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Socioenvironmental influences of the sustainable management of Cascavel river watershed

Influências socioambientais do manejo sustentável da bacia hidrográfica do rio Cascavel

Influencias socioambientales del manejo sostenible de la cuenca hidrográfica del río Cascavel

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Abstract

The city of Cascavel-PR has shown, over the years, an accelerated population growth in the urban area, thus increasing environmental problems and exposing the deficiencies in public policies for basic sanitation and the environment. In order to minimize the environmental impacts of these areas, a correct management of the watershed is necessary. The objective of this study was the analysis of how population growth in the watershed region has impacted its disposition as an integral part of the environment and the society within its limits. Through that, establishing quantitative and qualitative parameters of the different aspects of the watershed and its impacts within the city. In order to verify these characteristics, two different analyses were used, relating the morphometric characteristics of the Cascavel river's watershed, with the data of the Secretaria de Planejamento e Urbanismo - SEPLAN. The city population, according to the last Census, was around 286.172 inhabitants. The sewage service attends about 83% of the population and the pavement with asphalt in the roads reaches close to 93%. However, although public policies have improved the quality

of life of the population, there was a lack of maintenance and a significant amount of siltation near the municipal lake. This region is critical for the watershed because it is its source and the presence of impacts of this order may not only affect the watershed, but also damage the sustainable development of society and the environment during the next years.
Keywords: Morphometric analysis; Hydrography; Urban planning.

Resumo
A cidade de Cascavel-PR tem mostrado, ao longo dos anos, um crescimento populacional acelerado na área urbana, aumentando os problemas ambientais e expondo as deficiências nas políticas públicas de saneamento básico e meio ambiente. A fim de minimizar os impactos ambientais dessas áreas, é necessário um gerenciamento correto da bacia hidrográfica. O objetivo deste estudo foi analisar como o crescimento populacional na região da bacia hidrográfica impactou sua disposição como parte integrante do meio ambiente e da sociedade dentro de seus limites. Através disso, estabeleceu parâmetros quantitativos e qualitativos dos diferentes aspectos da bacia hidrográfica e seus impactos dentro da cidade. Para verificar essas características, foram utilizadas duas análises diferentes, relacionando as características morfométricas da bacia hidrográfica do rio Cascavel, com os dados da Secretaria de Planejamento e Urbanismo - SEPLAN. A população da cidade, de acordo com o último censo, era de cerca de 286.172 habitantes. O serviço de esgoto atende cerca de 83% da população e o pavimento com asfalto nas estradas chega perto de 93%. No entanto, embora as políticas públicas tenham melhorado a qualidade de vida da população, houve falta de manutenção e uma quantidade significativa de assoreamento perto do lago municipal. Esta região é crítica para a bacia hidrográfica porque é a sua fonte e a presença de impactos desta ordem pode não só afetar a bacia hidrográfica, mas também prejudicar o desenvolvimento sustentável da sociedade e do meio ambiente durante os próximos anos.
Palavras-chave: Análise morfométrica; Hidrografia; Planejamento urbano.

Resumen
La ciudad de Cascavel-PR ha mostrado, a lo largo de los años, un crecimiento poblacional acelerado en el área urbana, aumentando los problemas ambientales y exponiendo las deficiencias en las políticas públicas de saneamiento básico y medio ambiente. Con el fin de minimizar los impactos ambientales de estas áreas, es necesario una correcta gestión de la cuenca hidrográfica. El objetivo de este estudio fue analizar cómo el crecimiento poblacional en la región de la cuenca hidrográfica impactó su disposición como parte integrante del medio ambiente y de la sociedad dentro de sus límites. A través de ello, estableció parámetros cuantitativos y cualitativos de los diferentes aspectos de la cuenca hidrográfica y sus impactos dentro de la ciudad. Para verificar esas características, fueron utilizadas dos análisis diferentes, relacionando las características morfométricas de la cuenca hidrográfica del río Cascavel, con los datos de la Secretaría de Planificación y Urbanismo - SEPLAN. La población de la ciudad, según el último censo, era de unos 286.172 habitantes. El servicio de alcantarillado atiende cerca del 83% de la población y el pavimento con asfalto en las carreteras llega cerca del 93%. Sin embargo, aunque las políticas públicas han mejorado la calidad de vida de la población, hubo falta de mantenimiento y una cantidad significativa de sedimentación cerca del lago municipal. Esta región es crítica para la cuenca hidrográfica porque es su fuente y la presencia de impactos de este orden puede no solo afectar a la cuenca hidrográfica, sino también perjudicar el desarrollo sostenible de la sociedad y del medio ambiente durante los próximos años.
Palabras clave: Análisis morfométrico; Hidrografía; Planificación urbana.

