

City Biodiversity Index and the Cities-Biodiversity Relationship: a Case Study for Sorocaba, SP, Brazil

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Research Article

Keywords: City Biodiversity Index, conservation, local government, urban biodiversity.

Posted Date: May 24th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-363556/v1>

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Abstract

In order to adopt a strategic model which aims to mitigate the environmental pressures exerted by the process of unbridled urbanization, the Convention on Biological Diversity (CBD), an international agreement that permeates its conservation, the sustainable use of its resources and the equitable sharing of its resources, approved in 2010 the creation of the City Biodiversity Index (CBI), a political-legal instrument that aims to assess its management and progress. Later in 2016, the “Sorocaba: the city of biodiversity” program was launched by Secretariat for the Environment and Sustainability (SEMA), consisting of six specific objectives and among them, the establishment of criteria for the evaluation of conservation measures through indicators adapted from CBI, in order to propagate the urban ecology and ecosystems importance. Given the above, this study aimed to prove the compatibility between urban centers and biodiversity and to evaluate the environmental management of the city of Sorocaba, located in the interior of the State of São Paulo, through the application of 23 CBI indicators. The sum of the indicators resulted in a value of 57 points out of a total of 92 (61.9%), showing that, although Sorocaba has a relevant biodiversity, the low score of many indicators implies a need for greater mobilization of government spheres and the successive application of the CBI, in order to expand the conservation and environmental management of the city agenda over the years.

Introduction

Currently, about 50% of the world population occupies large urban centers and the perspective is that this percentage will increase exponentially by the year 2030 (United Nations Population Fund 2007). Urbanization has been a driving force for changes in several essential ecosystem services, significantly affecting biological systems and factors such as climate and biodiversity, the latter in terms of species composition, wealth, abundance, and distribution (Shochat et al. 2006; 2010). On the other hand, despite all the pressure exerted on the processes of biological diversity, a considerable number of species have their habitat areas inserted in urban perimeters (especially squares, parks, and gardens) as potential refuges due to the availability of food resources, abundance of habitats, ecological niches and, for the most part, the absence of natural predators (Angold et al. 2006).

Given all the problems inherent to urbanization processes, much is discussed about the difficulty in assigning a value to urban biodiversity, characterized by the variety of living organisms inserted in urban bordering areas (Dearborn and Kark 2009; Müller et al. 2013). In 2002 during the Convention on Biological Diversity (CBD), leaders of CBD signatory countries pledged to meet a goal of reducing biodiversity loss by 2010. However, a recent assessment using a couple of indicators showed a failure to achieve the objective and that the rate of biodiversity loss is the fastest ever observed (Convention on Biological Diversity 2010; Smith et al. 2018).

Due to the results obtained, the CBD approved in 2010 a metric known as the “City Biodiversity Index” (CBI), an essential mark in the conservation of species and ecosystems (Cabral 2012). Also, the Convention Parties have established 20 new targets to be achieved by the year 2020, a fact that led the

United Nations to name the period evaluated as “decade of biodiversity” (Mace et al. 2018; Secretariat of the Convention on Biological Diversity 2019). The strategy in question came to an end in October 2020 during the 15th Conference of the Parties (COP-15), reporting that many objectives have not been adequately achieved and adopting a new post-2020 approach that includes goals that aim to stop the loss of biodiversity and maintaining the integrity of ecosystems until 2030 (Hoban et al. 2020).

To take the biological diversity present in cities as a basis for the proper functioning of the urban environment is still a somewhat unusual practice, given that the approach and planning for biodiversity conservation are challenging actions for local governments (Pierce et al. 2020). It is necessary to understand that it is possible to link biodiversity conservation actions with the development of the urban environment and that its success is intrinsically linked to the people-nature intersection, since the population benefits from a wide range of cultural services, from regulation, provision, and support from ecosystems (Kowarik et al.; Sinisgalli et al. 2020).

Under a more local picture, the creation of Secretariat for the Environment and Sustainability (SEMA) in the city of Sorocaba, located in the interior of São Paulo State, was a driving force for discussions and projects aimed at the good management of biodiversity. Like the publication of two editions of the book “Biodiversidade no Município de Sorocaba” (Smith et al. 2014; Smith 2020), consisting of an inventory of animal and vegetable species in the city, and the presence of 33 parks in the municipality, eight of which classified as “natural” (of which many hosted environmental education activities).

