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Temporal analysis of land use and cover in an urban watershed in the city of Londrina / PR

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ABSTRACT

This study analyzed the changes in land use and cover of Ribeirão Cambé watershed (Londrina /PR), between 1975 and 2015, and evaluated how these changes impact on the runoff volume. For the classification of soil use and cover were used satellite images from the Landsat series (1-MMS, 5-TM and 8-OLI), which were acquired for free from the INPE/DGI website. The classification was made by the SPRING program, it was used to establish four themes of soil use and cover: urban, dense vegetation, underbrush and exposed soil. The CN value was obtained from the CN tables of SCS for urban and suburban basins. Morphological characterization of Ribeirão Cambé basin indicates low probability of flooding. Using satellite images, it was possible to affirm that significant changes happened in the soil use and cover of this basin, having grown 150% in 40 years, with the highest growth rates occurring in the first analyzed decades, 42%, 33%, 18% and 11%, respectively. Thus, the conclusion is that changes in soil use and cover in river basins reflect on the runoff, evidentiating the need of discussion about urban planning and flood control.

KEY-WORDS: Multitemporal analysis; Land use and cover; Urbanization; Remote sensing.

INTRODUCTION

According to IBGE (2015), the demographic census pointed that around 84% of the entire Brazilian population lived in cities in 2010, while in 1950 this number was 36%. This intense growth of the urban population occurred, in many municipalities, with no adequate planning, resulting in an accelerated and disordered urbanization process, in other words, lacking urban infrastructure.

This situation is ensured by the data from National Household Sample Survey (PNAD) of 1992 and 2017 for private households considered permanent urban in Brazil, which shows that in 1992 the population who lived in cities was 75.59% and from this percentage 79.59% of the households had water supply, 45.50% sewage collection system and 61.95% garbage collection. In 2014, 85.06% of the population was urban, of which 84.67% of the covered households had water supply, 56.91% sewage collection system and 79.30% garbage collection (SIDRA, 2016b; IBGE, 2016c).

The urban growth changes the soil use and occupation, these changes influence the hydrological behavior of the involved basins. The modifications on the vegetal cover, these being natural or artificial, have direct influence on the production of sediments and on the water quality, but above all, on the volume rise and on the runoff velocity increase. As consequence, it causes the magnitude and frequency of floods to increase, as well as the overflow of rivers and lakes, therefore causing damage to the environment and disturbance to the population.

In the city of Londrina/PR, particularly in the Ribeirão Cambé watershed, the urban floods are happening in a higher frequency and intensity, these due to the soil sealing, inefficient drainage system or the Igapó Lake siltation. Those factors become more evident during intense rains, when flooding and overflows occur in the Igapó Lake (I, II, III e IV).

The soil sealing, caused by the development of the urban environment, alters how the surface runoff of the rainwater occurs. The volume that was retained by vegetation and infiltrated the soil before the urbanization, now flows through the impermeable areas and through canals and ducts, which increase the rainwater runoff capacity. Thus, the water reach faster the macro-drainage canals (natural or artificial), what may cause floods.

To prevent flooding, structural and non-structural measures could be adopted. As an example, it is possible to cite the master plan for urban drainage as a non-structural measure highly recommendable, such as the urban zoning.

Hydrological models are frequently used as a support for handling water resources and for the prediction of the impacts caused by changes in the soil use and occupation. Those models, generally, describe the hydrological processes in a modulated and mathematical manner and its parameters are adjusted based on the basin data (morphological characteristics).

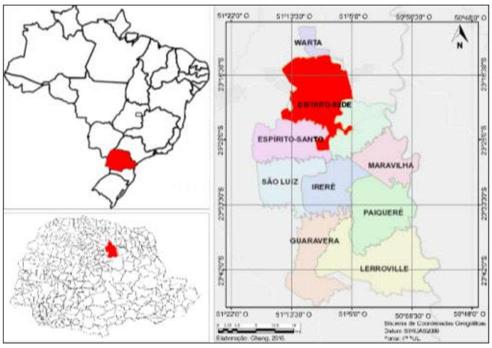
Therefore, this work aims to evaluate the relation between the growth of urban areas and the increase of the surface runoff volume in the river basin of Ribeirão Cambé in Londrina/PR. For improving the evaluation of such changes in the environment, the annual maximum daily rainfalls were studied and analyzed to verify the equation for the intense rain highly diffused in Londrina. Given the last intense rain occurrences in the city that caused the overflow of the Igapó Lake, it was sought to verify the characteristic quantities (intensity, duration and frequency) of these rainfalls.

This article is intended to morphologically characterize the Basin of Ribeirão Cambé, in addition it will estimate the soil use and cover of the basin between the years of 1975 and 2015 using satellite images in order to obtain the values of the Curve Number (CN) for the analyzed years.