1. Introduction

The city of Cascavel, state of Paraná, Brazil, over the years, has shown an accelerated population growth in the urban area, increasing its environmental issues, and exposing the deficiencies in public policies regarding the environment and basic sanitation. Tosin (2005) explains that several sources of the Cascavel river are found in the urban area of the city, as well as the federal highway, the BR 277, which crosses the basin region. In this way, the author warns that in cases of accidents with dangerous cargo, several environmental damages could come to fruition as well as a clear risk to the water quality and provision to the region.

Therefore, it is noteworthy that the relationship between urban and river areas results in several environmental problems, such as the soil sealing. Hence, it is possible to observe an intense urbanization process in the Cascavel municipal lake region, the source of the Cascavel river, aggravating the environmental conditions of the basin (Tosin, 2005).

The watershed can be defined as an area of natural water abstraction from the rainwater which, through the flow, converges to a single point of exit (Finkler, 2012). Likewise, Tucci (1993) defines the watershed as being the total surface area responsible for the abstraction of the rainwater, as an aquifer or a river system collects its water thereafter.

Consequently, the hydrological cycle is closely linked to the physical and biotic characteristics of a watershed, and may influence the infiltration process, the amount of water produced as outflow, evapotranspiration, and surface and subsurface runoff (Tonello 2005). Fioreze et al. (2010) also explain that to determine the water availability of a watershed, some factors must be considered, as the natural ones (climatic and physiographic) and the human influence.

Villela and Mattos (1975) argue that the physical characteristics of a watershed are extremely important to the understanding of its hydrological behaviour. Therefore, as of those characteristics are obtained, it is possible to analyse aspects related to drainage, topography, and geology, and being able to understand the local environmental dynamics (Christofoletti, 1970).

Fioreze et al. (2010) affirm that, to study the hydrological behaviour of a hydrographical basin, to develop its physical characterization is of major importance, so to obtain information about a watershed, it is necessary to obtaining the drainage area, main river length, drainage density, watershed slope and compactness ratio.

Therefore, according to Krupek (2010), these aquatic ecosystems are essential for supplying, recreation and as source of food, however, they suffer the impacts caused by anthropic actions, being visible the degradation increase of the watersheds. Human influence on watersheds, such as removal of vegetation cover, soil exposure to rainfall, erosion, and the interaction between urban and river environments tend to intensify impacts on watershed systems, increasing surface waterproofing (Lima, 2011).

Silva et al. (2016) points out there is a growing demand for natural resources and physical space in developing cities, hence, the streams and rivers' banks, which are Brazil's "Áreas de Preservação Permanente – APP" (Permanent Preservation Areas - PPA), are then occupied without any kind of planning and in a disorderly way, thus causing various environmental and urban problems, such as floods, discharge of polluted effluents into the hydric bodies, landslides, and others. In the same vein, the authors further explain the importance of analysing the environmental impacts on hydric resources in urban areas, to carry out an assertive planning for the society development in the physical space.

