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Relationship between land use and occupation and potential environmental services in an urban watershed

Joice Machado Garcia[1] **Jocimara Camargo da Silva**[2] **Regina Márcia Longo**[3]

[1]*Master in Urban Infrastructure Systems. Pontifical Catholic University of Campinas – PUC-Campinas, SP – Brasil.*
joiice_garcia@hotmail.com
[2]*Bachelor of Chemistry. Pontifical Catholic University of Campinas – PUC-Campinas, SP – Brasil.*
jocimaracamargo@gmail.com
[3]*PhD in Agricultural Engineering. Pontifical Catholic University of Campinas – PUC-Campinas, SP – Brasil.*
regina.longo@puc-campinas.edu.br

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Abstract

Objective: Identifying potential environmental services associated with different land use and occupation in an urban watershed in Campinas, São Paulo.
Methodology: Spatialization in GIS software of land use and occupation followed by qualitative and quantitative analysis of data with field verification. In this survey, it is assumed that the percentage of probable supply of environmental services in a watershed is exclusively associated to the typology of use and occupation in it.
Relevance: Urban advancement, industrial development and unsustainable agricultural practices have altered the quantity and quality of environmental services provided by natural ecosystems, reflecting changes in land use.
Results: 42.3% of the total area of the basin has conditions of use and occupation of the soil capable of providing component services of the four categories of services. The category of forest fragments is such that the provision of services occurs in greater quantity in the study basin, with a percentage of provision of 88.9%, followed by the category of green area (66.7%), agricultural activity and water resources (63% each) and exposed soil (15%).
Contributions: The diagnosis of ecosystem and environmental services in the Ribeirão das Pedras basin may support Payment for Environmental Services programs and assist in the implementation of management standards for environmental conservation and recovery.
Conclusion: The method applied to survey the potential supply of ecosystem and environmental services by watershed made it possible to understand the relationships between land use and occupation and services offered, as well as the priority areas for action by the municipal authorities.

Keywords: Landscape change. Urban river basins. Geoprocessing. Natural resources. Environmental economic instrument.

Relação entre uso e ocupação do solo e potenciais serviços ambientais em microbacia hidrográfica urbana

Resumo

Objetivo: Identificar potenciais serviços ambientais associados aos diferentes usos e ocupação do solo em uma bacia hidrográfica urbana em Campinas, São Paulo.
Metodologia: Espacialização em software SIG do uso e ocupação do solo seguida de análise qualitativa e quantitativa dos dados com verificação em campo. Neste levantamento, assume-se que o percentual de provável oferta de serviços ambientais em uma bacia hidrográfica se associa exclusivamente à tipologia de uso e ocupação na mesma.
Relevância: O avanço urbano, desenvolvimento industrial e práticas agrícolas insustentáveis têm

alterado a quantidade e qualidade dos serviços ambientais providos pelos ecossistemas naturais, reflexo das modificações do uso da terra.
Resultados: 42,3% da área total da bacia apresenta condições de uso e ocupação do solo capaz de fornecer serviços componentes das quatro categorias de serviços. A categoria de fragmentos florestais é tal cuja provisão de serviços se dá em maior quantidade na bacia de estudo, com percentual de provisão de 88,9%, seguida da categoria de área verde (66,7%), atividade agropecuária e recursos hídricos (63% cada) e solo exposto (15%).
Contribuições: O diagnóstico de serviços ecossistêmicos e ambientais na bacia do Ribeirão das Pedras poderá subsidiar programas de Pagamento por Serviços Ambientais e auxiliar na implementação de padrões de gestão para a conservação e recuperação ambiental.
Conclusão: O método aplicado para levantamento de potencial fornecimento de serviços ecossistêmicos e ambientais por bacias hidrográficas possibilitou o entendimento sobre as relações entre uso e ocupação do solo e serviços ofertados bem como das áreas prioritárias para ação do poder municipal.

Palavras-chave: Mudança de paisagem. Bacias hidrográficas urbanas. Geoprocessamento. Recursos naturais. Instrumento econômico ambiental.

Relación entre uso y ocupación del suelo y servicios ambientales potenciales en una cuenca urbana

Resumen
Objetivo: Identificar los servicios ambientales potenciales asociados con diferentes usos y ocupaciones del suelo en una cuenca urbana en Campinas, São Paulo.
Metodología: Espacialización en software SIG del uso y ocupación del suelo seguido de análisis cualitativo y cuantitativo de datos con verificación de campo. En este levantamiento se asume que el porcentaje de suministro probable de servicios ambientales en una cuenca hidrográfica está asociado exclusivamente a la tipología de uso y ocupación en la misma.
Relevancia: El avance urbano, el desarrollo industrial y las prácticas agrícolas insostenibles han alterado la cantidad y calidad de los servicios ambientales que brindan los ecosistemas naturales, reflejando cambios en el uso de la tierra.
Resultados: El 42,3% del área total de la cuenca tiene condiciones de uso y ocupación del suelo, capaces de brindar servicios componentes de las cuatro categorías de servicios. La categoría de fragmentos de bosque es tal que la prestación de servicios se da en mayor cantidad en la cuenca de estudio, con un porcentaje de provisión del 88,9%, seguida de la categoría de área verde (66,7%), actividad agrícola y recursos hídricos (63% cada uno) y suelo expuesto (15%).
Aportes: El diagnóstico de servicios ambientales y ecosistémicos en la cuenca de Ribeirão das Pedras puede apoyar los programas de Pago por Servicios Ambientales y ayudar en la implementación de estándares de gestión para la conservación y recuperación ambiental.
Conclusión: El método aplicado para relevar la oferta potencial de servicios ecosistémicos y ambientales por cuencas hidrográficas permitió comprender las relaciones entre uso y ocupación del suelo y los servicios ofrecidos, así como las áreas prioritarias de actuación de las autoridades municipales.

Palabras clave: Cambio de paisaje. Cuencas fluviales urbanas. Geoprocesamiento. Recursos naturales. Instrumento económico ambiental.

Introduction

For a long time, the capital market does not consider the impacts of its activities on the environment, assuming an interaction between ecological and economic systems. Natural capital, as it is not recognized and much less accounted for in the cash flow scheme, was defined as an externality, an indirect consequence of the economic activity considered. However, Santos and Silvano (2016) affirm that, while an economy bases its growth on the exploitation of natural resources and the use of these resources is not incorporated in the

economic analysis, the production process can be compromised by the rupture of the ecosystem boundaries.