STUDY AREA

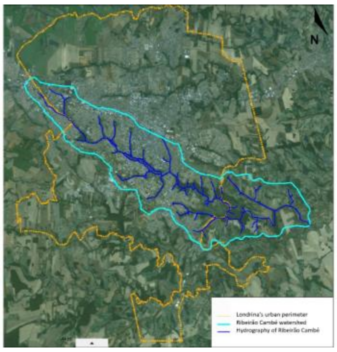
The municipality of Londrina is located in the North region of the Paraná State (Latitude 23° 18′ 37″ South and Longitude 51° 09′ 46″ West). According to the Brazilian Institute of Geography and Statistics (IBGE/2015), the area of the municipality is of 1.652,57 km². Figure 1 shows the municipality location.

Figure 1. Location of the urban limits of Londrina-PR.



Source: Authors.

Figure 2. Location of watershed Ribeirão Cambé in Londrina/PR.



Source: Authors.

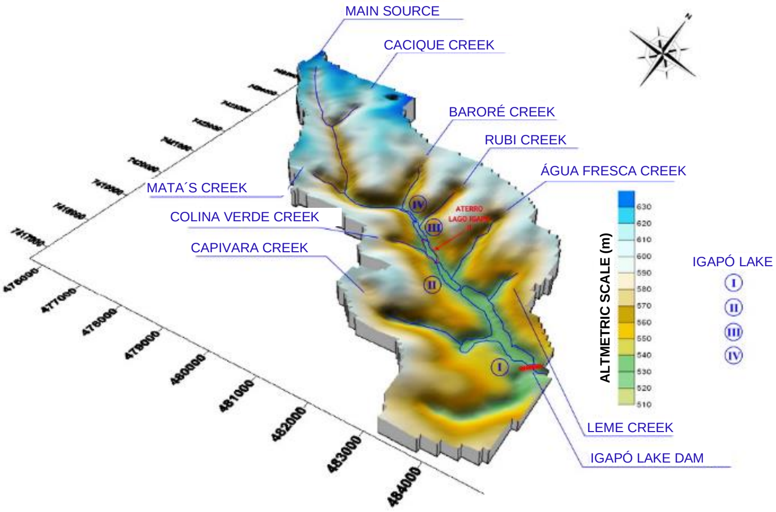
According to Vizintim et al. (2015) the drainage system of Londrina is dense and well distributed and it is composed by the following watersheds: Jacutinga, Lindoia, Cambé, Limoeiro, Cafezal and Três Bocas. The creeks in the municipality are all perennial and pointed in the direction west-east, once they have as mouth the Tibagi River (FARIA, 2005). Generally, the hydrography of Londrina has suffered intense impacts of its urbanization, among these impacts there are the canalization of some rivers and the anthropization of natural sources. Figure 2 represents the location of the Ribeirão Cambé watershed in Londrina city.

The Ribeirão Cambé originates in a plateau of 600m of altitude (Latitude 23°17′06,5′′ S and Longitude 51°14′00,0″ W), in the interchange of the roads Londrina/Cambé – São

Paulo/Curitiba, in a path of 21,5 kilometers (pointed northwest-southwest) of homogeneous relief, until it flows to the Ribeirão Três Bocas. The region of the Hydrographic Basin of Ribeirão Cambé shows a variation of altitude between 400 and 630 meters in in the form of steps, being divided in three strata: Upper, Middle and Lower (TAGIMA e TERABE, 2005).

According to Tagima e Terabe (2005), the upper stratum of Ribeirão Cambé covers an extesion of 11 kilometers, isohypses varying between 630 and 520m and area of approximately 3.900 hectares. The upper stratum has its source in Cambé and covers part of the urban center of Londrina, constituting the four lakes that form the Igapó Lake, as shown in Figure 3.

Figure 3. Delimitation of the area of study.



Source: SANTANA, CAVALARO E DE ANGELIS, 2012. (Values for the level curves obtained using the topographic chart Sf.22-Y-D-III-4, page Londrina. Elaborated by DALBÓ & CAINZOS, 2011).

The Ribeirão Cambé has in its totality 25 affluents, two of them are between the source and the lake IV, six of them in the extension of the Igapó Lake complex (I, II, III e IV) and after the Igapó Lake I barrage, it receives 17 more affluents.

According to the classification made by Barros et al. (2015), the classes of soils that are predominant in Londrina are: Latosol Red, Eutroferric, Dystroferric and Alumino-ferric; Eutroferric Red Nitossol and Dystroferric; Chernosol and Lithosol.

MATERIALS AND METHODS

Initially there was conducted a hydrographic delimitation of the basin and a data assessment of the morphological characteristics, such as: drainage area, perimeter and extension of the main course, declivity of the basin and spot elevation.