Consequently, the impacts caused by hydrographic basins, whether large or small, affect the rivers' courses and the region's wildlife, thus destabilizing the environment (Almeida et al., 2010). Therefore, the urbanization process of cities and their metropolitan regions has led to an increase in the consumption of water resources (with more water abstraction than replacement capacity), energy demand and soil pollution (inadequate waste disposal), thus generating an increase in pollution and greenhouse gases emissions (Hogan, 2016).

To minimize the environmental impacts of these areas, a correct management of the watershed is necessary. Therefore, a system of water supply, waste treatment and collection should be implemented in rural and urban areas (Águas Paraná, 2011). As of, water quality, soil types, amount of local vegetation are the image of activities performed by people living in the watershed. Therefore, the river water quality is dissolved by the industrial activity and rural properties that can cause effects from the source of the river to its mouth (Águas Paraná, 2011).

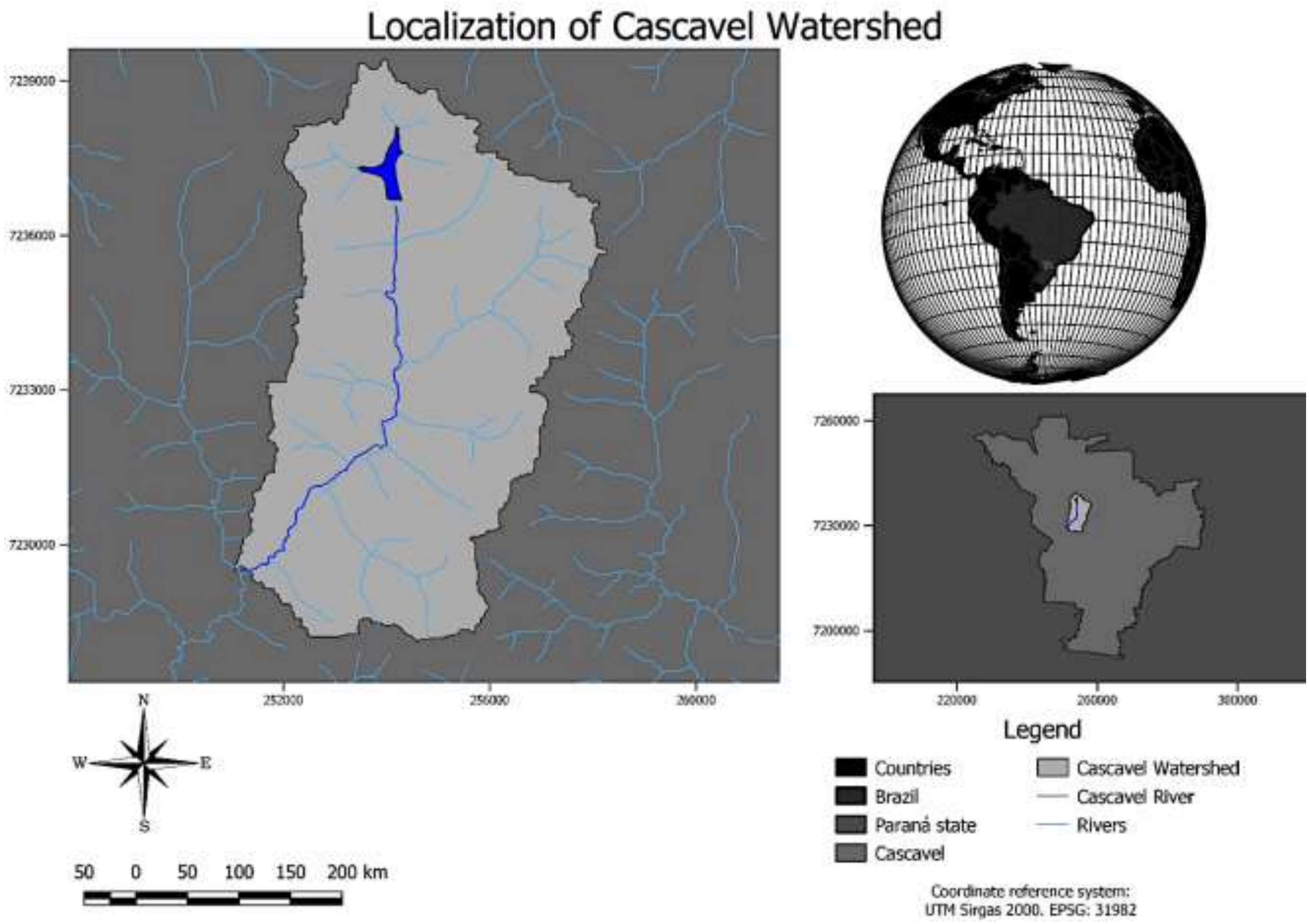
With this, there is a fundamental instrument for the planning and development of cities, the Master Plan, which defines the policies of urban expansion while protecting the natural resources and the well-being of the population, thus enabling the organized growth of cities. However, Villaça (1999) explains that there is no consensus among authors (engineers, town planners, real estate entrepreneurs, landowners, etc.) about what a master plan is, however, the author defines the master plan as a plan which, based on physical, social, economic, political, and administrative analysis of the city and its region, presents a set of proposals for the future development of the city, municipality and region, and these proposals are approved by law.

