INITIATIVES FOR SMART AND SUSTAINABLE CITIES FROM THE PERSPECTIVE OF CLIMATE RESILIENCE LENS - CASE STUDY OF RIBEIRÃO PRETO (SP)

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Abstract
The City Plan for Ribeirão Preto (SP) aims for intelligent and sustainable development in conjunction with the Sustainable Development Goals (SDGs). With significant ex-urban sprawl, the city faces high annual temperatures and few wooded areas, which impacts the quality of life of residents. The aim was to evaluate initiatives for smart and sustainable cities from the perspective of climate resilience. The main results showed that the strategies and actions contained in these targets are pertinent to the sustainable development of the municipality, with the main challenge being the lack of transparency in the monitoring of actions. The main uses and occupation of the land through the Geographic Information System (GIS) refer to farming and uncultivated land (59%) and urbanized areas (18.9%). Tree cover in 2023 represented only 15.7%, indicating a reduction compared to other studies that indicated 16.7% (2017) and 23.6% (2012), which points to concern regarding the lack of vegetation in compromising the recharge of the Guarani Aquifer.
Keywords: SDGs, Climate resilience, Tree cover, GIS, Ribeirão Preto.

1. Introduction

A sustainable city comprises an urban space planned with the main purpose of promoting environmental quality and protection, social equity, and long-term well-being. However, urban systems are associated with environmental, social, and economic impacts, which include unsustainable energy use, greenhouse gas emissions, air and water pollution, inappropriate land use, exploitation of natural resources, poor urban planning, reduced safety and public health (BIBRI; KROGSTIE, 2017).

Faced with rapid urban growth coupled with major challenges, municipal, regional, and national governments face the difficult mission of accommodating more and more inhabitants while addressing issues of environmental sustainability, urban resilience, and resource efficiency (RAZAGHI; FINGER, 2018). These administrations, for the most part, adopt traditional governance that devalues the participation of society and the use of technologies.

In this sense, the so-called "smart city" approach becomes relevant in emerging sociopolitical trends, because by promoting the participation of society and improving the use of technologies for its benefit, it is possible to achieve a better quality of life, since needs become oriented towards social well-being (GUIMARÃES et al., 2020).

The Sustainable Development Goals (SDGs), part of the 2030 Agenda, are targets set by the United Nations (UN) to tackle the most pressing global challenges, such as climate change and environmental management, which directly encompass the concepts of smart, inclusive, safe, resilient and sustainable cities (UN, c2023).

However, the SDGs focus mainly on long-term benefits, and because it is a relatively recent topic, the initiatives, plans, and strategies established by municipalities are still scarce and not very clear (KUTTY et al., 2020).

This article investigates the adoption of targets, strategies, and actions related to the SDGs and climate resilience at the municipal level. Thus, the main objective is to analyze initiatives for smart and sustainable cities from the perspective of climate resilience in the municipality of Ribeirão Preto (SP). The main questions that guided this study were: I) what are the targets, strategies, and actions contained in the City Plan about climate resilience; II) what is the situation of tree cover in the municipality; and III) what are the main risks to the outcrop areas of the Guarani Aquifer System (SAG) contained in the municipal perimeter?

2. Theoretical foundation

In general terms, the term resilience refers to the ability to withstand stresses and adapt to transformations, such as climate and environmental changes. In the urban context, it encompasses the management of multiple risks and challenges that arise due to rapid urbanization and global interconnectedness. The role of urban resilience about climate change, natural disasters, and urban development cuts across the UN's 2030 Agenda and its 17 SDGs, and a strategic plan geared towards urban resilience is recommended (CROESE; VERDE; MORGAN, 2020).

Cities should invest in creating a plan in partnership with universities, research centers, and Non-Governmental Organizations (NGOs). These partnerships provide several benefits to cities and contribute to the limited budget allocated by the government for the development of smart and sustainable cities. Another benefit is the continuity of ongoing projects, which can face certain challenges and oppressions due to party changes in power during project execution. The transformation of cities requires strong leadership, which does not necessarily have to be within local government bodies, but can also be formed by associations and community members (KUTTY et al., 2020).

Urban spaces have presented various problems, such as rising air temperatures, increased carbon dioxide levels, atmospheric pollution, damage to or loss of various habitats, flooding and groundwater depletion. The main elements that can affect human life include sunlight, air temperature, wind and humidity. Thus, urban tree cover plays a very important role in reducing the temperature and environmental quality of cities (DAHAR, HANDAYANY; MARDIKANINGSIH, 2022).