In the second stage, there was conducted a multitemporal estimation of the use and cover of the soil for the 40 years analyzed (1975 to 2015) using the satellite images, with the percentual quantification of the areas established for each theme (water, urbanization, dense vegetation, ground vegetation and exposed soil). The following stage consisted in the definition of the Curve Number (CN), of the SCS model, for different conditions of use and cover of soil, these obtained in tables generated using weighted average.

The values of the analyzed parameters for the geomorphological characterization of the basin were obtained based on the delimitation of the hydrographic basin and on the thematic map of the hydrography of the Londrina/PR municipality. The limit of the hydrographic basin of Ribeirão Cambé was set using topographic charts of the Directorate of Geographic Service of the Department of Engineering and Communications of the Ministry of Army (DSG). The chart that was used to set the limit of the basin for the analysis is found on the page SF.22-Y-DIII-4 MI-2758/4 (ITCG, 2016). For the acquisition of data about the basin was used the program AutoCAD of Autodesk.

In this study, it was a applied a temporal succession of images from the satellites LANDSAT relative to the last forty years, from 1975 to 2015, using 10 years intervals, intending to estimate the area occupied by distinct uses of the soil. For the classification of soil use and cover the program SPRING 5.3 was used. For the development of this stage, the following sequence was adopted: (1) selection of satellite images (1975-2015); (2) georeferencing the images; (3) generation of masks; (4) color composition (RGB); (5) Classification of land use and occupation; (6) retroanalysis and (7) obtaining the land use and land cover map (1975 to 2015).

The vectorial and matricial data imported to SPRING were the hydrographic basin limit and the plant containing the lots in the city of Londrina/PR, which was georeferenced in CAD, such that it was used to georeferentiate the satellite image.

The images from the LANDSAT multispectral sensors were freely obtained in the site of Image Catalog of the Imaging Division of the National Institute for Space Research (DGI/INPE, 2016). It was sought to use images from the same periods of the year, but the main caution was with the presence of clouds in order to avoid them. Table 1 presents the satellites used, the dates of passage and multispectral bands used.

Table 1. Satellite images used

Date		Satellite (sensor)	Orbit/point	Bands
1975	August 28th	LANDSAT-1 (MSS)	238/076	B4, B5, B6
1985	May 4th	LANDSAT-5 (TM)	222/076	B3, B4, B5
1995	May 4th	LANDSAT-5 (TM)	222/076	B3, B4, B5
2005	April 9th	LANDSAT-5 (TM)	222/076	B3, B4, B5
2015	December 17th	LANDSAT-8 (OLI)	222/076	B4, B5, B6

Source: AUTHORS.

In the software SPRING, the stage of image acquistion was proceeded by the georeferentiation of the satellite images using the plants of Londrina/PR. Thereafter, there was producted the masks regarding the delimitation of the hydrographic basin of Ribeirão Cambé, this process was executed using the importation of basin polygon vector file to the software.

After that, it was performed the images digital processing (PDI), by which the false-color compositions were elaborated (RGB). This treatment consists in selecting three spectral band and atributing to each of these a primary color (R=Red, G=Green and B=Blue), as well as adjusting the histogram to enhance the visual contrast.

This way, for the LANDSAT-2 MSS sensor, it was defined the composition B6-Red, B5-Green and B4-Azul, for the LANDSAT-5 TM sensors it was defined B5-Red, B4-Green and B3-Blue. For the LANSAT-8 TM sensor, the performed composition was: B6-Red, B5-Green and B4-Blue.

To ascertain the interpretation of the data obtained using SPRING there were performed visits in field, these observing the soils uses and occupations in the proximities of the mouth and exutory (the barrage of Igapó Lake I). In the case of the previous dates (1975, 1985, 1995 e 2005), these were analyzed using the images of the aerial photography assessment that are disponible in the Londrina City Hall website and in the Google Earth tool called Historical Images (2005).

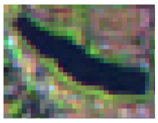
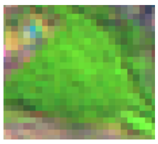
In SPRING, it was performed the supervised classification of the images applying the classifier algorithm Maximum Likelihood (MAXVER), with an acceptation threshold of 100%. There was executed the segmentation of the analyzed images by the process of growing regions, which implied that each image had different values of Similarity and Pixel Area, in order to convey more veracity to this classification stage. During this training stage, in the image were selected and grouped the regions of same soil use and occupation.

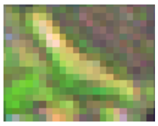
Thus, thematic maps were elaborated in respect of the multitemporal evolution of soil use and occupation for the analyzed years, 1975, 1985, 1995, 2005 and 2015, of which all the previous described procedures were performed.

To standardize the thematic classes for the 40 years analyzed a unique and with generic character caption was developed, this way easing the integration of information and also the quantification and qualification of the changes that occurred in the area. The interpretation of the images was performed using the analysis of texture (roughness impression), color, shape, location and context (Table 2). There were created five themes or classes to classify the images, four of these are related to soil use and cover (urbanization, dense vegetation, ground vegetation and exposed soil) and the other is related to water.