Ecosystems provide products and services that represent benefits to human beings. These services, called ecosystem services, received wide dissemination in 2005 with the international study entitled Millennium Ecosystem Assessment - MEA, in which services were defined as conditions and processes by which natural ecosystems and the species that comprise them support human life (MEA, 2005). Still according to an evaluation assessment, a human species, although protected from environmental changes by culture and technology, depends on the flow of services, as man acts as an integral part of these ecosystems.

In the literature, the term "ecosystem services" is commonly used as a synonym for "environmental services". However, in the Draft Law on the National Policy for Payments for Ecosystem Services (PL 792/2007), ecosystem services are defined as direct and indirect benefits provided by the functioning of ecosystems and environmental services are those that can favor the maintenance or the improvement of these benefits, through human management actions in natural systems.

In this context, ecosystem, or environmental services, depending on the ecological or economic origin of the approach that one wants to adopt, play a crucial role for human well-being, while they are fundamental for the balance of natural cycles, as they directly contribute and indirectly for human well-being and represent a considerable part in the economic value of the planet (Melo, 2016).

According to Costanza et al. (1997), in a pioneering work on the issue of valuing ecosystem services, in 1995 ecosystems provided US$33 tri in services, of which 63% corresponded to services offered by marine ecosystems, especially coastal systems (US$10.6 tri/year) and 38% of terrestrial environments, which has the largest provider in wetlands and forest systems (US$4.9 tri/year and US$4.7 tri/year, respectively). In updated data, Schuler et al. (2017) calculated an amount of US$125 tri for the year 2011. Hernández-Blanco, Costanza, Anderson, Kubiszewski and Sutton (2020) observed that in the year 2011, the total value of terrestrial ecosystem services in Latin America and in the Caribbean, they corresponded to a total of US $ 15.3 billion/year, with the largest representative in Brazil with US$6.8 billion/year due to the extensive coverage of tropical forest.

However, human interference in natural ecosystems, exploiting and degrading them has caused changes in the quantity or quality of various types of natural capital and, with the undervaluation of the services provided by them, has impacted on human well-being, as well as the costs of local human activities (MEA, 2005). Especially in urban centers, the supply of these services has become scarce, given that urban expansion causes changes in land use and occupation and promotes changes in the functionalities of natural services, especially in benefits for the civil and industrial construction sector (Burkhard, Kandziora, Hou & Muller,

2014).

In agricultural areas, the situation is no less problematic: according to Alves-Pinto et al. (2017), agriculture and livestock are among the main factors of change in land use, the latter being a major factor for the high rates of deforestation. In contrast, in Brazil, landowners are required by law to comply with the Forest Code - Law 12.651/2012 (BRASIL, 2012), which establishes percentages for the preservation of areas covered by native vegetation.

Currently, several economic instruments of an environmental nature are applied in Brazil, such as the Ecological Tax on Circulation of Goods and Services (Imposto sobre Circulação de Mercadorias e Serviços - ICMS), environmental compensation, charging for the use and disposal of water, forest concession systems and forest replacement, environmental easement, credits for greenhouse gas emission reductions, environmental certification and seals, and Payments for Ecosystem Services (PSA) (Young & Bakker, 2015).

The Payment for Ecosystem Services policy emerges, according to Seehusen and Prem (2011), as an economic instrument to deal with the market failure related to the tendency to sub-supply of environmental services, which, in turn, stems from the lack of interest on the part of economic agents in activities for the protection and sustainable use of natural resources. The main objective of a PES scheme is to share with the beneficiaries of the services the costs of carrying out the actions practiced by the providers, it is the internalization of external benefits (Jardim & Bursztyn, 2015).

PES programs appear as an innovation to finance economic, social, and environmental development. The central idea of these programs is to show that the economic issue is not opposed to the environmental issue, so that the environment can also be treated as an environment for economic development (Bolfe, Amaral, Pfitscher, Vicente & Tengaten, 2013).

However, for implementation and proper functioning, PES programs need to define which services are a priority, for which service there is a demand, establish the practices that lead to the generation of this service, identify whether there is a pre-disposition to payment as well as possible payers. The projects will be designed to meet case by case and will include the steps described above, as well as the monitoring of the services provided, to analyze the progress achieved by the project (Távora, Silva & Turetta, 2018).

Given the above, the objective of this study was to identify potential environmental services offered by the Ribeirão das Pedras watershed (Campinas, SP) associated with the different uses and occupations of the soil in the landscape to support the implementation of the Payment for Ecosystem Services Program in this basin.

Methodology

In this exploratory research, the methodological approach consisted of a survey of

geospatial information and subsequent elaboration of maps in GIS software (Geographic Information System) to spatialize and quantify the supply of potential ecosystem services (qualitative and quantitative analysis). At first, visits were made to the field in part of the Ribeirão das Pedras extension to verify the current circumstances of land use and occupation.

Characterization of the study area

The Ribeirão das Pedras sub-basin has an area of 29.3 km² and is located between the coordinates 22º47'10" and 22º52'20" S, and 47º07'15" and 46º02'55" W, being inserted mainly in the municipality of Campinas, São Paulo, while a small portion is located over the municipality of Paulínia. Ribeirão das Pedras is a tributary of Ribeirão Anhumas, which is born in the center of the city of Campinas, has its waters polluted by domestic sewage and industrial effluents and subsequently empties into the Atibaia River, whose waters supply the city of Campinas by 90% (Dagnino, 2007).