Even though the municipality of Sorocaba is moving towards effective results concerning the protection of biodiversity, such effects must persist so that it is possible to provide faster responses about environmental protection and, consequently, population well-being (Smith et al. 2016). In this context, this study aimed to prove the compatibility between cities and biodiversity and expose the importance of green areas for it, as well for urban centers, aiming to evaluate the level and management of biodiversity in the municipality of Sorocaba with the subsidy of 23 indicators included in the CBI, being extremely relevant for the city and the first Picture of urban biodiversity through the index in question.

Material And Methods

Study case

Sorocaba municipality is located in the interior of São Paulo State (S latitude: 23° 21' and 23° 35'; W longitude: 47° 17' and 47° 36'), being an important industrial pole due to its two main highways, Raposo Tavares (SP-270) and Castelo Branco (SP-280) (Emplasa 2018). Has an area of approximately 450 km², with an average altitude of 600 m above sea level and has more than 600.000 inhabitants (SEMA 2016). The city's climate is characterized by Cwb (hot subtropical) according to Köpen climatic classification, with an average monthly temperature that reaches less than 22°C and precipitation of approximately 1408,4 mm per year (Cepagri 2018). The declivity is between 0 and 15°, with more variations in the southeast portion. Is established in UGRHI-10 (The Water Resources Management System of the State of São Paulo) Sorocaba and Middle Tietê, encompassing 33 other municipalities (Bortoleto 2020).

Concerning its green area, the predominant and original vegetation of the city is characterized as Seasonal Semideciduous Forest with transition zones (ecotones) between Cerrado and Atlantic Forest, which contributes to the biodiversity conservation strategy, given that the municipality presents higher common species richness to the two biomes (Smith et al. 2016). Although it is quite fragmented, the Remaining Natural Vegetation (RNV) of the city corresponds to about 22% of the entire area, and 90% of your green areas are occupied by municipal parks, squares and public gardens (Fig. 1) (Smith et al. 2016).

Methodology

The methodology employed in this work was based on 23 indicators belonging to City Biodiversity Index (CBI), divided into three categories: Biodiversity (10 indicators), Ecosystem Services (4) and Governance and Management (9) (Table 1). To each of the indicators was assigned a value of 0 to 4 points, totaling 92, considering that, as higher the score obtained, the better the level of urban biodiversity in the municipality (Cabral et al. 2012; Machado 2014). The indicators were studied in order to evaluate if alterations would be necessary to suit the reality of the city, choosing to modify only one of them (20).

Table 1
Descriptive table of the City Biodiversity Index
(modified from City Biodiversity Index 2010)

Categories	CBI indicators	Adapted indicators	Methods of obtaining data	Score
Biodiversity	1. Proportion of natural areas in city	Proporção de áreas verdes em relação à área total	(Green areas) / (City area) x 100	4 points
	2. Connectivity measures	Verificar a existência de conectividade entre diferentes espaços verdes	Bibliographic consultation (Bortoleto 2019)	4 points
	3. Native biodiversity in built up areas (bird species)	Número de espécies de aves	Field surveys and Bibliographic consultation (Piratelli et al. 2016; Prefeitura Municipal de Sorocaba 2019)	4 points
	4. Change in number of vascular plant species	Change in number of vascular plant species	2014 and 2020 inventories (Smith et al. 2016; Smith 2020)	4 points
	5. Change in number of bird species	Change in number of bird species	2014 and 2020 inventories (Smith et al. 2016; Smith 2020)	4 points
	6. Change in number of butterfly species	Change in number of butterfly species	2014 and 2020 inventories (Smith et al. 2016; Smith 2020)	4 points
	7. Change in number of any other taxonomic group selected by the city	Change in number of amphibian species	2014 and 2020 inventories (Smith et al. 2016; Smith 2020)	4 points
	8. Change in number of any other taxonomic group selected by the city	Change in number of mammal species	2014 and 2020 inventories (Smith et al. 2016; Smith 2020)	4 points
	9. Proportion of protected natural areas	Proportion of protected areas in relation to the total area	(Protected areas) / (City area) x 100	4 points