Based on what was exposed in the previous paragraphs, the multitemporal classification of soil use and cover was fulfilled using old and actual images. Thereby, it was possible to analyze the evolution of soil use and cover by comparing the images and themes quantification.

Table 2. Mapping unities

Mapping Unity	Interpretation characteristic standards in the land	Interpretation characteristic standards in the image	Example in a colored composition
Water	Lakes and streams	Color pattern: Dark blue Texture: Smooth Shape: irregular	
Urbanized	Built areas, including multi-floor building, lots with residential or industrial constructions. These inserted in regions with high impermeabilization rate.	Color pattern: brown/black Texture: ruff Shape: irregular	
Dense Vegetation	Bottom Valley Vegetation Area, in other words, dense vegetation zones, whose characteristic is a high permeable cover.	Color pattern: green Texture: rough Shape: irregular	

Mapping Unity	Interpretation characteristic standards in the land	Interpretation characteristic standards in the image	Example in a colored composition
Ground Vegetation	Area whose use is of cultivated zones, pastures and lands of ground vegetation, with soil permeability lower than of vegetation	Color pattern: light green Texture: slightly rough Shape: slightly irregular	
Exposed Soil	Area lacking vegetal covering	Collor pattern: light pink Texture: smooth Shape: Regular/irregular	

Source: AUTHORS.

To obtain the coefficient CN (curve number) to use it in the SCS Method, it was necessary to use proper tables of the method. These initiate the soil classification based on its characteristics as infiltration capacity, use, cover and average condition of preceding humidity, classifying in groups A, B, C and D, such tables can be found easily in the literature, especially in Porto; Setzer, (1979); Porto, (1995) and Tucci et al, (1993), consulted for this study.

As Tomaz (2011) clarifies, the classification of the four types of soil is easy to understand, since it describes the characteristics of the soil presented by the SCS Method. The parameter CN also depends on another factor, which is the minimum capacity of soil infiltration which varies, according to McCuen (1989), from 7.62 to 11.43 mm/h for group A soils; from 3.81 to 7.62 mm/h for group B soils; from 1.26 to 3.82 mm/h for group C soils and from 0 to 1.27 mm/h for group D soils.

The average conditions of soil precedent humidity are of great importance, since the soil could be found in conditions such as normal (II), very dry (I) or very humid (III), therefore corrections are made in the tabled values considering situations that differ from the average. The tables for the obtainment of CN number refer to normal conditions, there are tables that provide adjustments for other humidity conditions (I e III) to be represented (TUCCI, 2009).

The applicability of the SCS method for basins with different types of occupations makes it the most used method to the obtainment of surface runoff. Thus, in the case of basins with different uses and occupations (mixed basin), it is required to use weighted average for the obtainment of the average CN, adopting as weighting the areas correspondent to each value of CN (TUCCI, 2009). The expression used for a mixed basin is shown in Equation 1.

$$\mathrm{CN_m} = \mathrm{p} \cdot \mathrm{CN_p} + \mathrm{i} \cdot \mathrm{CN_i} \qquad (1)$$

Where: $\mathrm{CN_m}$ is the curve number for mixed occupation; p is the permeable fraction of the basin; $\mathrm{CN_p}$ is the curve number of the permeable portion; i is the impermeable fraction of the basin ($\mathrm{i} = 1 - \mathrm{p}$); and $\mathrm{CN_i}$ is equals to 95 (admitted value).

Based on the previously presented elements values of CN were created for the mapping unities established in the classification performed in SPRING, in other words, for urbanization themes, dense vegetation, ground vegetation and exposed soil.

The soil group, according to the classification made by SCS, due to geological characteristics group C is the one that is the most adjusted to Londrina. It occurs due the fact that the local soil is highly porous and presents notable laterite soil characteristics, it means that the soil presents a high percentage of clay and variable layer depth (CAVALCANTE et al., 2007). The previous average humidity condition considered for the soil was condition II, in it the humidity field capacity of the soil corresponds to the average situation.

Using the established themes in the classification of soil use and cover, the values of CN were determined by a weighted average based on Table 5 of soil group and precedent humidity (Table 3).

Table 6. Evaluation of CN based on soil use and cover.

Soil Use or Cover	Evaluation	Average CN
Urbanized	20% Commercial and office zones; 60% Residential lots with 65% of impermeable area; 10% Paved and with rainwater drainage; 10% Parking lots, roofs, viaducts, etc.;	92
Dense Vegetation	25% Woods or areas with poor cover; 75% Forests: well covered;	72
Ground Vegetation	20% Cultivated zones: no soil conservation; 30% Cultivated zones: with soil conservation; 30% Pasture or land in poor condition; 20% Meadow in good condition;	81
Exposed Soil	100% Wasteland in good condition;	74

Source: AUTHORS.