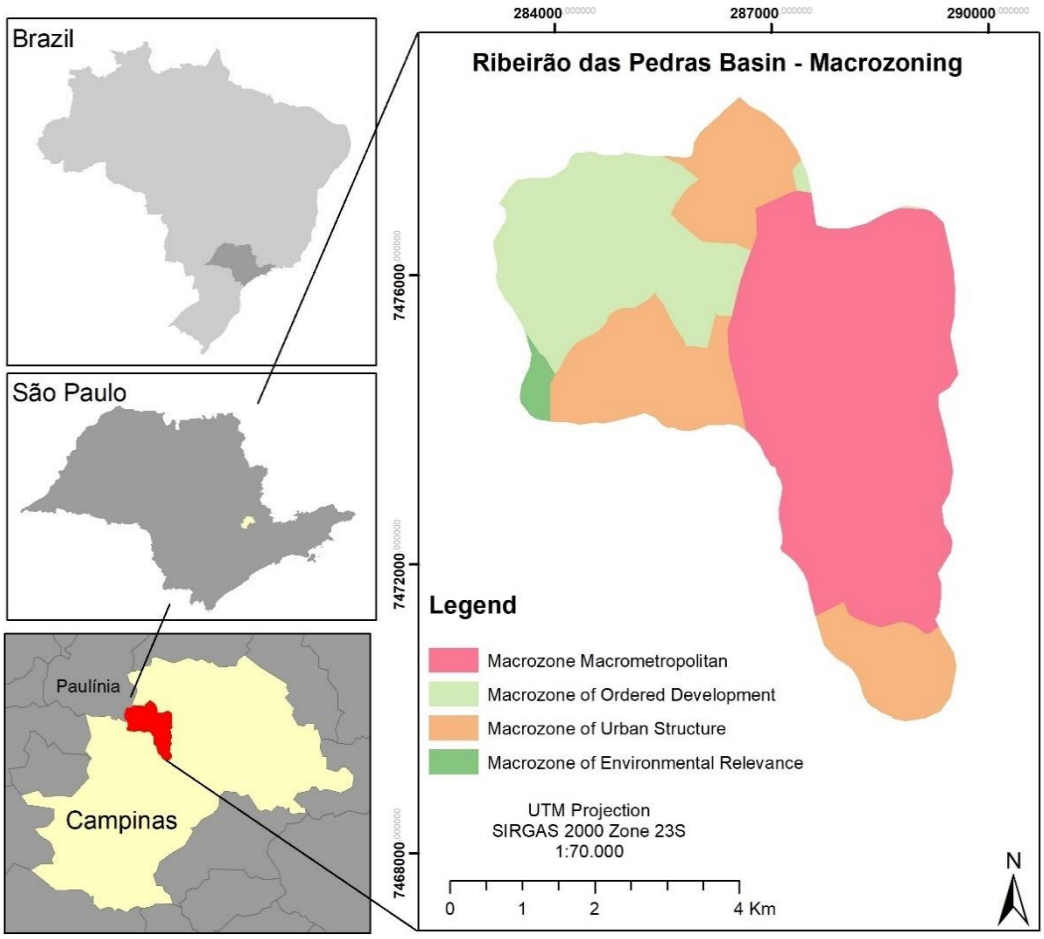
The pedological configuration of the micro-basin under study is predominantly by red latosols, followed by red-yellow latosols and yellow argisols. The first and second have a higher content of iron oxide, a factor that gives them the reddish characteristic, they are deep and porous, allowing good root development in depth. They usually have a slight susceptibility to erosion. The latter are equally deep, with a horizon of clay accumulation and low natural fertility (IAC, 2019).

Along its extension, Ribeirão das Pedras runs through urban areas, which include residential condominiums, rural areas, and preservation areas, to be mentioned part of the Mata de Santa Genebra (Dagnino, 2007). This configuration is because the study area is contained in four categories of macrozoning established by the Master Plan for the year 2018 (CAMPINAS, 2018), shown in Figure 1, which are: (1) Macrometropolitan; (2) Urban Structure; (3) Ordered Development; and (4) Environmental Relevance.

Zones (1) Macrometropolitan and (2) Urban Structure encompasses regions located entirely within the urban perimeter, with the difference that the first is impacted by road structures, equipment and economic activities of regional, national and international scope, suffering direct and indirect influence due to the proximity these structures in the territory that alter socioeconomic, cultural and environmental dynamics; the second, in addition to consolidated areas, is in the consolidation phase.

The Ordered Development zone (3) is located entirely in the rural area and destined to the development of rural and urban uses compatible with the terms of the specific legislation. The Zone (4) Environmental Relevance encompasses a region located, to a greater extent, in the rural zone and which presents environmental relevance and public and private areas that are strategic to environmental preservation and water resources.

Figure 1 - Macrozoning categories in the Ribeirão das Pedras Basin, Campinas, São Paulo



Source: Prepared by the authors (2021).

In the Ribeirão das Pedras basin, flood events are frequent, favored by the subtropical climate of dry winter and hot summer, whose volume of rain in the hottest months (January and February) reaches 245 mm (CEPAGRI, 2019). Souza, Laganá and Chaves (2012) also found that, pluviometric indexes of the municipality in 2012 had shown a considerable increase, which, together with the poorly planned infrastructure system, allow more recurrent flood events.

Land use and occupation and characterization of potential environmental services

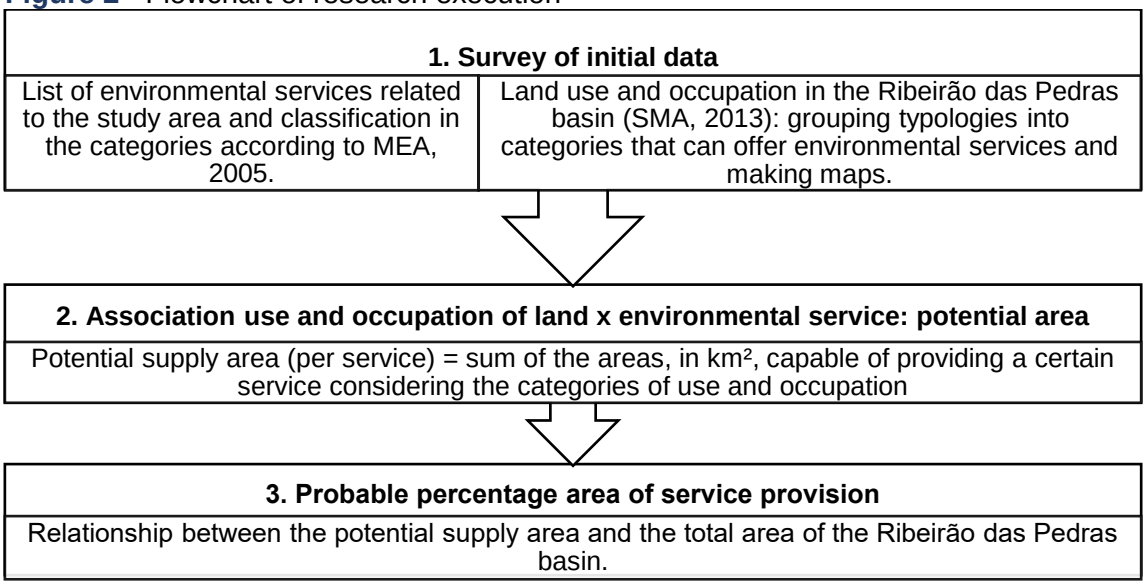
Figure 2 shows the flowchart for the execution of this research regarding the association between land use and occupation and environmental services.