So, based on the great importance of the Cascavel watershed, the objective of this study was the analysis of how population growth in the watershed region has impacted its disposition as an integral part of the environment and society within its limits. The objective is to establish quantitative and qualitative parameters of the different aspects of the hydrographical basin and its impacts in the city of Cascavel – Paraná, Brazil.

2. Methodology

The research area was the Cascavel watershed (Figure 1), which has a drainage area of 117.50 km^2 located between the parallels 24º 32 'and 25º 17' of South Latitude and the 53º 05 'and 53º 50' West longitude meridians located in the western region of the State of Paraná, presenting topographic, maximum, and minimum dimensions of, respectively, 767 and 580 meters.

Figure 1. Detail of the Cascavel river basin.



Source: Authors.

The Cascavel river's source is located in the Municipal Lake region which presents an accelerated urbanization, aggravating the environmental conditions of the watershed, even being an area of environmental preservation. As a result of the region urbanization around the Municipal Lake, the number of allotments, the population density, the lack of drainage and the pollution of the region's watercourses increased, alongside the production of solid waste that eventually went to the urban drainage system. In order to verify the impact of the region's accelerated urbanization and how these impacts may have affected the environment and society in general, two different analyzes were made relating the morphometric characteristics of the Cascavel river's watershed, alongside the data of the *"Secretaria de Planejamento e Urbanismo – SEPLAN"* (Urban Planning Department), of Cascavel.

The computation from Cascavel watershed morphometric technical features was executed after presented method acting by Porto et al. (1999), which consists of the sequential calculation from the following methods.

a) Form Factor and Conformation Index;
b) Drainage Density;
c) Compactness Coefficient;
d) Decline of the watercourse (S1, S2, S3);
e) Concentration Time;
f) Surface runoff

The Form Factor (Ff) is the reason between the balanced watershed width ($\bar{L}$) and the watershed axis length (L). Furthermore, in case the watershed area it's known it's possible to replace the balanced width, as described by the following equation 1.

$$F_f = \frac{\bar{L}}{L} \rightarrow \text{being } \bar{L} = \frac{A}{L} \rightarrow F_f = \frac{A}{L^2} \quad (1)$$

Conformation Index (Fc) is the relation between the watershed area and de its axis lengths squared. It is determinate by the same equation from Form Factor (Ff), nevertheless in spite of the resemblances in math terms, the conformation index takes after the basin area to a square, whose sides are the same width to axial basin length (L). The conformation Index display a demonstrates a potential production of flood peaks (the closer to 1 for this) (equation 2).

$$Fc = \frac{A}{L^2} \quad (2)$$

The Drainage Density (Dd) express the relation among the total water course length from a watershed (La) and its area (A), according to the equation 3.