RESULTADOS E DISCUSSÕES

The Ribeirão Cambé basin, in the municipality of Londrina/PR, is of 2nd order considering the Sthraler Method, what indicates that it presents few branches, has an area of 29.95 km² and perimeter of 27.14 km. The main canal length canal is of 11.25 km with a total drainage system of 24.09 km. The drainage density (D_d) is of 0.80 km/km² (Equation 4), indicating that the basin has a fine drainage capacity, it is an important factor since it indicates how developed is the drainage system of a basin.

The compactness coefficient (k_c) observed was 1.39, according to Villela and Mattos (1975), a minimum coefficient equals to the unit would correspond to a circular basin and with more tendency to flood, therefore a more elongated basin its value would be substantially greater than 1 and consequently presenting lower risks of flooding. Thus, it is possible to interpret that this basin presents a medium probability of flooding, since its compactness coefficient value is between 1.25 and 1.50.

The Ribeirão Cambé basin has a shape factor (k_f) of 0.24, which is considered low, indicating that the basin presents an elongated and narrowed shape, thus less susceptible to flooding, since there is a lower possibility of intense rains covering simultaneously all its extension. Likewise, the circularity index of the basin (IC) is of 0.51, this value indicates that the runoff is moderated and there is a low probability of rapid floods. The other parameters are presented in Table 4.

Given that the relief presents strong influence on the hydrological factors, the declivity of the main course is of 0.71% (altitude of the main course mouth is 600m) since the runoff velocity and, consequently, the concentration time of the basin are determined by the land. According to the IBGE (2015B), this hydrographic basin may be considered flat, given its declivity in lower than 3%. The characteristics of this relief are to present horizontal or smooth surface, where the unevennesses are small (IBGE, 2015b).

Table 4. Morphological parameters of the Ribeirão Cambé basin.

Parameter	Symbol/ Equation	Unit	Results
Area	A	km²	29.95
Perimeter	P	km	27.14
Main canal length	L	km	11.25
Courses total length	L_t	km	24.09
Main course declivity		%	0.71
Maximum altitude	-	m	630
Minimum altitude	-	m	520
Basin order	-	-	2nd Order
Compactness coefficient	$K_c = 0{,}28 \cdot \frac{P}{\sqrt{A}}$	-	1.39
Shape factor	$K_f = \frac{A}{L^2}$	-	0.24
Circularity index	$IC = \frac{12{,}57 \cdot A}{P^2}$	-	0.51
Drainage density	$D_d = \frac{L_t}{A}$	km/km²	0.80

Source: AUTHORS.

The K_c, K_f, IC and D_d indices were calculated according to the methodology proposed by Christofoletti (1981).

The drainage área of the Ribeirão Cambé hydrographic basin is between the altitudes of 630 and 520 m, as shown in figure 3.

The use of the LANDSAT (1, 5 and 8) satellite images, associated with geoprocessing techniques and remote censoring, proved to be effective to achieve the proposed objectives of this research. These tools facilitated the monitoring of the modification in soil use and cover over the period analyzed (1975, 1985, 1995, 2005 e 2015) in the Ribeirão Cambé hydrographic basin.

Knowing that the spatial resolution of the TM and OLI sensors is of 30x30m and of the MSS is of 80x80m, it is notable that these images present low and medium resolution and quality, respectively. Thereby the classification of soil use and cover was performed using few themes, only four, given the difficulty in distinguishing areas with similar characteristics. These satellites were chosen due its acquisition to be free.

The thematic maps for the analyzed years were generated in the SPRING software, as well as the area quantitative for each of the established themes: water, dense vegetation, ground vegetation and exposed soil. Figure 4 (a), (b), (c) and (d) present the thematic maps for soil use and cover.

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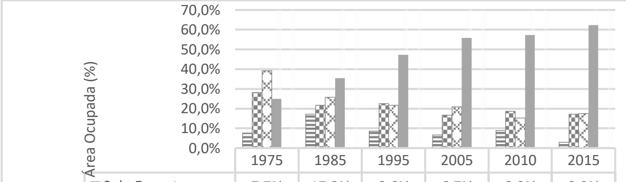
Using Graphic 1, which provides the percentage of occupied areas in each theme of soil use, it is notable that along the years occurred a gradative rise in the urban area, opposing the areas of dense vegetation, exposed soil and ground vegetation. The urban area grew 150% in 40 years, in contrast, the ground vegetation had a reduction of 55%, such as the dense vegetation that was reduced 40% during the same period.