In hydrological terms, impermeable surfaces contribute to surface runoff, which can lead to soil erosion, deterioration in water quality and the risk of flooding. In addition, inadequate

spatial management of rainwater, the occupation of threatened areas and the low natural retention capacity of river valleys limit effective actions in situations of extreme weather phenomena (BEDLA; HALECKI, 2021).

Contemporary studies on ecosystems increasingly consider the role of organisms as regulators of climate change, with spatial heterogeneity determining ecological connectivity and environmental functions in cities. In this sense, it is recommended to include Nature-Based Solutions (NBS) in innovative strategies, which can solve problems such as water quality, while providing additional profits (BEDLA; HALECKI, 2021).

3. Methodology

The research is based on a literature review, exploratory analysis and a case study. The literature review consists of synthesizing data pertinent to the topic in a logical sequence, while exploratory studies allow data to be analyzed for quantitative and/or qualitative descriptions of the object of study, so that the researcher can conceptualize the interrelationships between the properties of the phenomenon, fact or environment observed (MARCONI; LAKATOS, 2003). The case study investigates the detailing of a certain contemporary phenomenon in its real context (YIN, 2015).

The research stages consist of: I) characterization of the study area; II) identification of the targets, strategies and actions contained in the City Plan; and III) evaluation of land use and occupation in the study area.

3.1 Characterization of the study area

Databases were consulted to understand the urban structure of the municipality of Ribeirão Preto: Brazilian Institute of Geography and Statistics (IBGE), SEADE, 2019 Environmental Synthesis Report (City Hall) and the Sustainable City Development Index (IDSC-BR).

3.2 Identification of the targets contained in the Ribeirão Preto City Plan (SP)

The Ribeirão Preto City Plan covers 10 years and provides for coordination between the various segments of the city, such as the Executive, Legislative, councils, productive sectors, institutions and citizens in general. This plan was drawn up by representative entities in the municipality and published in 2021.

Among the 27 signatories are the Ribeirão Preto Academy of Education, the Ribeirão Preto Commercial and Industrial Association (ACIRP), the Ribeirão Preto Engineering, Architecture and Agronomy Association (AEAARP), the Association of Developers, (ASSILCON), the São Paulo State Industries Center (CIESP), the Institute for Advanced Studies - USP/RP and the Ribeirão Preto Social Observatory (INSTITUTO RIBEIRÃO 2030, 2021).

The Plan is divided into four axes of action: (1) Modernization of Management; (2) Economic Development; (3) Social Policies and (4) Urban and Environmental Policies, with a total of 30 targets, guiding strategies and actions systematized from an execution chronogram. For this research, Axis 4 was selected in order to specifically assess the relevance and challenges

of targets 25 and 27, which refer to public policies for afforestation in urban areas and enabling climate resilience, respectively.

3.3 Analysis of land use and occupation in Ribeirão Preto (SP)

This stage of the research makes it possible to analyze the achievement of Target 25 (Afforesting urban areas) in accordance with Strategy 2 (Promoting diagnoses in order to guide the public policies to be adopted), as it includes an updated diagnosis of the rate of tree cover in order to visualize strategic locations for planting trees, among other related topics.

The Land Use and Land Cover map was drawn up using Landsat 9 OLI/TIRS satellite images dated September 2, 2023, provided by the United States Geological Survey (USGS) Earth Explorer website at a scale of 1:250,000. For the delimitation of the municipality of Ribeirão Preto (SP), the bases provided by the IBGE in 2022 were used.

For a more complete analysis, the National Water and Sanitation Agency (ANA) database was also used to obtain the outcrop areas of the Guarani Aquifer System (SAG) in the municipality, in order to verify land use in this region.

Bands 6, 5 and 4 were composited for better visualization of the images using the Geographic Information System (GIS) tool ArcGis version 10.8. Subsequently, the Maximum Likelihood Classification tool was used to classify land use and occupation, which performs supervised pixel-by-pixel classification using the Maximum Likelihood and Minimum Euclidean Distance algorithms with the visible (blue, green and red) and near infrared bands (SANTOS et al., 2019; SILVA; DOURADO, 2016).

To obtain tree cover per inhabitant (m²/inhabitant), the following land use class was adopted: Urbanized Areas, Agricultural and Uncultivated Areas, Water and Tree Cover, described in **Chart 1** (SILVA; DOURADO, 2016). This classification was adopted by Pestana et al. (2023) to analyze land cover at the surface water catchment of the Corumbataí River in Piracicaba (SP). The area of each class (km²) was calculated using ArcGis 10.8 software using the Field Calculator tool.