$$Dd = \frac{\sum L_a}{A} \quad (3)$$

Compactness Coefficient (Kc) is the relation of the watershed perimeter and a circumference from a circle with the same area as the watershed, therefore relating by the equation 4.

$$Kc = \frac{P_{watershed}}{P_{circle}} \rightarrow Kc = \frac{P_{watershed}}{\left(\frac{2\pi\sqrt{A_{watershed}}}{\sqrt{\pi}}\right)} \rightarrow Kc = 0.28\ \frac{P}{\sqrt{A}} \quad (4)$$

To measure the water's course declivity, it's divided in three proceedings that search to determine a water's course declivity average in a way to establish a standard to study the water's runoffs. The first proceeding, Slope based on Extremes (S1), it's obtained dividing the total difference between the runway elevation (ΔH) by the horizontal extension from the water's course in two points (L1) as presented by the equation 5.

$$S1 = \frac{\Delta H}{L_1} \quad (5)$$

Weighted Declivity (S2) is basically a water course longitudinal graphic profile and define a line in a way that the comprehended area among this line and the abscissae's axis. Following this data, apply the equation 6 for the S2 calculus.

$$S2 = \frac{2A_2}{(L_2)^2} \quad (6)$$

The third method, equivalent constant slope (S3), takes in matter the longitudinal profile stretches (Li) and the constant declivity in which stretch (Di), equivalent to the described by the equation 7.

$$S3 = \left[\frac{\sum L_i}{\sum\left(\frac{L_i}{\sqrt{D_i}}\right)}\right]^2 \text{ were } Di = \frac{Hi}{Li} \quad (7)$$

Surface Runoff (Q) is given by the relation between the surface runoff coefficient (C), precipitation intensity (im) and the watershed total area (A), divided by a humidity adjust coefficient, being 360 (equation 8) in this case.

$$Q = \frac{C\, i_m\, A}{360} \quad (8)$$

The concentration Time (tc) was calculated by the SCS-Cinematic method which, is the most indicated method for medium and large sizes watershed (Bigger than 500 ha). It is the division of the basin in equal smaller pieces, that are calculated the speed (V) and distance (L) in which one of them. After that, it's summarized and applied in the next equation 9.

$$t_c = \frac{1000}{60} \sum \frac{L_i}{V_i} \quad (9)$$

The social and environmental impacts were verified by the analyzes of maps elaborated for the City Master Plan, established in the years 2006 and 2016, made available by SEPLAN as the obtained data by the research of Tosin (2005). Out of this parallel and the in loco photographic register, from the city lake, it was possible to establish a data base in a way to compare such impacts to a social and environmental level.

3. Results and Discussion

In order to verify the urbanization process of Cascavel, two fronts of analysis were used. The first was based on population data from the city of Cascavel. According to the last Census, conducted in 2010, the population of the city of Cascavel was around 286.172 inhabitants, an increase of 16.63% since the Census made back in 2000, where the population was around 245.369 inhabitants. The population growth is described in the Table 1.

Table 1. Populational Census of Cascavel - Paraná, Brazil, from 1950 to 2010.

Census (year)	Population (inhab.)	Variation (%)
1950	404	-
1960	39.598	9701.49
1970	89.921	127.08
1980	163.459	81.78
1990	192.990	18.07
2000	245.369	27.14
2010	286.172	16.63

Source: IBGE (2017).

In addition, based on data from Tosin (2005) and data from the 2010 Census, it was possible to establish a comparison between the populations living in the urban and rural part within the limitations of the Cascavel watershed area, as presented in Table 2. It is estimated that around the year 2000, the population living within the watershed region was around 32,321 inhabitants, while in 2010 it was around 44,074 inhabitants.