Categories	CBI indicators	Adapted indicators	Methods of obtaining data	Score
	10. Proportion of invasive alien species	Proportion of invasive alien species and verification of their conservation status according to the Red List of Threatened Species	(Number of invasive alien species) / (Number of native species) x 100 e bibliographic consultation (IUCN 2020).	4 points
Ecosystem Services	11. Regulation of quantity of water	Proportion of permeable and impermeable areas	(Permeable areas) / (City area) x 100	4 points
	12. Climate regulation	Proportion of tree cover	(City canopy cover) / (City area) x 100	4 points
	13. Area of parks with natural areas / 1000 persons	Number of formal education visits per child below 16 years to parks with natural areas per year	(Green areas) / 1000 persons	4 points
	14. Number of formal education visits per child below 16 years to parks with natural areas per year	Obtainment number of formal education visits per child below 16 years to parks with natural areas per year	Consult the database of the Secretariat for the Environment and Sustainability	4 points
Governance and Management	15. Budget allocated to biodiversity	Verificar budget llocated to biodiversity	(Environment-related settlement) / (Total settlement) x 100 (Prefeitura Municipal de Sorocaba 2019)	4 points
	16. Number of biodiversity projects implemented by the city annually	Verify number of biodiversity projects implemented by the city annually	Consult the database of the Secretariat for the Environment and Sustainability	4 points

Categories	CBI indicators	Adapted indicators	Methods of obtaining data	Score
	17. Existence of local biodiversity strategy and action plan	Verify existence of local biodiversity strategy and action plan	Consult the database of the Secretariat for the Environment and Sustainability	4 points
	18. Number of essential biodiversity-related functions	List essential biodiversity-related to biodiversity	Consult the database of the Secretariat for the Environment and Sustainability	4 points
	19. Number of city or local government agencies involved in inter-agency cooperation pertaining to biodiversity matters	Number of city or local government agencies involved in inter-agency cooperation pertaining to biodiversity matters	Consult the database of the Secretariat for the Environment and Sustainability	4 points
	20. Existence of formal or informal public consultation process	Verify the existence of public environmental policies	Consult the database of the Secretariat for the Environment and Sustainability	4 points
	21. Number of agencies/ private companies/ NGOs/ academic institutions / international organisations with which the city is partnering in biodiversity activities, projects and programmes	Number of agencies/ private companies/ NGOs/ academic institutions / international organisations with which the city is partnering in biodiversity activities, projects and programmes	Consult the database of the Secretariat for the Environment and Sustainability	4 points
	22. Is biodiversity or nature awareness included in the school curriculum	Check the inclusion of biodiversity in formal education	Consultation to the Municipal Education Plan of the municipality	4 points
	23. Number of outreach or public awareness events held in the city per year	Number of biodiversity-related events held publicly in the city per year	General bibliographic search mediated by keywords (events, environment, Sorocaba, 2019)	4 points

Categories	CBI indicators	Adapted indicators	Methods of obtaining data	Score
				Total of 92

Results

Biodiversity

The results showed that Sorocaba obtained a good performance in six indicators inserted in "Biodiversity". About the indicator 1, the city has exact 45,000,0 ha and 1,654,17 ha of green areas, 90% occupied by 23 municipal parks. For the calculation of the indicator 1 were considered all the parks, squares and public gardens, obtaining a proportion of 0.036 (3,7%). Besides that, has about 9.890 ha of remaining forestry (661 fragments), fact that enables the existence of green corridors (described on indicator 2). However, geoprocessing works carried out in the municipality point in their results that the city original landscape presents many anthropic barriers, like the presence of highways and private properties, making it extremely fragmented and, consequently, making connectivity difficult.

About your biological diversity addressed on indicators numbered 3 to 8 and 10, Sorocaba has a total of 310 bird species, 632 angiosperms, 65 amphibians and 28 mammals. In the 2014 inventory, these numbers corresponded respectively to 280, 441, 48 and 23. The butterfly group, otherwise, was not sampled on the first inventory, which influenced the score obtained in indicator 6, considering that there was not species increase or decrease (43 inventoried in the current edition) (Fig. 2).

The application of indicator 10 is important due to the relevance of knowing and distinguishing the invasive alien species that will cause some damage to the ecosystem where they are inserted. After literature review has been confirmed 42 invasive alien species of a total of 1.376 species (proportion of 3.05%), 24 of these presents some degree of threat. Compared to the year of the first inventory there is a small difference in the proportion, the native species being equal to 1.182 and the exotics, 36 (2,95%).

Sorocaba is composed of five protected areas (CUs) registered in National Register of Conservation Units (CNUC), ensuring biodiversity conservation and allowing only indirect use of its resources. Besides that, has nine areas of environmental interest and 19 public spaces of social interest. For the calculation of indicator 9 was considered only CUs, making a total of 181,17 ha of protected areas and obtaining a proportion of 0.40%.