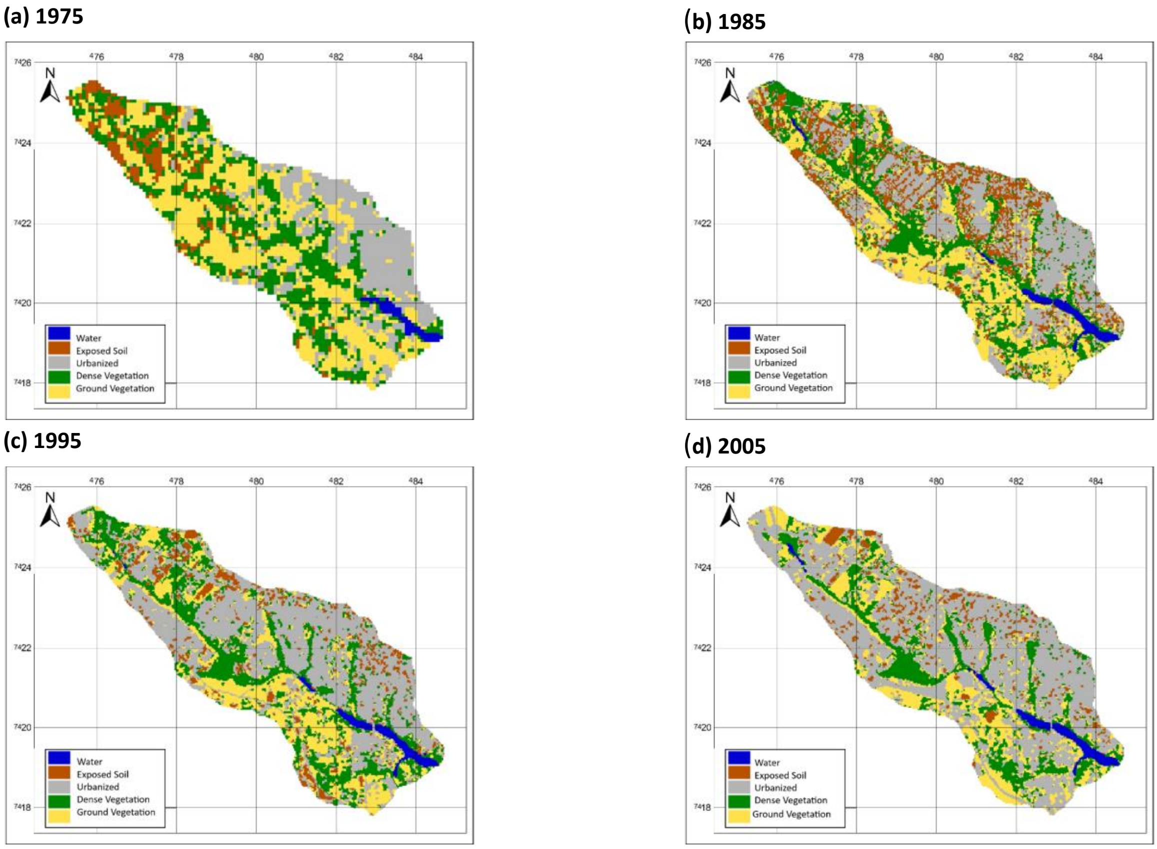
Graphic 1. Soil use and cover in the Ribeirão Cambé Basin.



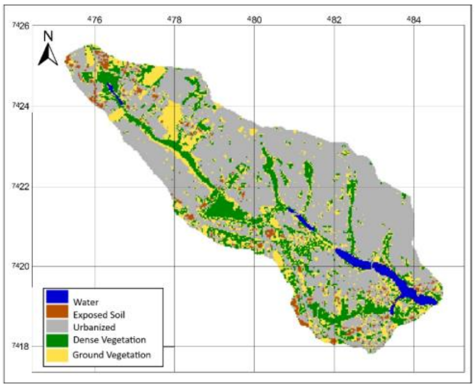
	1975	1985	1995	2005	2010	2015
Solo Exposto	7,7%	17,2%	8,6%	6,7%	8,9%	2,9%
Vegetação Densa	28,3%	21,7%	22,5%	16,6%	18,6%	17,2%
Vegetação Rasteira	39,1%	25,7%	21,7%	20,9%	15,2%	17,6%
Urbanizada	24,9%	35,4%	47,2%	55,9%	57,3%	62,4%
Total	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

Source: AUTHORS.

Figure 4. Thematic map of soil use and cover from 1975 to 2015



(e) 2015



Source: AUTHORS.

The values of exposed soil constantly varied along the years in detriment of changes in the soil use. One factor may be the rotational cultures, given that the rural activity is of great importance for the local economy. Another cause of this variation may be the cleaning of land for the construction of buildings.

According to Archela et al. (2016), in the decade of 1960 the population of Londrina presented its highest urbanization rates, since the city received industries, becoming a regional, economic, cultural and services pole. Such expansion occurred until the east of the Ribeirão Cambé basin (next to the Lakes I and II), given that the urban area of the city grew radially from the central quad.