Table 2. Populational Comparison between different regions of the city of Cascavel from 2000 to 2010

Population	2000	2010
Total	245.369	286.172
Urban	228.673	266.835
Rural	16.696	19.370
Watershed area	32.321	44.074

Sources: Tosin (2005); Brazilian Institute of Geography and Statistics (IBGE, 2017).

The second method was the analysis of historical photographic data, taken from the Google Earth software, which presents satellite images of the region from 1984 to 2016. The Figure 2 presents a series of those images, dating backwards from 1984, 1992, 2000, 2008 to 2016.

Figure 2. Photographic record of the urbanization process of Cascavel-PR. Highlight: hydrographic basin of the Cascavel river.

Source: Google Earth (2018).

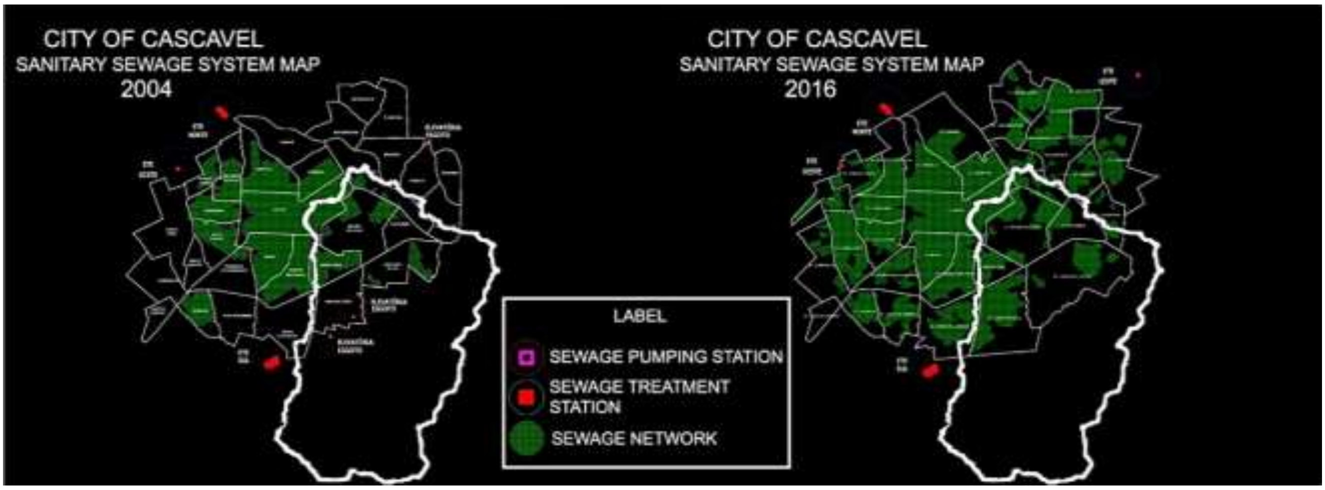
This accentuated urbanization process resulted in different impacts, mainly those related to the soil usage and occupation and its socio-environmental reflexes. In order to adapt to the growing population and their demands, several public services and characteristics related to infrastructure were implemented to increase the population's quality of life.

According to SEPLAN data, in 2004, when the surveys used for the implementation of the master plan were made to be effective in 2006, the sewage network service covered only around 44.17% of the population. The coverage jumped to around 83% in 2016, according to data collected for the current master plan. Figure 3 presents the comparative data for the sewage network service between the two years (Cascavel, 2016).

The city pavement in 2004 was composed of 71.6% asphalt, only 3.7% paved as uneven stone, 0.9% of low-cost pavement and a large portion, corresponding to 23.8% of areas not pavemented. In 2016, on the other hand, 92.9% of the roads were already pavemented with asphalt, 0.9% irregular stone, 0.5% low-cost paving and only 5.8% of the roads had no pavement, according to the comparative shown in Figure 4 (Cascavel, 2016).