For this study, the term vegetation cover was adopted instead of vegetation or vegetation cover because it is the term most used in recent publications, which is defined by the Brazilian Society of Urban Afforestation as data obtained through remote sensing that represents the set of trees, palms and shrubs, cultivated or spontaneously occurring in public and private areas, which articulate with each other and form part of the green infrastructure network of cities (SBAU, 2021).

As a final product, the public expenditure per inhabitant spent, in reais, on the preservation, protection and conservation of environmental heritage at federal, state and municipal level, in the years 2015 to 2021, was obtained from the SIDRA IBGE collection, in order to verify the progress made in investments by municipalities.

Chart 1: Description of land use and occupation classes

Class	Features
Urbanized Area	Presence of urban infrastructure (roads, bridges and public facilities), buildings, residential, commercial, industrial and institutional constructions.
Farming and Uncultivated Land	Agricultural Activities, Livestock, Pasture, Deforested Areas, Exposed Soil and Scrub.
Water	Rivers, streams, lakes, reservoirs and dams.
Tree Cover	Data obtained through remote sensing that represents forests, environmental preservation areas, urban green areas, squares, parks or places where the tree canopy plays a significant role in ground cover.

Source: Authors (2023), adapted from Silva and Dourado (2016) and SBAU (2021).

4. Results

4.1 Characterization of the Study Area

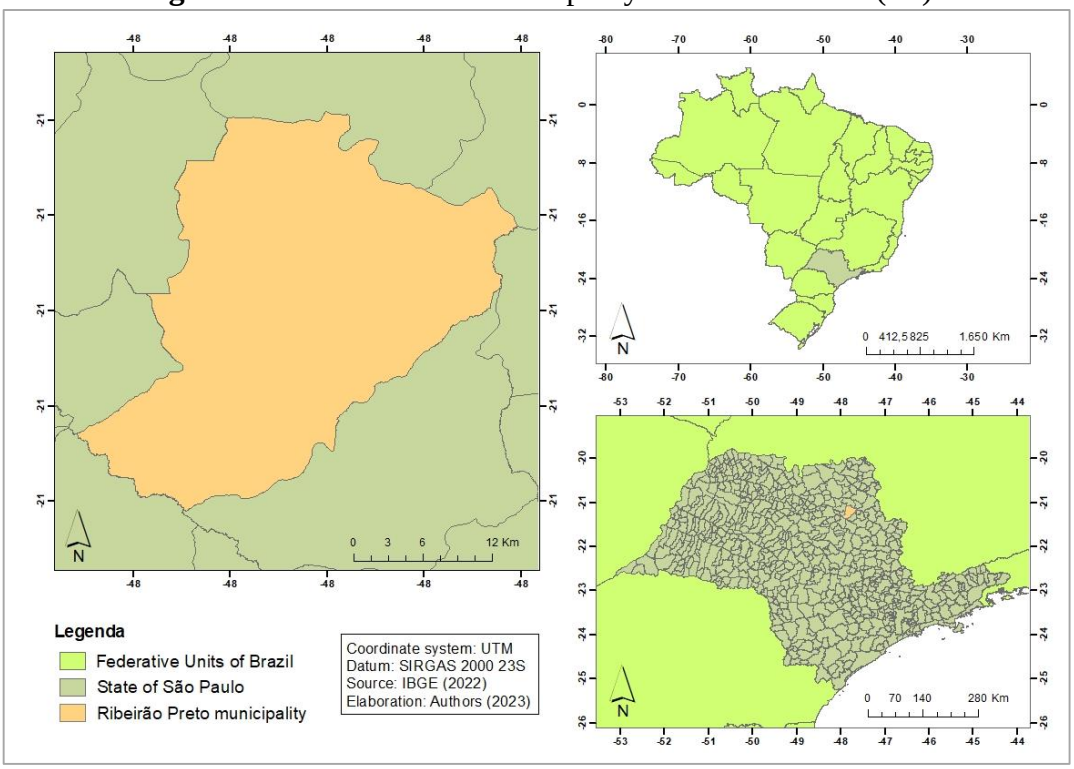
Ribeirão Preto (**Figure 1**) is located in the northeastern region of the state of São Paulo, is the ninth largest municipality in the state with a total area of about 650 km², has an average altitude of 546.8 meters and is about 330 kilometers from the capital (SEADE, 2021). With a high standard of living (income, consumption, longevity), the municipality has good social indicators (health, education and sanitation) and a privileged location close to large consumer centers and easy access to transport and communication infrastructure (USP, 2015).