The potential term added to environmental services refers to the independence of demand for the function, or even when the service is the result of a natural process (Longo & Rodrigues, 2017). From the list of environmental services found in the literature, a list of those associated with the landscape of the study area was drawn up. The potential services identified were grouped into four categories, according to the classification proposed by the Millennium

Ecosystem Assessment (MEA, 2005): support services (necessary for the production of the others), provision (supply services), regulation (control of the environment through regulatory characteristics) and cultural services (non-material benefits).

It should be noted that, with the initiative of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Common International Classification of Ecosystem Services (CICES), three categories are currently considered: provision, regulation and cultural services, as it is understood that Support services are characterized as a function of services necessary for the provision of all others (MMA, 2019).

Figure 2 - Flowchart of research execution



Source: Prepared by the authors (2021).

To assess the provision of environmental services in the study basin, a survey was made of the use and occupation of the soil in the Ribeirão das Pedras basin. The diagnosis was made using the "Land Use and Coverage Map of UGRHI 05 (PCJ) - 2013" developed by the São Paulo State Secretariat for the Environment based on a visual interpretation of the SPOT image with a 10 m resolution, for the period 2007 to 2009 (SMA, 2013). The information was updated through field visits in October 2019.

Subsequently, to analyze the potential environmental services offered by the Ribeirão das Pedras basin, different types of land use and occupation were considered able to provide ecosystem and environmental services in four large groups: forest fragments, green areas, agricultural activity, and water resources, according to Table 1.

It should be noted that the type of exposed soil, not covered by Table 1, was also considered for the provision of services, considering only its own typology. The geospatial data used were acquired on the Geoenvironmental platform of the Municipality of Campinas (SVDS, 2019) or adapted from the use and occupation file. The information was treated in a GIS environment (Geographic Information System) using the ArcGIS software.

Table 1 - Categories of land use and occupation and specimens of the study area

Use category	Original classes considered (SMA, 2013)	Examples in the study area
Forest fragments (*FF*)	Forest, reforestation	  a) Mata de Santa Genebra; b) Santa Genebrinha fragment.
Use category	**Original classes considered (SMA, 2013)**	**Examples in the study area**
Green areas (*GA*)	Natural countryside and Urban Green Space - parks, squares, urban agriculture areas and other public areas	  a) Association of Hortas Santa Genebra; b) Hermógenes de Freitas Leitão Filho park.
Agricultural activity (*AA*)	Perennial, semi-perennial, temporary crop and pasture	  a) and b) agricultural area between PUCC and UNICAMP universities.
Water resources (W*R*)	Bodies of water, springs.	  a) Ribeirão das Pedras spring; b) Shopping Dom Pedro containment pond.

Source: Prepared by the authors (2019).

The percentage of probable supply of environmental services by the basin is associated exclusively with the manifestation of the type of land use and occupation in the basin, emphasizing that these areas, in their original conditions, are potential to provide these services. Therefore, a service that can be offered by the four categories described in Table 1 and by the class of exposed soil will have a probable percentage area referring to the sum of expression of these categories in relation to the total area of the basin.

Results and discussion

Land use and occupation in the Ribeirão das Pedras basin

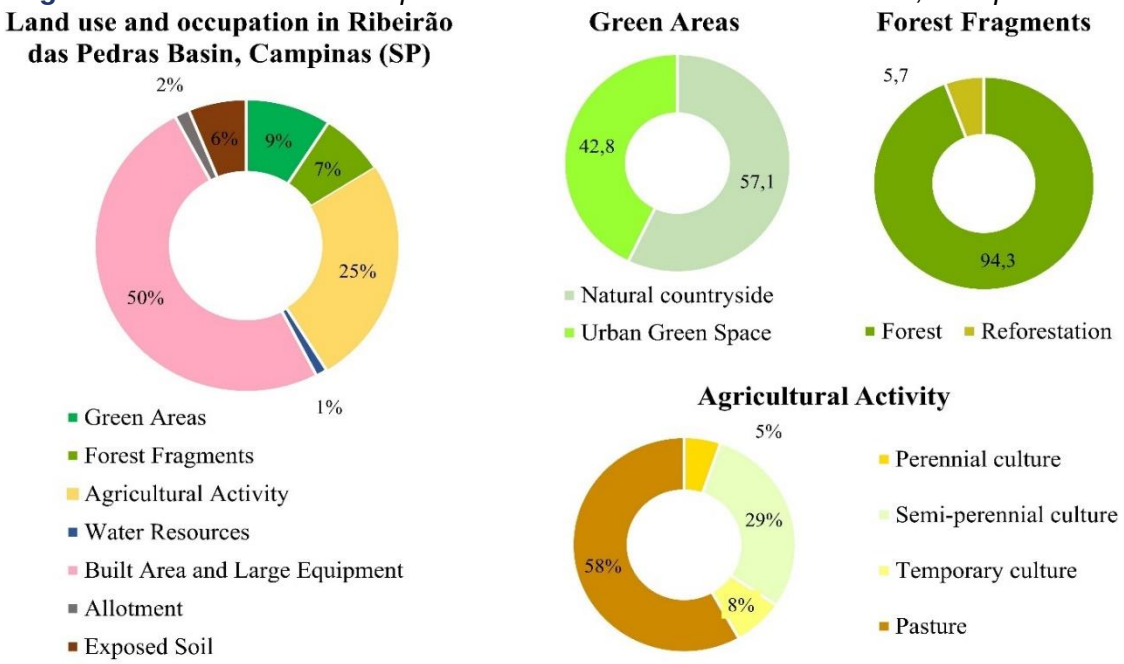
The pressure arising from population and industrial growth currently constitutes impact factors on hydrographic basins, especially in the provision of environmental functions, goods, and services, which may compromise the ecological processes that occur within these areas (Andrade, Romeiro, Fasiaben & Garcia, 2012). The decline in the supply of ecosystem services is problematic since the demand for them continues to grow in the face of population growth and the adoption of current consumption and production patterns (Dominati, Patterson & Mackay, 2010; Bennett, Peterson & Gordon, 2009).

In response to this observation of degradation, in the last decades several institutions and researchers have directed efforts towards research in ecosystem services, seeking to promote the advancement of knowledge and the development of mechanisms capable of answering the main questions on the subject (Seppelt, Dormann, Eppink, Lautenbach, & Schmidt, 2011; Balvanera et al., 2012; McDonough, Hutchinson, Moore & Hutchinson, 2017; Jiang, 2017; Parron et al., 2019).