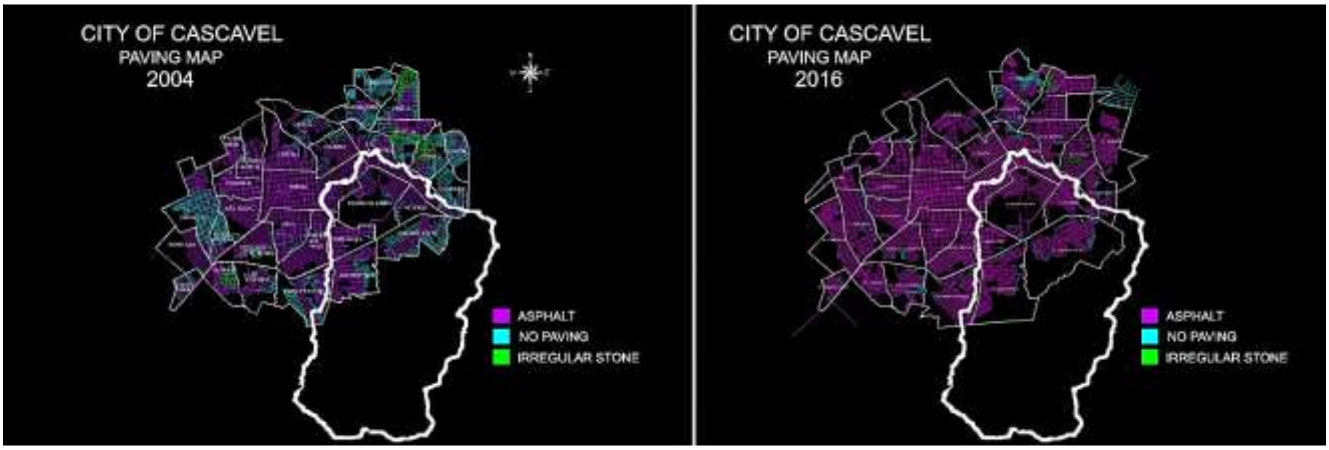
SEPLAN provided only one map corresponding to the garbage collection in the municipality of Cascavel, referring to the year 2004 (Figure 5). The garbage collection, in most of the city, is done 3 times a week. In the city center, the collection is mostly done daily at night. Within the watershed region, prevails the daytime collections 3 times a week and, in a small portion, it is a nocturnal collection on a daily basis (Cascavel, 2016; Tosin, 2005).

Figure 3. Comparative map of sanitary sewage between 2004 and 2016. Highlight: hydrographic basin of the Cascavel river.



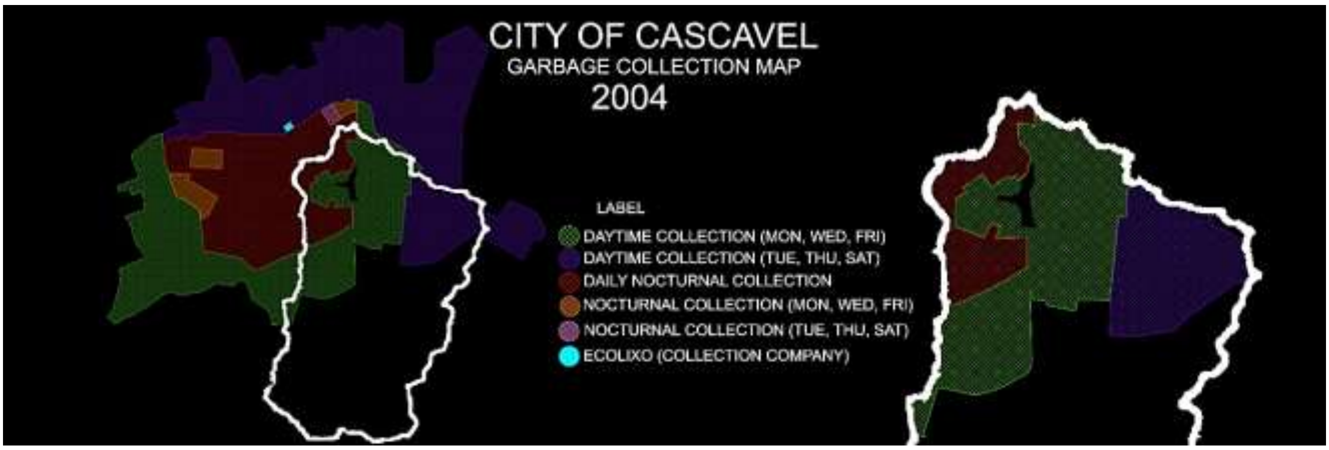
Source: Cascavel (2016).