In Figure 4(b), it is noticeable the modification in the soil use and cover in the remaining east side of the basin, southeast region. On the other hand, in the west side of the basin (northwest), in the 1980 years, began the "peripheralization" of this area, that stabilized during the 90's. Today this area is known as the neighborhood of Sabará, Sabará II, Olímpico, Housing Complex João Turquino and Maracanã Yard. The "peripheralization", according to Barros (1998 apud DE PAULA et al., 2013), is responsible for the formation of extense "urban voids" that contributed to the process of conurbation. The growth of the urbanized area in relation to the previous decade was 42%.

In the years of 1995 to 2005, as in the presented figures, in what remained of the basin some construction occupied it in an isolated form, resulting in an urbanized area growth of 33%. The occupation of the southwest region was intensified in the early 2000s in detriment of the construction of Catuaí Mall, whose result was the valorization of the Gleba Palhano neighborhood. As consequence there was a growth of 18% in the basin urban area between 1995 to 2005.

The occupation of the northwest of the basin, the Gleba Palhano neighborhood, occurred very rapidly between the years 2010 and 2015, in this year there was also a boom in the national real estate market, contributing even more to this growth. In numbers, the growth of the constructed area in this period (1995 to 2015) was 11%.

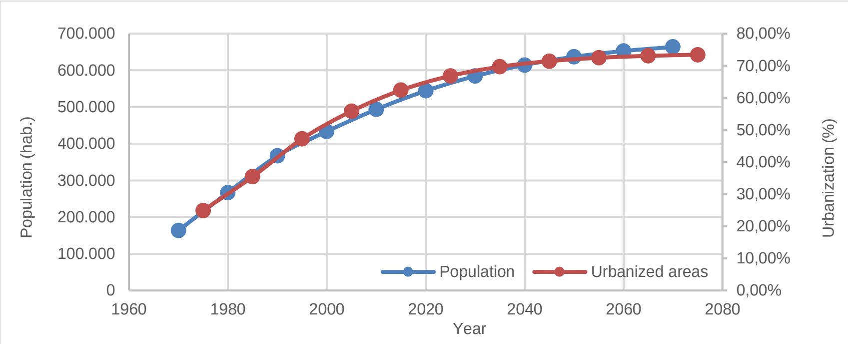
According to De Paula et al. (2013), the population growth altered the characteristics of the city territorial occupation, defining a socio-political segregation. An example in the Gleba Palhano neighborhood, which has only commercial buildings and high standard residential buildings. This is due the increasing level of real estate speculation that boosted the emergence of this type of occupation.

According to data from SIDRA (2016a), the urban population of the city of Londrina/PR tripled in 40 years (Graphic 2). Such fact corroborates with the values obtained in the multitemporal analysis of soil use and cover of Graphic 1. Demonstrating that the occupation of the basin occurred along the population growth of the city.

Between the years of 1970 and 1980 the urban population growth in the municipality of Londrina (PR) was 63%, between 1980 and 1991 of 37%, between 1991 and 2000 of 28% and between 2000 and 2015 of 14%. Such values are along with the expansion of the urbanized area of the basin, especially in the beginning. Currently the variation on the occupation rate of the basin is under this percentage of population growth, indicating that the city grows also in other regions.

Using growth logistic model projections were obtained for the percentages of urbanized areas such as the populational growth. For the urbanization, the saturation value was 73,94% and for the populational growth the value tends to 687.289 inhabitants. Graphic 2 shows the growth curves and the saturation lines.

Graphic 2. Comparison between the urban population growth of Londrina/PR and the urban growth in the Ribeirão Cambé Basin



Source: AUTHORS.

Using the graphic 2, it is possible to verify how the curve for populational growth and the curve for the urban area percentage are almost overlapped. It is also possible to note, how the urbanization and the populational growth lead to the saturation.

It is necessary to emphasize that these are probabilistic values, which mathematically tend to these values, however these values could be modified in detriment of environmental changes, such as, political, economic and social conjunctures for the populational growth case. Considering the areas, these values could be modified by real estate speculation as well as zoning changes in the basin neighborhood.

The final CN_{medium} is the result of the multiplication between the percentages for each type of soil use and cover (shown in Graphic 1) and its respective value of CN_{medium}, given in Table 6 and lastly the sum of these values. This operation was followed for all the analyzed years (1975 to 2015). It was verified, using Table 5, that the final CNmedium increased during the analyzed years.

Table 5. Final CN_{medium} of the Ribeirão Cambé Basin analyzed per year .

Theme	1975	1985	1995	2005	2015
Urbanized	22,9	32,6	43,4	51,4	57,4
Dense Vegetation	20,3	15,6	16,2	12,0	12,3
Ground Vegetation	31,7	20,8	17,5	16,9	14,2
Exposed Soil	5,7	12,7	6,4	4,9	2,2
CN_{Medium}	**80,7**	**81,7**	**83,6**	**85,2**	**86,1**

Source: Authors.