Ecosystem Services

The Sorocaba Urban Afforestation Diagnosis showed the existence of 74.638 trees in central flowerbeds and sidewalks and 30.000 in gardens and backyards, adding the fragments areas, and riparian forests obtained by aerial photographic surveys, totaling 6.014,05 ha of permeable areas (proportion of 13.36% to indicator 11) and 25.6% canopy projection in the urban environment, which corresponds to about

11.520 (indicator 12). As already mentioned, Sorocaba is composed of 1.654,17 ha of green areas and it is estimated a total of 679.378 inhabitants, obtaining a proportion of 2.435 ha to the indicator 13, although the acceptable value for a green infrastructure is 40 m² per inhabitant.

Concerning indicator 14, more than 500 annual formal and educational visits in municipal parks were made in 2019, like the Parque da Biquinha (with 81 participants) and the Água Vermelha (440). For the calculation it was considered that each child under the age of 16 made at least three (3) visits throughout the year.

Governance and Management

The general budget of Sorocaba in 2019 was R\$ 1.783.756.790, the part spent on natural resources, ecosystems regeneration and biodiversity equal to R\$ 20.087.475,06, equivalent to a proportion of 1.13% to indicator 15. Part of this amount corresponds to parks, squares and gardens maintenance (R\$ 9.689.077,24), environmental control (R\$ 101.429,91), environment support fund (R\$ 241.837,64), Zoo (R\$ 4.635.450,39), Environmental Education (R\$ 5.766,88) and other expenses.

The indicator 16 evidenced the existence of 13 improvements of environmental quality projects and actions by government institutions in 2019, predominantly by ecological parks through SEMA. Some of them involve monitored visits to the green areas, donations seedling plantations, vacation projects and socio-environmental awareness activities with birdwatching practices. Besides that, indicator 17 showed the existence of strategies and action plans for biodiversity conservation in the municipality, like the creation of Municipal Environmental Education Program (ProMEA), a political-legal instrument which aims to guide Environmental Education projects with strategies plans and guidelines, having as basic principle its institutionalization and capillarization in the formal and non-formal spheres, and others.

About the infrastructures related to the environment and biodiversity covered in indicator 18, Sorocaba has eight (8) installations that involve services aimed at fostering research, environmental education and awareness, discussion induction and strategies for the great city management. In addition, the municipality participates in numerous measures concerning biodiversity, management and environmental sustainability in cooperation with other secretariats and agencies. The installations identified in indicator 18 that carried out partnerships in campaigns, actions and projects were: CETESB together with SEMA, in the evaluation of black smoke emissions in the city; "Irmãos Villas-Bôas" Botanical Garden in association with Legado das Águas in the donation of native orchids from the garden to the private reserve; Zoo Park "Quinzinho de Barros" in partnership with SEMA and Secretary of Education (SEDU) in the elaboration of the contest "Zoo and the city", and Autonomous Water and Sewer Service (SAAE) in association with SEMA in the creation of the Rio Sorocaba Environmental Education Center, totaling five (5) installations involved in inter-agency partnerships.

Regarding indicator 20, it was found that the municipality has several environmental policies, such as the Municipal Environmental Education Policy (n. 7.854/2006), enacted to direct institutions in the process of activities aimed at environmental awareness; the Sorocaba Municipal Environmental Policy (n.

10.060/2012) that comes into full agreement and compliance with international agreements, including the Convention on Biological Diversity based on this study; the Municipal Policy of Biodiversity Refuges Protection (n. 12.059/2019), which aims to protect green areas of the region that provide shelter and food for the resident species, and others.

In addition to inter-agency cooperations, the Sorocaba City Hall also entered partnerships with four (4) higher education institutions to achieve projects and actions related to environmental awareness and increased researches, and events with the objective of preparing inventories and reports. Other sectors, also in collaboration with City Hall, involve an Environmental Education center and other departments, making a total of seven (7) installations involved in partnerships.

About the formal education, in Sorocaba the basic education is divided into three cycles: basic, elementary and secondary education, jointly encompassing integral teaching based on Law 11.133/2015. Throughout the second cycle (subdivided into Elementary School I and II) issues such as the relationships and interactions between living beings and sustainable development are addressed, aiming to understand the universe and environment in which the human being is inserted through the combination of subjects such as Physics, Chemistry and Biology (forming the knowledge area of Natural Sciences). In this way, biodiversity is part of the scope of promoting science on the part of students about the way scientists build new knowledge, and of developing a critical eye in the search for solutions inherent to anthropic impacts.

Finally, the survey carried out in indicator 23 indicates a total of eight (8) events inherent to biodiversity and the environment, including universities, associations and other installations, with a good part of these (workshops and forums) having the institutions inserted in the higher education network as the main headquarters and directors, being one of the indicators with the lowest score in governance.