The impact of land use modification on the provision of ecosystem services has been widely discussed in Latin America, so that changes in the carbon stock, primary production and in the flow and quality of water are recognized. Such changes can be observed by mapping and quantifying the offer of these services, with examples of application cases in Argentina, Colombia, Mexico, Panamá and Chile (Balvanera et al., 2012).

These interventions in the natural environment, exemplified by changes in land use and occupation, when analyzed in the Ribeirão das Pedras basin, allowed the transition from a predominantly rural condition, with specimens of coffee and sugar cane (Damame, Longo & Oliveira, 2019) for an urbanized situation. Figure 3 shows the percentages of land use and occupation in the Ribeirão das Pedras basin, as well as the subcategories analyzed.

Figure 3 - *Land use and occupation in the Ribeirão das Pedras Basin, Campinas*



Source: Prepared by the authors (2019).

About 50% of the entire length of the Ribeirão das Pedras basin is built and with large equipment (institutional, industrial, commercial and sports areas). In addition, there is 2% area for allotment, still in the process of being implemented, mainly located along the Rhodia road, as verified by Jacomazzi (2015). The same author states that the growth vector found in the Ribeirão das Pedras basin was mainly due to the appreciation of the lands close to the UNICAMP and PUC-Campinas university centers. The presence of other institutional and technological centers such as Boldrini' Children Center and Technological Pole strongly influence the urbanization process.

In contrast, when analyzing the extent of forest fragments (forest and reforestation), it appears that the fragments, which are increasingly degraded and dispersed due to anthropic action, occupy an area of approximately 7%. Despite being recognized as major suppliers of ecosystem services to society, the fragments of the Ribeirão das Pedras basin have, according to a study by Silva, Longo, Bressane and Carvalho (2019), low circularity rates and little representativeness of the nuclear area, being subject to the edge effect, capable of compromising their stability and resilience.

When evaluating the typology of use and occupation in the category of green areas (natural countryside and urban green space), it makes up 9% of the total. Within the context of urban planning, the concept of ecological infrastructure captures the role that vegetation, within or near the built environment, plays in the provision of environmental services (Gómez-Baggethun et al., 2013; Calderón-Contreras & Quiroz-Rosas, 2017).

The category of agricultural activity formed by areas of pasture and cultures (perennial,

semi-perennial and temporary) add up to a total of 25%, of which: 58% represent pasture areas, with significant presence of shrubs, formation domain herbaceous and few tree elements, 5% form the areas of perennial culture, especially citrus, 29% semi-perennial, represented mainly by the cultivation of sugar cane and 8% comprise areas of temporary culture.

In the case of water resources, the water bodies in the study basin add up to 0.35 km², or even a percentage around 1%. Gomes et al. (2016), when analyzing Ribeirão das Pedras, whose river gives its name to the basin of this study, found that the anthropic influence on the main course of the river, resulting from changes in natural use and occupation, negatively influences water quality parameters, such as dissolved oxygen, biochemical oxygen demand, phosphorus, and nitrogen total. Complementarily, Garcia et al. (2018) when analyzing the environmental conditions of the springs distributed under an area of the same basin found that, despite being distributed over the urban network and suffering from anthropic pressure, they still presented good quality, thus revealing the possibility of use for supply after due treatment.

The basin also has a percentage of exposed soil of 6%, whose areas have suffered anthropic intervention from earthworks or plowing, making it possible for erosion processes that exposed the soil to occur.

As verified by Etto, Longo, Arruda & Invenioni (2013) by the detailed analysis of land use and occupation in the Ribeirão das Pedras basin, there was a decrease in the percentage of rural use in favor of urban development. According to the same authors, there was a reduction in the extent of forest fragments located in the Northwest portion of the basin and replacement by urban activities and conglomerates, especially in the North and Northeast parts of the basin.

According to Boumanns, Ambrosio, Romeiro & Campos (2010) the conditions of land use are closely related to ecosystem services, so that their conservation does not allow the provision of these services. Polasky, Nelson, Pennington & Johnson (2012) point out that changes in land use or management can change not only the provision, but also the value of ecosystem services. This finding can be seen, for example, by the study by Zhou, Sun, Zang and Wang (2017), in the city of Daqing, China. These authors found that wetlands and water bodies were the two main types of land use with the greatest contributions to the value of environmental service. Even so, with the urbanization process, the use of empty land has increased, while the percentage of cultivable areas, water bodies and pasture areas has decreased, with a reduction of 11.95% in the value of the ecosystem service in the period from 1995 to 2015.

Damame, Longo and Oliveira (2019) note that the loss of the rural area in river basins, as verified for the study basin, causes damage to society, since they can provide services, such as food supply, infiltration of water in the soil and recharge of the groundwater. In

Ethiopia, however, in disagreement with what was seen previously for the reduction of agricultural areas, Gashaw et al. (2018), in a study in the Andassa basin, verified the significant expansion of these, as well as of built areas and a decrease in forest cover during the period from 1985 to 2015. This transaction of use and occupation, marked by the reduction of forest cover, enabled the value of ecosystem services from US$26.83 x 10^6 in 1985 to US$22.58 x 10^6 in 2000 and US$21.00 x 10^6 in 2015, with an expected value of US$ 15.25 x 10^6 for 2045.

The decrease in forested areas is still a reality in some countries, being verified in Thailand (Arunyawat & Shrestha, 2016), in Bangladesh (Akber, Khan, Islam, Rahman & Rahman, 2018), in Mexico (Martínez et al., 2009) and Nepal (Sharma et al., 2019). Quijas et al. (2019) noted that, in Latin America, although they are associated with the provision of various services such as climate regulation and water supply, forested areas have increasingly been converted into pastures for livestock activities, for the establishment of large-scale commercial crops and for the development of infrastructure for tourism and industry. However, several other countries have tried to adapt their conditions of use and occupation to conserve the environmental services offered mainly by forested and/or arable areas and to reconcile with the desired rural productivity. For this, more appropriate cultivation techniques and government incentives are used to direct the greater offer of these services.

Yuan, Li, Yang & Wang (2019), in a study in the Shangzou district, China, found an increase in the value of ecosystem service in response to a policy of converting agricultural land into forests. In the United States, the increase in the extent of forested areas in the face of an incentive policy led to significant increases in the production of wood (18%), biomass carbon (8%), and helped in the conservation of species (Lawler et al., 2014). In Spain, the implementation of the Common Agricultural Policy led to a specialization of the agricultural system and favored the afforestation of abandoned lands through government subsidies (García-Llamas et al., 2019).