The municipality has a population of 698,259 (IBGE, 2022) and a tropical climate, with rainy summers and dry winters, average temperatures of 19ºC in winter and 25ºC in summer, average annual rainfall of 1426.80 mm and relative humidity of 71% (RIBEIRÃO PRETO, 2019).

With a significant amount of its territory covered by Red Latosol (about 73%), this soil has a moderate reserve of macro and micro-nutrients, which gives it stability, resilience and a stable productive capacity over years of cultivation. In addition, due to their favorable chemical fertility and good physical properties, they have low erosion rates. However, it original vegetation (Atlantic Forest) has been replaced by intense agricultural activity (RIBEIRÃO PRETO, 2019).

In terms of hydrography, Ribeirão Preto has the largest part (77.6%) of its territory contributing to the Pardo River Basin - UGRHI 04, and a smaller part (22.4%) of its territory contributing to the Mogi-Guaçú River Basin - UGRHI 09 (CESTB, 2021). In terms of sub-basins and micro-basins, the most significant are: I) Ribeirão Preto sub-basin; II) Córrego das Palmeiras micro-basin and III) Córrego do Esgoto micro-basin. These together occupy the areas of greatest urban occupation and their immediate surroundings in the municipality, thus receiving the greatest impact in relation to the other areas (RIBEIRÃO PRETO, 2019).

Figure 1: Location of the municipality of Ribeirão Preto (SP)



Source: Authors (2023).

Ribeirão Preto is one of the 105 cities that have outcrops and recharge areas of the Guarani Aquifer System (SAG) in its territory. Among its boundaries (650.9 km²), 148.22 km² are covered by this feature, that is, approximately 17.3% of the municipality (RIBEIRÃO PRETO, 2019).

With its essentially urban characteristics and high population density, Ribeirão Preto was institutionalized as a Metropolitan Region on July 6, 2016, by State Complementary Law No. 1,290. The region is made up of 34 municipalities, grouped into four sub-regions, and is considered a hub for services, especially commerce, health and education. It also has significant industrial and agricultural importance, with regional and national recognition in the sugar-alcohol and metallurgical sectors (SÃO PAULO, 2018).

According to the Sustainable Development Index for Cities (IDSC-BR), Ribeirão Preto has an overall score of 57.67/100, classifying it as having a medium level of sustainable development. One of the biggest challenges lies in SDG 15 (Protect Terrestrial Life), with a score classified as very low (0 to 39.99). Among the indicators of this SDG is the rate of forested and natural areas, which also has a challenging value (ICS & SDSN, 2021).

Although a letter of commitment was signed on September 21, 2021, bringing together Non-Governmental Organizations (NGOs), companies, the academic community, public authorities and civil society with the aim of increasing tree cover to 30% by 2030 and reducing the municipality's temperature by -3ºC (RIBEIRÃO PRETO, 2021), Ribeirão Preto still lacks a municipal afforestation policy.

The proposal to revise the Environment Code, mentioned by the city council at a public hearing in March 2020, includes drawing up a "Strategic Plan for the Development of the Green Areas and Urban Afforestation System". However, this plan is scheduled to be developed over a period of two to five years, which puts it far from the city's immediate needs. Furthermore, there is no sector, department or team specifically dedicated to the issue of urban afforestation in the organization chart of the Secretariat for the Environment (INSTITUTO RIBEIRÃO 2030, 2021).

3.2 Identification of the Targets, Strategies and Actions contained in the Ribeirão Preto City Plan (SP)

The lines of action contained in the Plan and their respective targets are shown in **Chart 2**.

Chart 2: Axes of action and targets contained in the Ribeirão Preto City Plan (SP)

Axes	Targets
1: Modernization of Management	1) Balancing public finances; 2) Reforming the administrative structure; 3) Networking management; 4) Stimulating partnerships; 5) Monitoring public policies; 6) Acting transparently; 7) Investing in technology.
2: Economic Development	8) Developing regionally; 9) Encouraging local development; 10) Strengthening the economy; 11) Encouraging technological hubs; 12) Boosting inter-nationalization.
3: Social Policies	13) Prioritizing early childhood; 14) Improving education indicators; 15) Eradicating extreme poverty; 16) Providing efficient health services; 17) Promoting mental health; 18) Reducing the housing deficit; 19) Assisting homeless people; 20) Increasing the level of security; 21) Promoting equal opportunities; 22) Adopting inclusive policies; 23) Strengthening cultural identities.
4: Urban and Environmental Policies	24) Advancing sanitation; 25) Afforesting urban areas; 26) Improving mobility; 27) Encouraging sustainable practices; 28) Enabling climate resilience; 29) Boosting the use of historical heritage; 30) Rehabilitating urban spaces.

