 3b – Regeneration and adjustment recommendations for urbanized valley bottom areas.

URBANISTIC DIMENSION	RISK MANAGEMENT RECOMMENDATIONS	PUBLIC	Flood mapping with permanent update
			Creation of an Integrated Risk Management Plan for the city of São Paulo supported by: preparation, mitigation, prevention, and recovery actions
			Creation of a Risk Zoning in line with flood mapping (use/heights/typologies/occupation/permeability rate)
			Alarm System and Evacuation Plan in risk areas
			Removal and Control Plan in risk areas
			Population training for risk situations
	RECOMMENDATIONS FOR ADJUSTMENTS IN FLOOD AREAS (LID)	PUBLIC	Technical and financial support to partial or integral building adjustment (second floor, use adjustement)
			Creation of flood insurance with governmental subsides
			Financing adaptations in buildings located in flood zones
			Granting benefits and tax exemptions to properties located in risk zones
			Retention tanks (LID Strategies)
			Staggered banks (floodable areas)
			Riverbeds expansion
			Creation of buffering strips
			Basin permeability Increase
		PRIVATE	Creation of a protected 2^{nd} floor (flood level) with priority activities regarding lives, equipment, and assets protection while keeping nonessential activities on ground-floor
			Increase private units permeability
			Partial or integral adjustment of properties to flood events
			Increase floodable lanes x Reduce paved roads
			Increase afforestation with drainage flowerbeds
			Expand riverbeds with implementation of staggered floodable banks
INFRASTRURAL DIMENSION	RECOMMENDATIONS FOR DRAINAGE ADJUSTMENT	PUBLIC	LID Strategies (in structural works)
			Improvement in household waste and rubble collection systems.
			Increase sweeping coverage
			Implementation of sedimentation basins (solid waste containment)
			Increase soil permeability
		PRIVATE	LID Strategies (increase permeability, rainwater retention, reuse)
			Proper disposal of waste and debris
			Non polluting uses

Source: Prepared by the authors.

5. Discussion

City planning must adapt to periodic floods and this implies new social and technical arrangements, more so when considering the effects of climate change and extreme events that have been challenging authorities and causing great impact in cities all over the planet.

In this regard, introducing "floodable areas" as well as their buffer zones into the municipal codes; using dynamic infrastructure devices; promoting environmental education, and encouraging people to adapt their buildings to floods imply giving back to urban waters the natural spaces that were once taken and are now being claimed.

With no intention of exhausting this complex topic, such recommendations contribute to restore/recover riverside spaces, promote a closer relationship between people and water, predict flood risks, reduce socio-environmental damage and losses, and promote the resilience of urban spaces.

These recommendations consider the nature of the actions and the interrelationships with urban space producers, both public and private, inspired by the concept of "local sustainable self-development" as advocated by Magnaghi (2005). This concept is based on principles of citizenry and civil society participation, but it also acknowledges the political and operating limits of every social group and determines the responsibilities that are due to private and public agents and local communities.

6. Conclusions

In the context of extreme climate events, it is pressing to reconsider the urbanization models and infrastructure solutions adopted in Brazilian cities and point to sustainable paths that can promote a closer relationship between urban rivers and the population.

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In a metropolis as large and complex as São Paulo, strengthening local management can offer clarifications for implementing more viable, more economical and more efficient infrastructure and land use solutions in comparison with large-scale construction works that require heavy public investment and are subject to political pressures and influences, which are often external and unrelated to the interests of local groups.

By aligning speech and practice (Villaça, 1999) it is possible to subdue disputes with large projects of hegemonic interest. In the context of Brazilian cities, overcoming environmental injustice must face socio-spatial segregation, weaknesses in management and urban planning systems, and a cronyism that promotes the inappropriate deployment of scarce financial resources, generally allocated to regions where the land is worth more.

Planning tools must be perfected and must effectively include physiographic characteristics, different patterns of spatial occupation, and social dynamics that reflect on the use and permanent change of urban spaces represented by valley bottom areas. It is paramount that they promote environmental regeneration in these regions and ensure the quality of water supply in the cities. The environment that results from this arrangement builds landscapes and habitats for all living species and determine natural resource patterns of consumption: they are the living space of cities.

This study aimed to contribute with the urban studies that relate infrastructure, urbanization, and environment, especially in the sense of overcoming die-hard conceptual and functionalist paradigms. It also pointed to the need to adopt systemic and multi-scale approaches to integrate socio-environmental complexities. Finally, it has evinced the need for an overhaul of the territorial and governance management approach, so that local cultures may be galvanized once and for all by means of participatory processes.

Valley bottom regions with floodable areas play a vital role in hydrological regimes, in climatic balance, and in the quality of urban life when they are changed into green-blue systems. The latter are home to several biomes and play a major role in absorbing the impacts of the basin waterproofing, in filtering and infiltrating rainwater, and in restoring balance in the hydrological regime, besides privileging the public use of green spaces.

To contribute precisely to planning and water management improvement in valley bottom areas, starting with the general recommendations, we suggest four essential guidelines that can trigger important changes in the production and management of Brazilian cities urban space. They should be incorporated in urban plans:

- Enhancing planning at the local level as determined by the adoption of river basins as planning units;
- Establishing of a type of zoning that incorporates hydrographic and geomorphological elements and thereby takes into account and signalizes floodable areas, adopting specific criteria in these areas for either preserving existing urbanization or promoting the gradual removal of populations from regions considered at risk;
- The implementation of a permanent risk management process, which provides administrative autonomy and resources that allow integrated actions with other administrative sectors to promote the protection of populations exposed to risks and the adjustment of these areas;
- And a permanent Environmental Education program that educates people, clarifies their issues, and cherishes rivers, creeks, streams, their preservation areas for public use, and the contact with water as a way of overcoming the paradigm established by an urbanization model that neglected the original territory of the city of São Paulo, which was built over rivers.

Promoting a sustainable and integrated management of urban waters, drainage and built environment in Brazilian cities seems to be a utopic proposition on the one hand; on the other hand, it is about changing the ruling paradigm in the urbanization of cities and signalizes that recovering urbanized valley bottom areas is an essential step towards societal sustainability.

We acknowledge there is still a long way to go towards improving measures aimed at building environmental justice situations in the valley bottom regions in Brazilian cities. They must be inscribed into the territory by means of land use and regulation laws, and also into people's minds.

The regeneration of valley bottom areas is essential for the future and the quality of life in cities and is one of the most important strategies to face extreme events resulting from climate change.

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