Morphometric analysis and land use-occupation in the Campestre creek watershed in the city of Lins, São Paulo State, Brazil.

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ABSTRACT
The increased demand for natural resources, economic growth and graph growth can influence the reduction of individual land use coverage, which makes water infiltration difficult. The objective was to evaluate, through the morphometric parameters and land-use occupation, the flooding susceptibility in the Campestre creek watershed. An analysis of the morphometric indexes was performed with the help of the tools presented in the SPRING 5.4.3 software. The characteristics of land use and occupation were identified by the of classification by regions, using images from three different periods: 1990, 2005 and 2021. The satellite images used were LANDSAT 5, TM sensor and LANDSAT 8, OLI sensor, and finally, as an auxiliary project to the study, Numerical Terrain Modeling data from the SRTM Project was used, with a spatial resolution of 30 meters. The morphometric results show that the Campestre creek watershed has a circular shape and straight channels, which contributes to the classification of medium-high susceptibility to floods and inundations. There was a 13% increase in built-up areas in regions that were previously water and vegetation, from 4.2 km² to 4.87 km² in 2021. The reduction of permeable areas makes it difficult for water to infiltrate, contributing to the occurrence of floods and inundations.

KEYWORDS: Flood and Inundation; Environmental Management, Hydrographic Basins.

1. INTRODUCTION

The increased demand for natural resources, economic interest and population growth influences the characteristics of land use and cover (PREIDL et al., 2020). With the expansion of population occupation areas, water bodies have become an easy object of anthropic intervention. The concentration of population in certain areas (urban centers, in this case) has intensified basic needs such as: increased areas for residences, power generation and sanitation systems, thus affecting soil coverage (BARROS et al., 2016).

According to Tucci (1997) a hydrographic basin can be defined as an area that has slope surfaces and natural water channels that converge until resulting in its outlet. Watersheds have vulnerabilities associated with changes in land use and land cover, which is considered to be of paramount importance. Therefore, changes in this parameter in a watershed can lead to impacts on the biogeochemical cycle, water flow, biodiversity, among others (ALVES et al., 2021).

And according to Barros et al. (2016), other problems arising from soil cover are: compaction, soil waterproofing, and reduced water infiltration into the soil, which generates the phenomena of flooding in watersheds. A basin is in equilibrium when it does not suffer anthropic interference.

Studies in watersheds can be carried out through geotechnologies, using high spatial resolution satellite images to obtain land use and occupation classifications. Such images allow for the extraction of more pertinent results in the identification of elements of urban composition, such as morphometric characteristics multitemporal (VAEZA et al., 2010).

Geotechnology or geoprocessing can be applied in geographic information systems, digital cartography, remote sensing, global positioning system and topography (ROSA, 2005). The application of Remote Sensing and Geographic Information Systems allows temporal analysis and quantifies land use and land cover changes. The use of these tools becomes indispensable because of their low-cost techniques (LOLLO et al., 2018).

According to Lobo et al. (2021) the morphometry parameters facilitate the definition of physical elements of a watershed, and the relationship between morphometry, land use and cover parameters allows for identifying the level of anthropic interventions that occur in the area under study, since intensity values are attributed to the processes that occur in the place (BARROS et al., 2016).

The Campestre creek watershed is located in the city of Lins, São Paulo State - Brazil, is characterized by the cultivation of sugar cane and pastures, covering a channeled stretch in the urban area, where it underwent an urbanization process around the water body over the years. The channeled part of the Creek has suffered serious flooding in recent years.

The use of geotechnologies, more specifically geographic information systems (GIS), is of great importance in determining morphometric parameters, soil use and occupation, which can help in the planning and environmental conservation of the studied basin (SOARES et al., 2016).

Given the importance of these studies, many works have been developed to evaluate the morphometry and the evolution of the use and occupation of the soil as a subsidy to an environmentally adequate management of the hydrographic basin (BARROS et al., 2016; LOBO et al., 2021; SANTOS et al., 2021).