In the Brazilian territory, one of the strategies taken to increase agricultural productivity and, at the same time, increase environmental services concerns the Crop-Livestock-Forest Integration System. This system, according to Franchini, Balbinot, Debiasi & Sichieri (2015), can provide a higher rate of carbon sequestration, conservation of biodiversity and improvement of soil, water and air quality when compared to other non-integrated systems. Other agroforestry system techniques have also been applied by Southeast Asian farmers and smallholders in the Ecuadorian Andes (Fedele, Locatelli, Djoudi & Colloff, 2018).

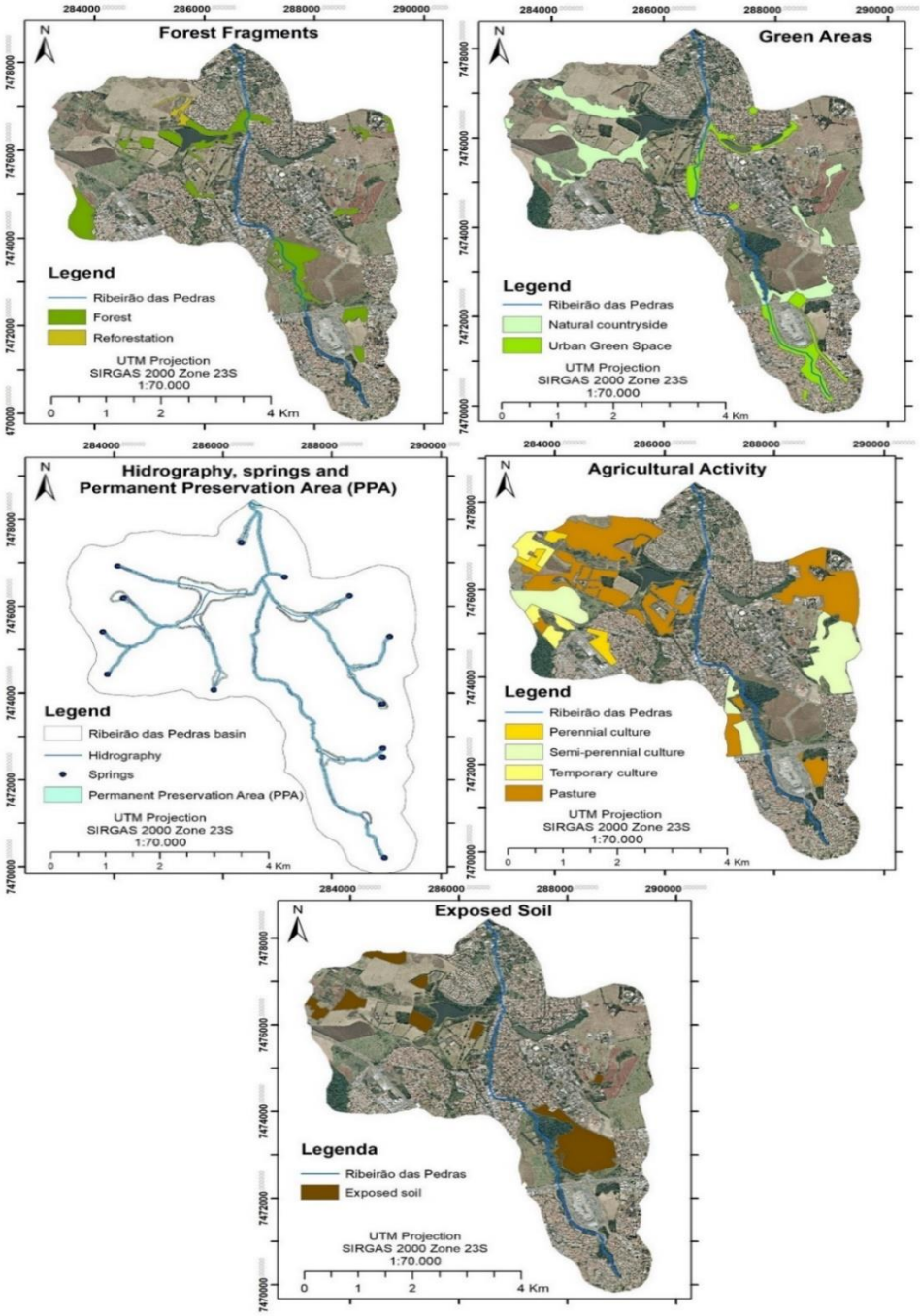
Potential environmental services offered by the Ribeirão das Pedras basin

The discussion of land use and occupation allows an understanding of its influence on the supply and quality of potential environmental services. Understanding which services are

provided by these uses and occupation is essential so that the actions of decision makers are directed to priority areas (IUCN, 2013). In the urban environment, temporal studies of ecosystem services linked to changes in land use and land cover changes can assist in understanding the effects of urbanization on the level of expansion and densification under local biophysical and socioeconomic conditions (Dobbs, Hernández-Moreno, Reyes-Paecke & Miranda, 2018).

Figure 4 shows the spatial distribution of the categories of use and occupation previously mentioned as potential suppliers of environmental services.

Figure 4 - Spatial distribution of areas providing potential environmental services



Source: prepared by the Authors (2019).

Revelli (2017) states that urban forests and, in general, urban green spaces, are an important component of the urban ecotone and provide not only environmental, but also economic and social benefits. For Elmqvist et al. (2015), the environmental services provided by the existence of green areas in urban environments, configure those captured by monetary metrics, such as removal of local pollutants, carbon sequestration and storage, regulation of water flow, and even those not accounted for, as correlation with longevity, stress reduction and mental health, which translate into greater well-being for the population.

Calderón-Contreras and Quiroz-Rosas (2017) in the study of urban ecosystem services in Mexico City observed that the quality, quantity, and diversity of green infrastructure can produce different services, which in turn have different implications for the construction of urban resilience.

In a complementary way, Jenerette, Harlan, Stefanov and Martin (2011) found that temperature regulation in urban environments has been one of the many reasons why urban forest expansion programs have become popular. The authors cite several cities in the United States (Los Angeles and San Francisco in California; Phoenix, Arizona; Chicago in Illinois) and Berlin in Germany as examples of an initiative in planting trees to alleviate urban temperature.