The application of 23 CBI indicators resulted in 57 points out of a total of 92 (61.9%) for the studied city. Taking into account the extensive urban area analyzed in Sorocaba and the suppression of remain forests triggered by the city's infrastructure, the indicators 1, 2, 6, 9, 11, 15, 16 and 23 contributed to lower performance on the index, being four of Biodiversity, one of Ecosystem Services and three of Governance and Management (Table 2).

Table 2
Results of calculations for the 23 CBI indicators

Indicators	Score obtained
Biodiversity	
1	1 point: 1,0%–6,9%
2	0 points: <200 ha
3	4 points: >240 species
4	4 points: increase in 4 species or more
5	4 points: increase in 4 species or more
6	0 points: the number of species remains the same or decreases
7	4 points: increase in 4 species or more
8	4 points: increase in 4 species or more
9	0 points: <1,4%
10	3 points: 1,0%-11,0%
Ecosystems services	
11	0 points: <33,1%
12	2 points: 19,2–29,0% of tree cover
13	4 points: >0,9 ha/1000 persons
14	3 points: 3 formal education visits per year
Governance and management	
15	1 point: 0,4%-2,2%
16	1 point: 12–21 programs/projects
17	4 points: existence of action plans and local strategies related to biodiversity
18	4 points: >3
19	3 points: cooperation of 5 agencies
20	4 points: existence of public environmental policies related to biodiversity
21	2 points: partnership with 7–12 agencies / private companies / NGOs / academic institutions / international organizations
22	4 points: biodiversity and nature are included in the school curriculum
23	1 point: 1–59 events per year

Indicators	Score obtained
	Total of 57

Discussion

The CBI indicators allow an integrated analysis of the environmental management of cities. Although Sorocaba presents a reasonable number of public spaces that aim to concatenate the needs of local demand and conserve biodiversity in all its interfaces (Macedo et al. 2012), many of these are under mismanagement and abandoned. Furthermore, has a significant urban portion that, even in detriment of the rural area, could not be avoided due to its degree of urbanization and growth (approximately 98,98%) (Seade 2019). According to Ofori et al. (2018), due to forest fragmentation, habitat loss, decrease of local biodiversity and disturbance-tolerant species are relatively frequent phenomena. The result obtained for indicator 1 reflected the aforementioned reality, being evident the urban area advance on the open spaces (parks, squares and other places related to recreation) and the ineffectiveness of many action plans aimed at restoring areas damaged by human intervention (Lanças 2007).

The indicator 3, based on a group that responds to urbanization in different ways and looks for urban parks to meet their needs (Franchin e Júnior 2004) presented satisfactory results, since the 320 birds species sampled in the municipality corroborate the idea of calling Sorocaba as the “City of Biodiversity”. From the same perspective, the difference in the number of species in the groups covered in indicators 4, 5, 6, 7 and 8 reflects the importance of conducting studies and surveys about the municipality floristic and fauna diversity over the years, since there is a great potential for increasing the list.

Following the definition proposed by Mota et al. (2016), “protected areas” could be defined as: Conservation Unit for indirect use, aimed at preserving biodiversity without external anthropic interference, according to the National System of Conservation Units (SNUC), and Conservation Unit for sustainable use (or direct), which also promote the conservation of species and others components, allowing recreation and leisure upon the population demand. Sorocaba obtained a lower score on indicator 9, since it consists of only five (5) Conservation Units. In compensation, these are part of about 47% of the forest coverage of all parks, with only one of them closed for visitation (Natural Park Dr. Bráulio Guedes da Silva, with 71.55% of coverage).

The problem involving invasive alien organisms is often overlooked and camouflaged in nature, triggering a certain concern due to the impacts inherent to biological invasions that happen slowly and, for the most part, irreversible (Ziller 2010). This fact attributed a certain advantage to indicator 10, which aims to measure the impact that these species have on the city, since the discrepancy between the number of exotic and native species found in Sorocaba is relatively large.

The indicators that most favored a low performance of the “Ecosystem Services” axis belong to the themes “Climate regulation” (11) and “Proportion of tree cover” (12). Regarding this first, although permeability through vegetation contributes to the infiltration of water in the soil, it is known that this

element is appeased by deforestation and the paving of large areas (Hülsmeier and Souza 2007). The municipality of the study has mostly waterproofed areas, although it has 25.6% of tree cover in relation to the total area (Mello et al. 2016).