Source: Authors (2023), based on Instituto Ribeirão 2030 (2021).

The targets selected for the study (25 and 28) were described respectively as: I) encouraging afforestation so that by 2030 the municipality has at least 30% of its urban area covered by trees and no region has less than 25%; and II) establishing environmental sustainability as a cross-cutting theme in urban planning as of January 2021, in order to reduce the financial, human and social costs of climate events and promote a better quality of life for the population. The strategies and main actions of targets 25 and 28 are shown in **Charts 3 and 4**.

Chart 3: Strategies and main actions to achieve target 25 (Axis 4) in Ribeirão Preto (SP)

Target	Strategies	Main Actions
25) Afforesting urban areas	(1) Structuring public administration to develop and implement afforestation policies;	Create the Municipal Coordination of Afforestation; the Municipal Fund for Urban Afforestation; Include Urban Afforestation in the Annual Budget Law and Multi-Year Plan; Revitalize the Municipal Garden.
	(2) Promote continuous and up-to-date diagnoses in order to guide the public policies to be adopted;	Draw up the "Strategic Plan for the Green Areas and Urban Afforestation System"; Promote the continuous preparation of diagnoses of the rate of tree cover and specific projects for strategic neighborhoods, with localized revitalization actions.
	(3) Encourage partnerships and the participation of society in planting and in defining public policies;	Create a Tree Planting Incentive Policy; Set up a Tree Planting Committee; Encourage the creation of and partnerships with nurseries; Create a register of public areas of interest for planting; Set up a seal for companies that adopt good practices.
	(4) Monitor and preserve existing seedlings and trees.	Require in the contract notices for mowing services that measures be adopted to preserve seedlings and trees; Use technology to identify and track trees, especially those planted through environmental compensation, by means of a QR Code or similar.

Source: Authors (2023), based on Instituto Ribeirão 2030 (2021).

Chart 4: Strategies and main actions to achieve target 27 (Axis 4) in Ribeirão Preto (SP)

Target	Strategies	Main Actions
28) Enabling climate resilience	(1) Measure environmental comfort indicators to create targeted public policies;	Monitoring temperature and humidity in parts of the city; Diagnosing heat islands through technology and partnerships.
	(2) Expand afforestation and green systems;	Carry out the actions set out in target 25 and -3ºC program; In the formulation of the Strategic Plan for Green Areas and Urban Afforestation, identify the places where planting will be encouraged.
	(3) Execute the incentives of Complementary Law 2.996/19, in particular the installation of green roofs and tree planting;	Monitor the incentives granted, cross-referencing data with environmental comfort diagnoses;
	(4) Revise the Civil Protection and Defense Contingency Plan, incorporating monitoring and warning Technologies;	Encouraging creative solutions in partnership with society, especially through calls for proposals, examinations and hackathons.
	(5) Establish environmental sustainability as a transversal axis in all public policies, especially in construction work.	Observe purchases of sustainable materials that promote climate comfort in renovations and constructions; Carry out studies on sustainable interventions, such as green roofs.
	(6) Encourage the creation and revitalization of linear parks, especially on the banks of streams.	Promote research into local desires for the development of parks and consider these interventions as priorities for environmental compensation policies or Terms of Conduct Adjustment (TACs) signed to make developments possible.

Source: Authors (2023), based on Instituto Ribeirão 2030 (2021).

There were no assessments of the level of difficulty in achieving the targets contained in the document, since these are relative concepts that move from one intensity to another depending on the capacity of the interlocutors, the strength of the involvement and the priorities established (INSTITUTO RIBEIRÃO 2030, 2021).

The strategies and main actions established for targets 25 and 28 have proven to be extremely pertinent and in line with the SDGs, as they demonstrate the interest of the parties involved in investing in disaster risk reduction and urban resilience strategies. However, in order for the targets to be met, financial investment and monitoring by the local government are necessary, as well as raising awareness among the population of the importance and benefits of urban and environmental policies.

The biggest challenge is the transparency of the progress of the actions suggested by the Plan, considering that the last report published on the Ribeirão 2030 Institute website refers to 2021. There is no clear timetable for the implementation of each action, but they are only commented on and presented in a sequence throughout the document.