Figure 4. Comparative map of paving between 2004 and 2016. Highlight: hydrographic basin of the Cascavel river.



Source: Cascavel (2016).

Figure 5. Map of garbage collection in the urban perimeter of the city of Cascavel. Highlight: hydrographic basin of the Cascavel river.



Source: Cascavel (2016).

In addition to public services and infrastructure, the environmental changes caused by the urbanization process and the sustainable management of natural resources were also observed. Table 3 shows the results of the morphometric characteristics of the Cascavel watershed.

Table 3. Morphometric characteristics of the Hydrographic Basin of the Cascavel river – Cascavel, Paraná, Brazil.

Morphometric Characteristics	Results
Drainage Area (km²)	50.20
Perimeter (km)	40.38
Water's course total length (km)	51.69
Form Factor	0.4406
Conformation Index	0.4406
Drainage density (%)	1.03
Compactness coefficient	1.5957
Declivity - S1 (m/m)	0.01455
Declivity - S2 (m/m)	0.01562
Declivity - S3 (m/m)	0.010657
Total outflow (m³/s)	703.97
Concentration time (min)	42.15

Source: Authors.

Tosin (2005) presents similar data for the morphometric characteristics of the watershed. Although the urbanization process did not generate significant impacts on the physical characteristics of the basin, it is verified that the social and environmental impacts, especially in the vicinity of the Municipal Lake, are significant, as verified by the photographic records made in the Municipal Lake region of Cascavel.

During a visitation held on September 09, 2018, were identified some points there were demonstrating lack of maintenance of the urban drainage devices in the Paulo Gorski Ecological Park. The Park represents a particular point of interest because it is the beginning of the Rio Cascavel basin, and there are reports, in other academic papers, about the siltation occurring at that point (Detofol et al., 2017).

The water level lowering due to sediment transportation is one of the effects of sedimentation. Pereira and Baracuhy (2008) explain that the deposit of inorganic substances compromises the water quality. Mukai (2003) states that soil pollution may be a consequence of the urbanization process and may be characterized by flash floods that carries sediments to the watercourses.

There are many urban drainage devices discharging their flows into the lake. Figure 6 shows an occluded drain with leaves, which means that the drainage device is not functioning properly, since a large amount of its section is filled.

Figure 6. Leaf accumulation inside a drain, located on the Municipal Lake vicinity.

Source: Authors.

Figure 7 shows a double-tube concrete culvert operating with only half of its projected capacity, due to the accumulation of sediments inside one of its cavities.

Figure 7. Sediment Accumulation inside a double-tube concrete culvert located near the Municipal Lake.

Source: Authors.

4. Conclusion

In the last decade, public policies have brought improvement in the population quality of life.

Basic sanitation and infrastructure services have improved significantly in the Cascavel municipality, when compared to data from previous master plans.

There is a lack of maintenance and a significant amount of silting in the vicinity of the Municipal Lake. This region is critical for the watershed because it is the region of its source and the presence of environmental impacts of this order may not only affect the watershed as a whole, but also damage the sustainable development of society and the environment during the next years.

It is of an urgent matter to implement sustainable management of water resources strategies, so as to enable the correct maintenance of the watershed and ensure the preservation of the environment, through maintenance and correct control of soil usage and occupation in the region.

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