It can be said that biodiversity protection is intrinsic to man, since he aims to maintain a connection with nature and its services. The Conservation Units for indirect use and municipal natural parks are intended for the conservation of biological diversity, Environmental Education (EE), scientific research, recreation and leisure (Assad 2000). In this context, the value given to indicator 13 was one of the highest in the category. The city has more than 30 parks (closed and open) that are part of the union of protective measures aimed at the conservation of certain places and presents a reasonable performance when developing measures to reconcile EE with conservation actions (Rodrigues et al. 2019). The activities not only cover students from the formal school environment, but are also aimed at training professionals, be they teachers, managers or employees, and for socio-environmental awareness.

About half of the indicators included in "Governance and Management" reached maximum scores, except for those referring to the city's budget for biodiversity (15), number of projects (16), government agencies (19), institutions involved in partnerships (21) and annual events (23). Regarding this first, it is clear that the obstacles found for the conservation of areas, resources and species are, in part, linked to political and budgetary neglect (Milano 2001). The value attributed to the fifteenth indicator corroborates this statement, since the city budget spent on biodiversity is considerably low, taking into account all the amount spent in other departments.

Given the entire environmental infrastructure of the municipality, mobilization by the municipal spheres could be greater in the increment of annual projects. On the other hand, it has institutions of socio-environmental interests and facilities related to the environment, mostly aimed at promoting Environmental Education activities, which attributed a certain advantage to indicator 18.

The median score attributed to indicators 19 and 21 was possibly due to the methodology used to consult data referring to agencies that work in partnerships (electronic databases provided by the City Hall and other electronic addresses associated with the City Council). The city of Lisbon achieved a considerably satisfactory valuation (102), a fact that may have been triggered by the effective contact method carried out by Cardoso (2011), where each institution identified in indicator 18 was contacted via e-mail to survey which of them worked together with other entities in programs and projects.

The search for evaluation (be it diagnostic, procedural or global) of the existence and effectiveness of policies that involve the mitigation of predatory actions on the environment, as well as the conservation of biodiversity, is extremely important for a municipality, since it can subsidize improving environmental quality and promoting the development of new projects (Assis et al. 2012). Sorocaba is very precursor in this sense, given the existence of public policies that aim to integrate public power and civil society and concatenate its needs with the preservation of nature, also counting on the establishment of strategic areas for the conservation of species and natural resources (Mota Junior et al. 2020), giving a good score for indicator 20.

Based on the assumption that the interactive approach to themes inherent not only to the conservation of biodiversity, but also to the adoption of measures and solutions for environmental issues, contributes a lot to the change of values and behaviors, resulting in what we call “ecological subject” (i.e. the one that proposes to adopt sustainable practices for the benefit of nature and the well-being of the population) (Loureiro 2004), the evaluation carried out by indicator 22 is so important as the others, since the ethics of safeguarding all the natural system surrounding the planet must apply at the individual, community, national and global levels.

In this segment, many institutions have adopted progressive views so that the environmental issue does not become something banal and a simple requirement in legal areas, but an essential factor in reconciling economic development and conservation of species, natural resources and ecosystems, whether through projects, programs or events (Lins and Silva 2009). However, the low score obtained in the last indicator shows a lack of significant mobilization on the part of the municipal authorities and indicates a need for reassessment by them in the increase of events on the agenda.

Conclusion

The CBI aims to improve the biological diversity maintenance in the cities, given that the methodology makes it possible to identify species and ecosystems and recognize the importance of conservation. This work allowed the creation of a database capable of providing information for future works and applications of CBI, to compare the city’s progress over the years. The index application showed that the city was well evaluated in most of the indicators, ten of which with maximum score (4) and four with minimum (0). Therefore, to ensure the progression of city sustainable development – and particularly in obtaining higher values – it is recommended to adopt a new environmental ethics that reconciles developmentalism ad sustainability. This way the city can develop economically, socially and environmentally, in order to meet the growing demand of the population without causing major damage to ecosystems. The successive application of CBI can support the expansion of conservation and environmental management of the agenda in the city. The data provided by the index may indicate a good or bad administration of environmental issues, and may suggest proposals for interventions and improvements, so that the city reaches a good level of sustainability.

In this case it is necessary to think about the urban environment as a factor intrinsically linked to the defense of the environment. The mobilization by governmental segments to regulate laws and policies that aim the sustainable development, as well as of the citizens in the adoption of “green measures” in their daily lives, are progressive attitudes capable of taking the city to a new level. Furthermore, society needs to participate in decision-making so that it can go hand in hand with the Public Authorities in establishing of effective public policies.