Aquatic ecosystems, on the other hand, provide extremely important services, such as water supply, food supply and recreation. For Karabulut et al. (2016) water-related services receive greater attention because they are vital to life and are easily appreciated by human beings. Grizzetti, Lanzanova, Liquete, Reynaud & Cardoso (2016) point out that most ecosystem services related to water can be verified by people and quantified, such as water and leisure provision, but some, especially regulation and maintenance services, are less evident. However, for the correct use and sustainable management of water resources, all ecosystem services must be considered.

In the analysis of the areas of agricultural expression, Rebello and Turetta (2017) point out that agroecosystems offer the greatest opportunity to increase the provision of environmental services through the adoption of conservationist practices. Agroecosystems, combined with non-conventional techniques, such as permaculture and other sustainable systems, contribute strongly to the maintenance and greater offer of the desired services (Doherty, 2015). The adoption of these practices emerges as a response to contain the unwanted effects, called disservices, of an industrialized and conventional agriculture, citing pollution and depletion of groundwater, erosion (with possible desertification) and silting, introduction of invasive pests, nitrogen loading and phosphorus to water courses and consequent aquatic eutrophication (Swinton, Lupi, Robertson & Hamilton, 2007).

Another bias points to urban agriculture in view of the rapid development of urban centers and the need for food production for an equally growing population. The services provided by these areas go beyond the supply of food and fiber, also encompassing water

management, soil regeneration, nitrogen fixation, biological control, and socio-cultural values. Through the supply of foods usually treated organically, urban agriculture can also contribute to improving human health due to changes in the diet of the population that uses it (Clinton et al., 2018).

Antoniazzi (2018) notes that the literature hardly addresses the issue of agricultural areas as the sole provider of services, being often treated in situations of combined land use uses, as is the case of the forest-agriculture scheme of the Payment for Environmental Services in New York and the crop-livestock-forest integration programs in Brazil.

With respect to the soil as a service provider, Vezzani (2015) highlights that the soil is part of the biogeochemical cycles, regulating the amount of nutrients. Still, the author emphasizes the role of soil in the water cycle, allowing its drainage and storage and as a filtering element, by retaining and degrading toxic compounds from the atmosphere. Adhikari and Hartemink (2016), when analyzing the period from 1975 to 2014, found that of all published studies that relate soil and ecosystem services, 41% were related to regulation services, such as CO_2 sequestration, followed by 34% referring to provision services (on agricultural land, for example).

From the list of environmental services found in the literature, exemplified by the excerpts described above, it was possible to elaborate Table 2, in which the main services related to the categories of land use and occupation are presented, as well as the potential area of supply by analyzed service.

Table 2 - Potential environmental services by category of land use and occupation **(Continua)**

Category	Potential services	GA	FF	AA	WR	ES	Supply area (km²)
Regulation	Moderation of extreme events (floods, landslides)	x	x	x	x		12,4
	Climate regulation	x	x	x	x		12,4
	Carbon sequestration and storage	x	x	x	x	x	14,2
	Removal of air pollutants	x	x	x	x		12,4
	Water infiltration into the soil	x	x	x		x	13,9
	Groundwater recharge	x	x	x		x	13,9
	Regulation of water flow	x	x	x	x		12,4
	Water and air purification	x	x	x	x		12,4
	Contaminant purification		x		x	x	4,2
	Erosion and silting control	x	x		x		5,1
	Biological pest control and disease vectors		x				2,0
	Ecological corridor component	x	x		x		5,1
	Pollination and seed dispersal		x				2,0
	Shelter and reproduction of ichthyofauna				x		0,4
	Shelter and reproduction of wild fauna		x				2,0
Provision	Raw material, fibers, wood, medicinal plants	x	x	x	x		12,4
	Food (food security)		x	x	x		9,7
	Water (water security)		x	x	x		2,4

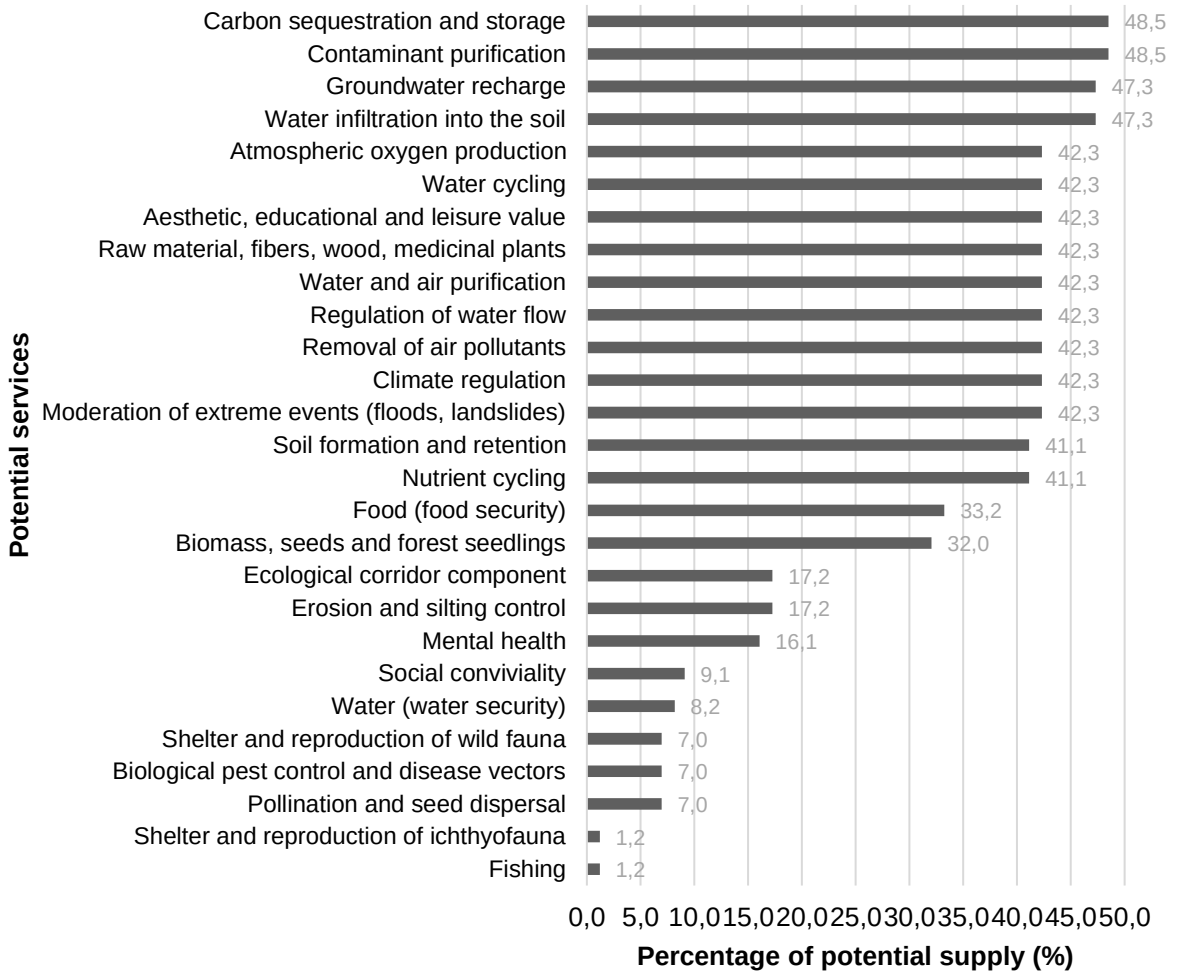
(Conclusão)