Nor were any official documents from the municipality identified that support the City Plan, with the only exception being the letter of commitment to the Ribeirão -3ºC program, signed on 21/09/2021, formalizing the government's commitment to make the urban area 30% greener by 2030.

3.3 Analysis of land use and occupation in Ribeirão Preto (SP)

Figure 2 shows the classification of land use and occupation using ArcGis 10.9 software. The representativeness of each class can be seen in **Table 1**. According to both, the municipality of Ribeirão Preto (SP) has most of its territory covered by Farming and Uncultivated Land (59%), followed by Urbanized Areas (18.9%). The municipality's tree cover is only 15.7%, which is around 20km² less than the urbanized areas.

For the amount of tree cover per inhabitant (m²/inhabitant), a population of 698,259 was considered (IBGE, 2022), so as to identify 22.5 m² per inhabitant in the urban perimeter. This figure would be even lower if only the urban area of Ribeirão Preto (SP) was considered.

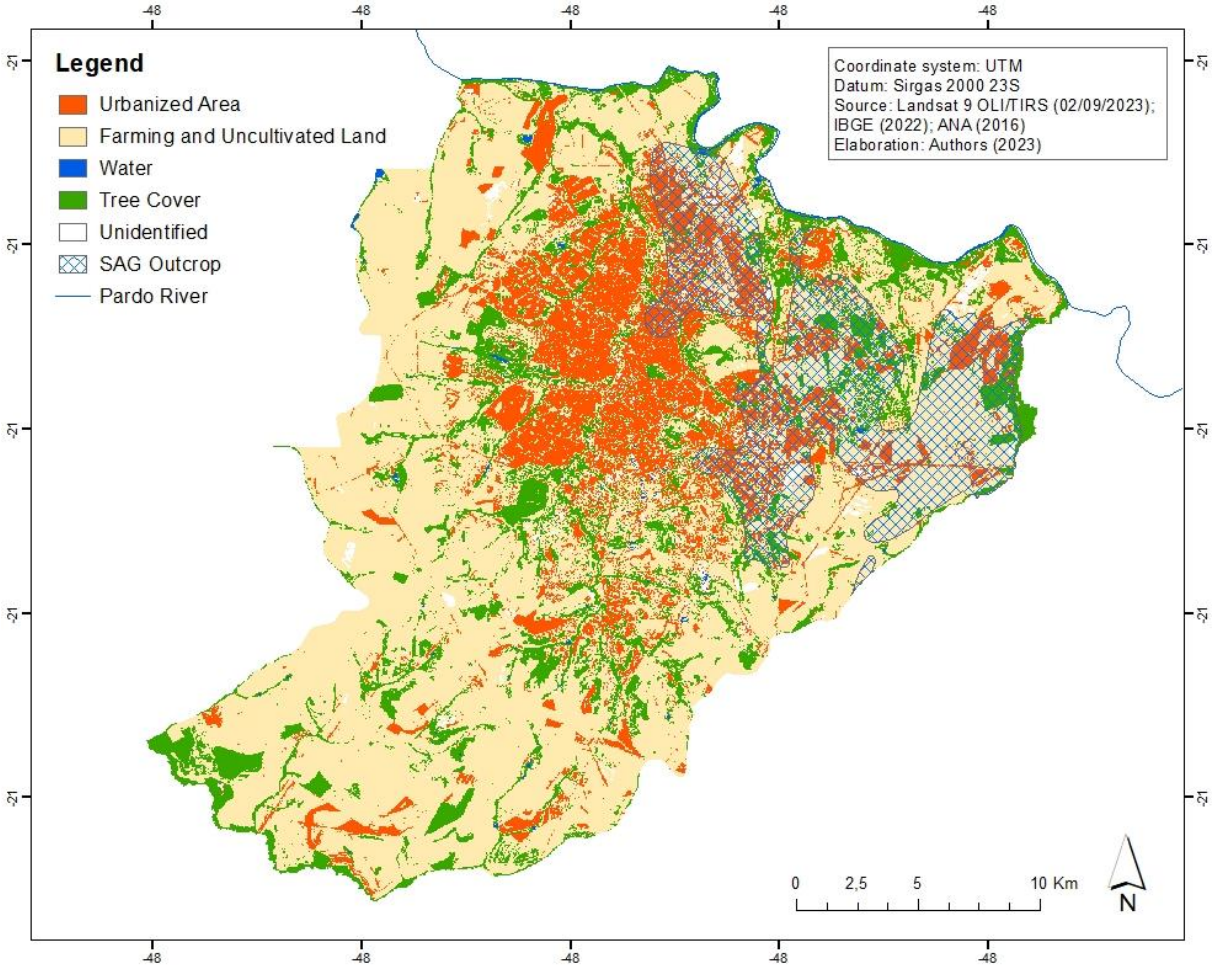
In a similar analysis carried out by Pestana et al. (2023) in Piracicaba (SP), they found around 689 m²/inhabitant of tree cover within the municipal perimeter and 60 m²/inhabitant considering only the perimeter of the urban area; Teixeira and Gonçalves (2020) also found around 86.8 m²/inhabitant of tree cover in São Gabriel (RS), which demonstrates the precariousness of tree cover in the study municipality when compared to others.