Declarations

Acknowledgments

The authors are grateful to Universidade Paulista – UNIP Vice-Rectorry of Graduate Studies and Research for the financial support, and to Sorocaba’s Secretariat for the Environment and Sustainability (SEMA) for providing the data presented in the project.

Funding

Open Access funding provided by Universidade Paulista – UNIP Vice-Rectorry of Graduate Studies and Research.

Conflict of interest

The authors declare that they have no conflict of interest.

Data availability

Due to the sensitive nature of the species locations the datasets from the current study are not publicly available but are available from the corresponding author on reasonable request.

Code availability

Not applicable.

Author contributions

WSS conceived the research idea and helped with statistical advice and corrections; JFC designed the methodology, collected field data, led the writing and editing of the manuscript; FLS was responsible for the maps design. The final version of the manuscript was read and approved by all authors.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

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Figures

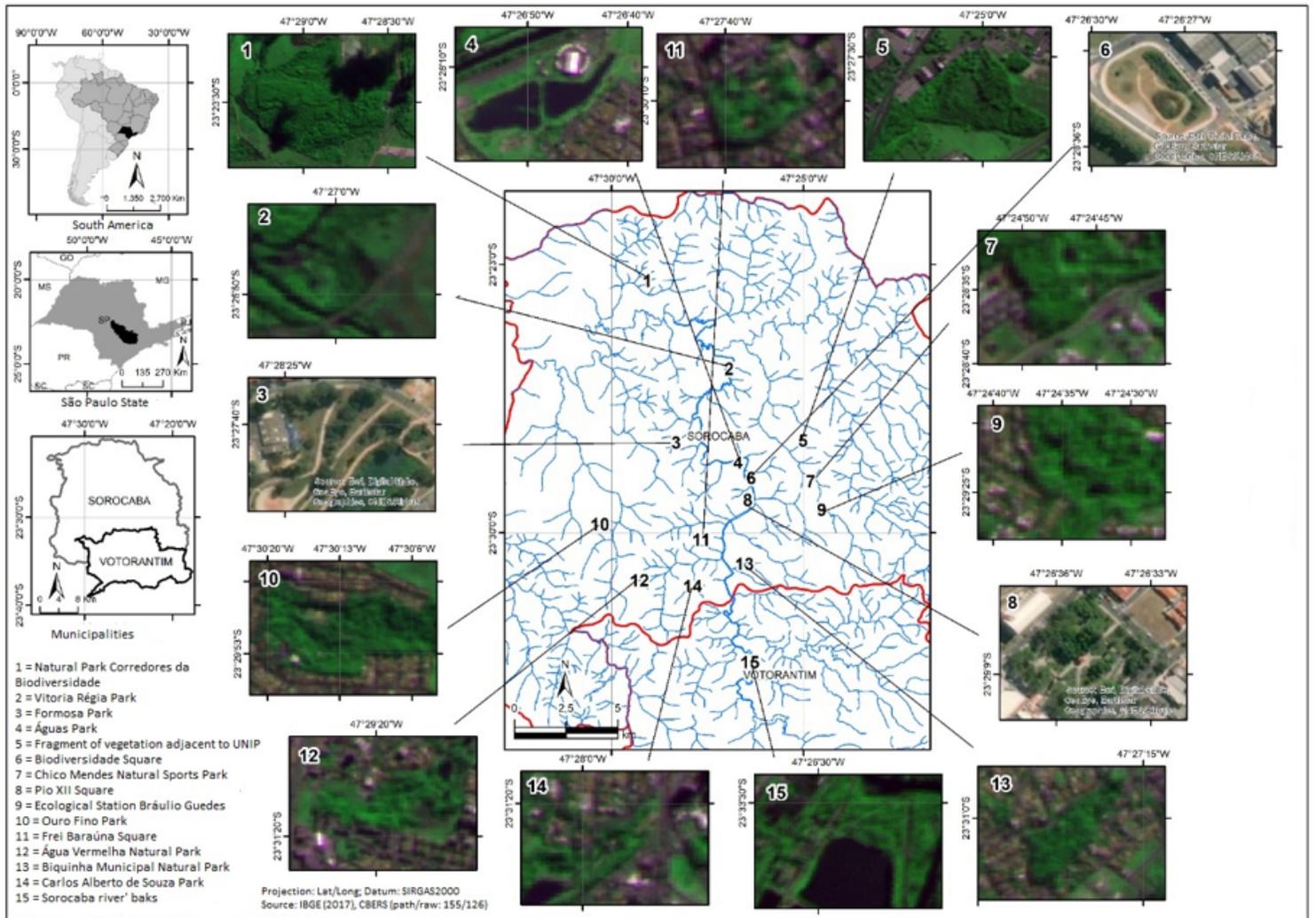


Figure 1

Geographic location of the Brazilian municipality of Sorocaba (SP) and some of its main green areas. Organized by Silva (2020) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