	Biomass, seeds and forest seedlings		x	x			9,4
Cultural	Aesthetic, educational and leisure value	x	x	x	x		12,4
	Mental health	x	x				4,7
	Social conviviality	x					2,7
	Fishing				x		0,4
Support	Nutrient cycling	x	x	x			12,0
	Water cycling	x	x	x	x		12,4
	Atmospheric oxygen production	x	x	x	x		12,4
	Soil formation and retention	x	x	x			12,0

OBS: GA: green areas - 2.66 km² in the basin, FF: forest fragments - 2.04 km², AA: agricultural activity - 7.34 km², WR: water resources - 0.35 km², ES: exposed soil – 1.81 km².
Source: Prepared by the authors (2019).

As shown in Table 2, the category of forest fragments is the one whose service provision occurs in greater quantity, being able to offer a total of 24 services out of the 27 listed, corresponding to a percentage of provision of 88.9%. The category of green area succeeds the first, which may offer 18 listed services, or 66.7%. The ability to provide services by the categories of agricultural activity and water resources appears in third place, with a potential offer of 17 out of 27 being verified, totaling 63%. Finally, there is the category of exposed soil, whose provision allows the provision of 4 services: carbon sequestration and storage, water infiltration in the soil, groundwater recharge and biological effluent purification. In a complementary way, Figure 5 was elaborated, which allows a better visualization of the percentage of service offered by area.

Figure 5 - Probable percentage area of service provision



Source: Prepared by the authors (2019).

Of the 27 services analyzed, 2 services (carbon sequestration and storage and contaminant purification) had the maximum potential to be offered, they are likely to be provided by the five groups of land use and occupation listed, totaling a percentage of area, per service, of 48.5%.

In the Brazilian territory, activities aimed at sequestrating, conserving, maintaining, or increasing carbon stocks, whether through forest maintenance or reforestation actions, are provided for in the Forest Code, and within the scope of Payment for Ecosystem Services programs, these projects are relevant facing climate issues (Brasil, 2012). Although forests are recognized as sinks of atmospheric carbon, it is not only in the vegetal composition that it is possible to store carbon. The existence of carbon in the soil at different depths also contributes to its capture and stock and helps to increase fertility (Almeida, 2019).

In addition to the carbon sequestration service, the soil is also capable of purifying contaminants to reduce their concentrations in its structure. Martins, Leitão and Henriques (2019) state that several organic compounds and metals can be removed through particle retention, adsorption, transformation, and biodegradation.

As the soil, the water resource also has a self-cleaning capability. According to Lopes and Magalhães Junior (2010), the morphometric dynamics of a hydrographic basin, such as drainage network and density, form factor and circularity index, can favor the self-cleaning of the polluting load of a lotic water body. Still, Salla, Pereira, Alamy Filho, Paula and Pinheiro (2013) affirm that the capacity of self-purification can be a natural option, although slow, to reestablish the water balance in the face of conditions of financial scarcity for the treatment of water bodies.

In a complementary manner, two other water services (groundwater recharge and water infiltration in the soil) showed a percentage of provision for 47.3% of the basin area. Such data is extremely important, given that, mainly in urban centers, the disordered exploitation of this resource ends up reducing its quantity and quality. Oliveira, Silva, and Mello (2020) affirm that the reduction of availability is linked to the decrease of water infiltration in the soil, and consequently access to drinking water becomes difficult.

Yet, 42.3% of the total area of the basin has conditions of use and occupation of the soil capable of providing component services of the four categories described by MEA (2005), such as support services (ex: water cycling), provision (ex: raw material, wood, and medicinal plants), regulation (ex: removal of air pollutants) and cultural (aesthetic and leisure value). In contrast, two services (fishing - cultural; shelter and reproduction of ichthyofauna - regulation), whose existence is due to the unique presence of water resources, are those that have the least potential for supply, because, in the study basin, the category of water resource corresponds to the smallest area, being 1.2% of the basin area.

Conclusion

Recognizing the ecosystem services and the resulting benefits can contribute to a greater weight regarding the importance of preserving and maintaining hydrographic basins. The spatialization of categories of land use and occupation which provide environmental and/or ecosystem services made it possible to understand the priority areas for action by the municipal authorities, with the aim of making it possible or increasing their supply in the study basin.

It should be noted the existence of a Payment for Ecosystem Services program in the municipality of Campinas, instituted by Municipal Law N°15.046 of July 23, 2015. Although it has defined PES subprograms that aim to promote sustainable development and encourage maintenance and expansion of services related to carbon, soil, water, socio-biodiversity, and others of a cultural nature, until now only PES-Water is regulated by decree. The emergence of the carbon sequestration service as having the greatest potential for supply in the basin serves as a diagnosis of prioritization of actions within the scope of municipal management.

The method applied to survey potential supply of services by watershed can be applied in other basins in the city of Campinas to assist in their environmental management.

Through the maps presented and in line with the consulted literature, it was found that the use and occupation of the soil influences the quality/quantity of services offered. Because the Ribeirão das Pedras basin has a large urban extension, due to the drop in the percentage of agricultural and forested areas, the remaining forest and green areas constitute areas of relevant importance for the protection and conservation of biodiversity, also contributing to the improvement of quality of human life and the environment.

It is also necessary to understand the dynamics of urban ecosystems and the flow of goods and services provided by them so that it is possible to have a technical and scientific basis at the time of urban planning based on sustainability.

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