In 2012, the municipality's Master Plan for Afforestation indicated around 23.6% of vegetation (INSTITUTO RIBEIRÃO 2030, 2021), which means that there was a reduction of 7.9% in 2023 (Table 1) compared to 2012, which is worrying given the UN's recommendations regarding environmental sustainability through the expansion of green areas as an instrument to improve quality of life.

The Arborization Master Plan proposed in 2012 made no progress in its implementation and there were no resources allocated to the issue in the budget laws. In 2017, another study was carried out, indicating a tree cover of 16.7% (INSTITUTO RIBEIRÃO 2030, 2023), representing a drop of 6.9% compared to 2012. It can therefore be seen that the greatest reduction in tree cover occurred between 2012 and 2017, and will persist in 2023.

This decrease in tree cover can be explained by urban sprawl and political discontinuities, since plans such as the implementation of squares and the afforestation of neighborhoods are actions that need to be thought out and carried out over the long term. This process is hampered by the alternation of political groups in the administration, considering that the policies, plans and targets drawn up, when they are implemented, generally do not extend beyond the management period (LOBODA; ANGELIS, 2005).

Figure 2: Classification of land use and occupation in the municipality of Ribeirão Preto (SP)



Source: Authors (2023).

Table 1: Percentage of area by land use and occupation class in Ribeirão Preto (SP) in 2023.

Classes	Area (km²)	Percentage (%)
Urbanized Areas	123,1	18,9
Farming and Uncultivated Land	384,1	59,0
Water	3,0	0,5
Tree Cover	102,3	15,7
Unidentified	38,4	5,9
Total	**650,90**	**100%**

Source: Authors (2023).

The SAG outcrop region (Figure 2) is threatened, especially by urbanization and agriculture, which leads to the sealing of the recharge area and the generation of risks. These two categories of land use are responsible for various sources of contamination in the water recharge region: city cemeteries, neighborhoods with poor sanitation systems, agricultural chemicals used in the sugar cane industry, and the old municipal landfill (VILLAR; RIBEIRO, 2009).

Ribeirão Preto has around 449.7 m³/hab.year of water availability per inhabitant from surface water, which is considered "Critical". Between 2016 and 2020, the municipality showed a drop in water availability, from 469.5 m³/hab.year to 449.7 m³/hab.year (-4.21%) in surface availability and from 48.6 m³/hab.year to 46.6 m³/hab.year (-4.11%) in groundwater availability. In view of the situation, it was recommended that studies be carried out to estimate the potential of the SAG for public and private supply in the municipality, establishing its maximum capacity, resilience and sustainability over time (CETESB, 2021).

Therefore, the reduction in tree cover over the years in Ribeirão Preto is worrying given the risks to water availability for consumptive uses (withdrawal of water from collections without replacement, such as human supply, use in agriculture and others), which could compromise the various uses in the short and medium term for the aforementioned river basins and the recharge of the Guarani Aquifer.