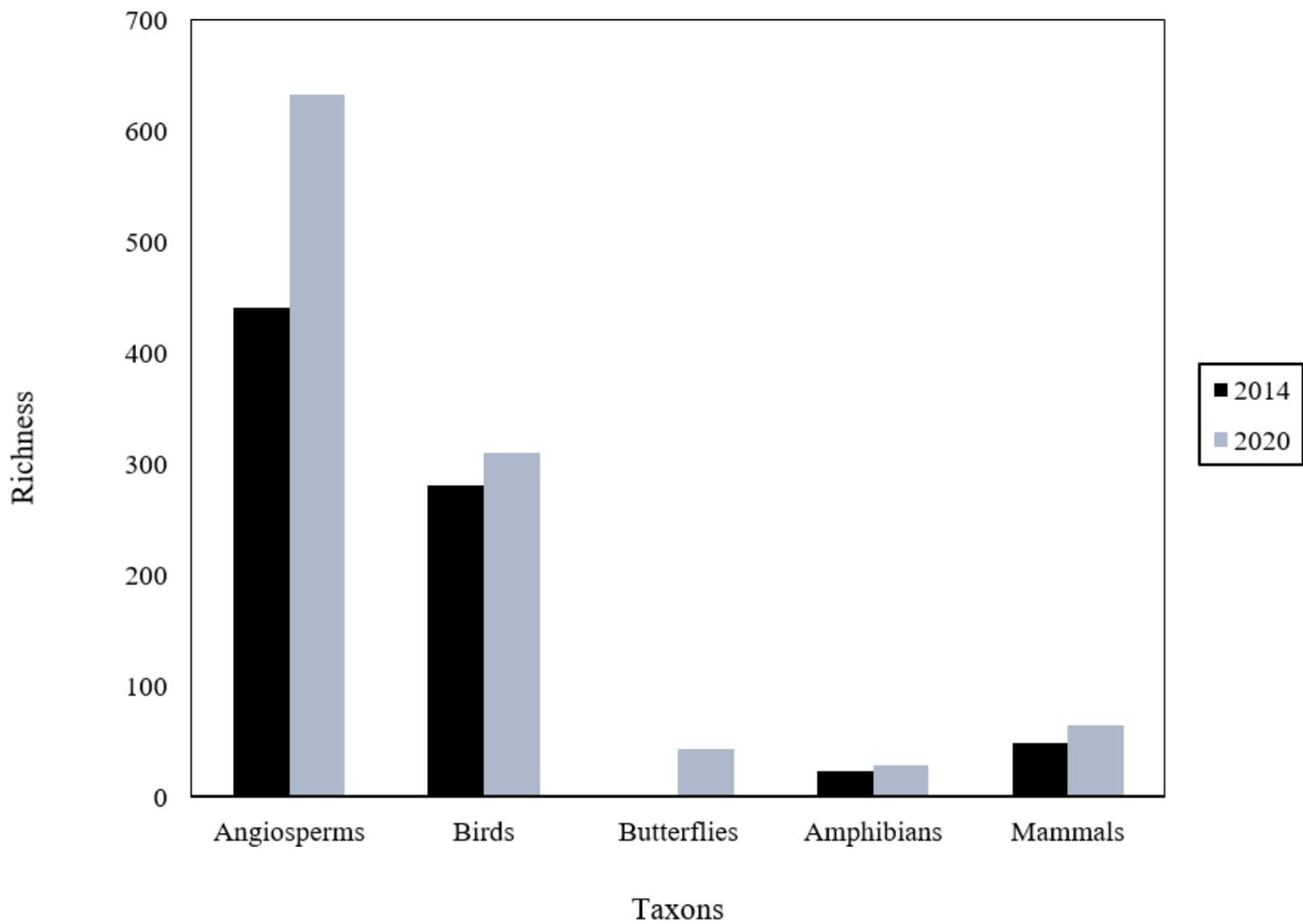


Figure 2

Richness of species belonging to the taxons referenced in the surveys carried out in 2014 and 2020