The CN_{medium} growth is explained by the increase in the urbanized areas, due the reduction of green areas (dense and ground vegetation), construction of residential and commercial buildings and the opening of paved streets. The value of CN increases with the impermeabilization (superior limit – 100), in parallel, it decreases with the permeabilization of areas (inferior limit).

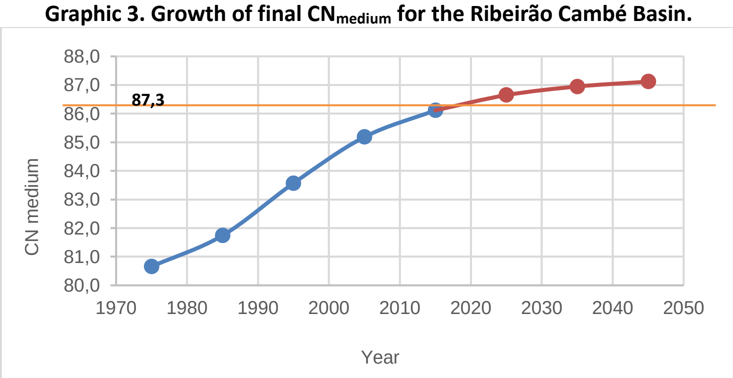
It is noticeable that the CN_{medium} variation in relation to the urbanized area growth in the basin is low, such that the urban area increase in relation to the previous decade is 42%, 33%, 18% and 12%, respectively, the CN_{medium} is 1.3%, 2.2%, 1.9% and 1.1%. It reveals the importance of (ground and dense) vegetation preservation for the control of the CN value, since the permeable area follows an inverse relation with the coefficient.

The basin has a natural saturation limit, which will cease the modification in soil use and cover, it due its own population saturation or real estate speculation. The fact is that the moment will come, when the modifications in soil use and cover will face a great reduction or cession. Therefore, using the equation for logistic growth, the value for CN asymptotically tends to a saturation value. This saturation value for the analyzed basin is 87.3. The growth curve for the final CN_{medium} is shown in Graphic 3.

Graphic 3 illustrates the variation in the CN_{medium} value for the basin. In the graphic, it is noticeable that during the initial years studied (1975 and 1985) the CN_{medium} growth rate was higher than during the latest years (2005 and 2015), however the significant increase was during 1985 to 1995 and 1995 to 2015. This rate higher rate occurs due the local real state speculation, which had its "boom" in the 2000s. From 2005 to 2015, the rate was low, indicating how close is the saturation.

As the CN approaches the saturation value, maximum limit for the basin occupation, the growth rates over the years decrease. In the graphic, estimated values for the CN_{medium} are shown for the years 2025, 2035 and 2045, which are: 86.6; 86.9; and 87.1, respectively.

Graphic 3. Growth of final CN_{medium} for the Ribeirão Cambé Basin.



Source: Authors.

CONCLUSIONS

In the morphologic characterization of the Ribeirão Cambé basin, in the municipality of Londrina/PR, the drainage area of the basin, perimeter, maximum and minimum altitudes, main canal length and drainage density, which were equal to: 29.95 km², 27.14 km, 630 and 520 m, 11.25 km and 0.80 km/km², respectively and it is worth emphasizing that this last value indicates that the basin has a good drainage capacity. Other parameters as the shape factor, compactness coefficient and circularity index also indicate that the basin presents low risk of flooding.

The LANDSAT satellite images combined with the SPRING software were used to accompany the modification of the soil use over the 40 years analyzed. It was verified that the urbanization expanded over the areas of ground and dense vegetation and that the occupation is in accordance to the history of the municipality development. The growth of the basin urbanized area was 150% during the analyzed period, the ground vegetation reduced 55% and the dense vegetation reduced 40% during the same period.

The rate of urbanization growth decreased over the years, being more intense in the initial years, equivalent to 42%, 33%, 18% and 11%, respectively. The values of CN_{medium} followed the same increase proportion over the decades, indicating a higher impermeabilization in the soil over the years and the saturation value is tending to 87.3.

It is possible to correlate the growth of urbanized areas with the urban population growth, which had very similar growing rates, these of 63%, 37%, 18% and 14%, between the decades of 1970 and 2010 for the population growth. Using the logistic growth curve it is possible to verify that the urban population and the basin urbanization are already next to the saturation values, these being equal to 687.289 inhabitants and 73.94%, respectively.

Therefore, it is demanded a discussion with the public managers of the municipality about the urban planning and flooding control, since these are becoming more necessary for the city development. The Urban Drainage Master Plan is a good measure to be taken towards the mitigation of social, environmental and economic impacts that people are subjected during each intense rain that occurs in the city.

Therefore, the maxim is that a better urban planning leads to a more adequate urbanization of the hydrographic basin, for the purpose of improving the infiltration of rainwater in the soil and consequently decreasing the surface runoff, thus reducing the basin tendency of flooding and inundation.

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