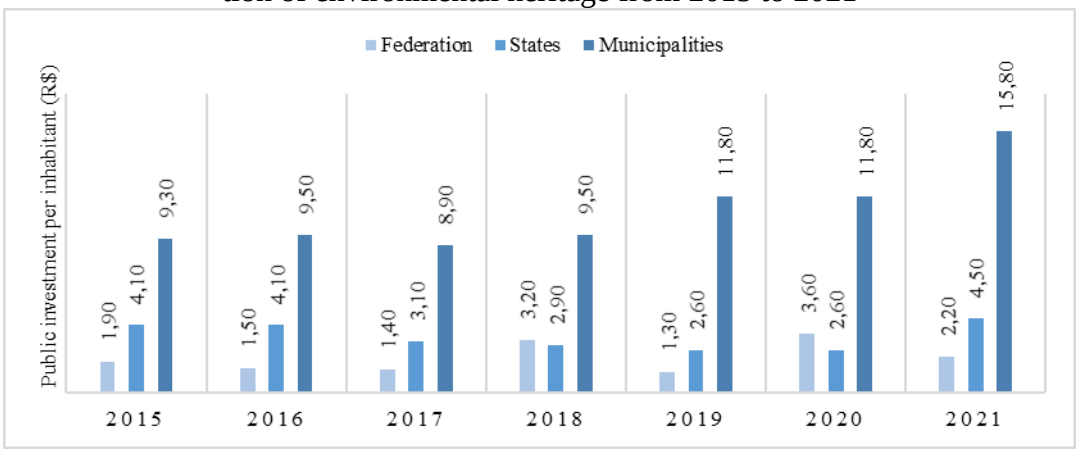
Without promoting sustainability and adopting innovation in urban areas, cities will not be able to face global challenges (RIETH, 2017). The same author also points out that cities that move forward with this agenda understand that current and future needs must be met with a stance that moves towards developing integrated solutions that are closely connected to their inhabitants.

One of these initiatives is investment in Nature-Based Solutions (NBS), which use natural and built systems that employ physical, chemical and microbiological processes, with reduced operating and maintenance costs, low environmental impacts and provide added value by promoting biodiversity, mitigating the effects of climate change, restoring ecosystems, improving quality of life and increasing environmental resilience (O'HOGAIN et al., 2018). Some examples are afforestation, reforestation, pasture management, green roofs and walls, urban open

spaces, rainwater harvesting and community gardens (OSAKA; BELLAMY; CASTREE, 2021).

Figure 3 shows the public expenditure per inhabitant spent on environmental preservation, protection and conservation at federal, state and municipal level between 2015 and 2021.

Figure 3: Investment (R$/per inhabitant) in the preservation, protection and conservation of environmental heritage from 2015 to 2021



Source: IBGE (2021)

Investment in the preservation, protection and conservation of environmental heritage (Figure 3) has increased over the years, especially at municipal level, from R$9.30 per inhabitant in 2015 to R$15.80 in 2021. In relation to average state and federal investments, these went from R$4.10 (2015) to R$4.50 (2015) and 1.90 (2015) to 2.20 (2021), respectively. In general, these results show that municipalities are becoming more concerned about the environment.

5. Conclusions

The study achieved the proposed objective and showed that the strategies and actions contained in targets 25 and 28 of the Ribeirão Preto City Plan for 2030 are relevant to the sustainable development of the municipality and are aligned with the SDGs, demonstrating the interest of signatory entities and civil society in investing in disaster risk reduction and urban resilience strategies.

The main challenge observed in meeting the targets set out in the Plan is the lack of transparency in relation to the progress of the actions, since it is not disclosed through official channels of the municipality or on the Institute's website. We also found no official documents from the city council in support of the City Plan, with the exception of the letter of commitment to the Ribeirão -3ºC program.

Through the use of GIS software, it was observed that the main uses refer to agriculture and uncultivated land (59%) and urbanized areas (18.9%), which characterizes the municipality economically, with an emphasis on the agricultural sector, commerce and services. The sealing of the soil and the trampling of cattle on the ground makes it difficult for water to penetrate, interfering with the hydrological cycle and, consequently, leading to an increase in temperature in the municipality.

The outcrop region of the SAG is threatened by urbanization and farming, which result in multiple sources of contamination in the water recharge region, such as neighbourhoods with poor sanitation systems and agricultural chemicals. The reduction in the availability of surface and groundwater has been reported by Cetesb (2021), which recommends that studies be carried out to estimate the potential of the SAG for supply in the municipality, establishing its maximum capacity, resilience and sustainability over time.

The decrease in the percentage of tree cover over the years has been worrying, since in addition to the increase in local temperatures, the absence of vegetation is reflected in risks to the watershed, the recharge of the Guarani Aquifer and natural disasters. In 2023, the percentage of the territory occupied by tree cover represented only 15.7%, indicating a reduction when compared to other studies which indicated 23.6% for the year 2012 and 16.7% for the year 2017.

The land use and occupation map allowed for a visual analysis of the main points in the city that need to be taken care of, indicating possible strategic locations for the expansion of tree planting. In order to achieve 30% tree cover by 2030, as set out in the Plan, it is necessary to intensify tree planting both immediately and in the long term.

It is recommended that analyses be carried out covering the municipality's urban area, in order to better visualize the area's tree cover and possible locations where public green areas, such as squares and parks, could be implemented, as well as a more detailed assessment of the occupation present in the SAG recharge área

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