2 OBJECTIVE

Evaluate the susceptibility to flooding through a morphometry, and land-use occupation analysis in the Campestre creek watershed in the city of Lins, using the contribution of geotechnologies.

3 METHODOLOGY

In order to determine the morphometric characteristics, soil use and occupation of the Campestre creek watershed, maps of delimitation, drainage, slope, hypsometry and land use and occupation were elaborated.

The maps were prepared using cartographic materials, satellite and radar images (SRTM), which served as the basis for further processing in a GIS environment through the use of the SPRING Software (CAMARA et al., 1996).

3.1 CHARACTERISTICS OF THE STUDY AREA

The municipality of Lins is in the west-center region of the São Paulo State, between the coordinates 21°40' 43" South and 49° 44' 33" West, altitude of 437 meters, with a territorial extension of 570.2 km² and an estimated population of 78,978 inhabitants, resulting in a demographic density of 124.98 inhab/km² (IBGE, 2021). According to Rossi (2017) the predominant soils are: Red and Red-Yellow Latosols, and Red-Yellow Argisols.

The Campestre creek watershed, the focus area of the study, has an extension of 32.45 km² and the main channel runs a stretch of 7.95 km to the city center, where the point of confluence with the Barbosa and Barbosinha streams occurs (Figure 1).

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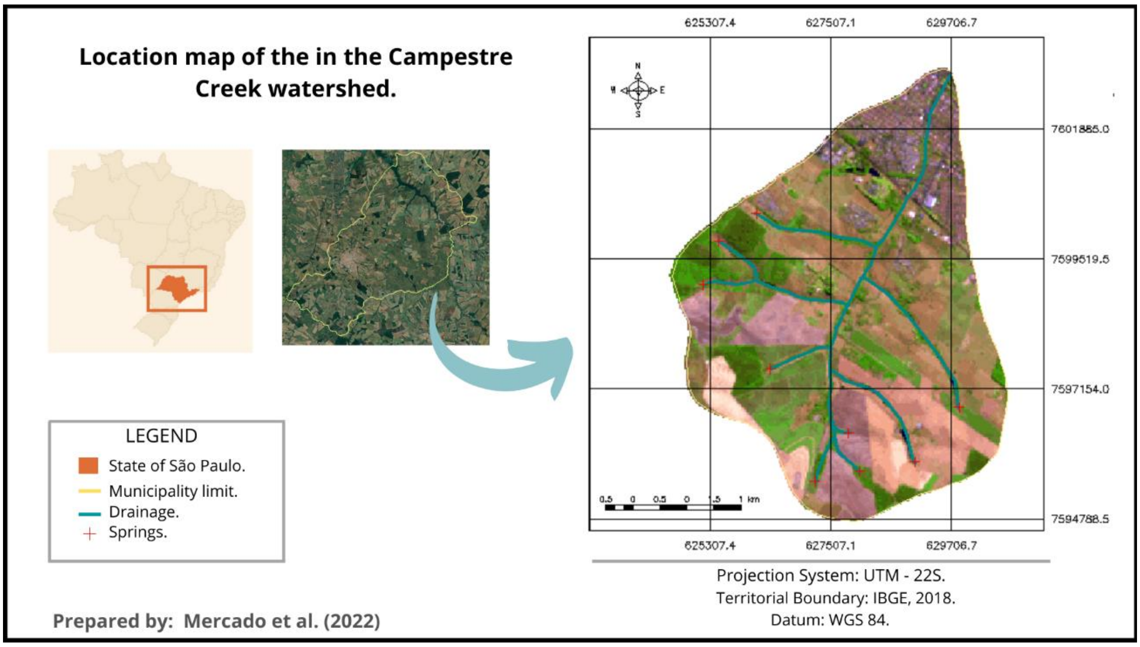
Figure 1: Location of the municipality of Lins-SP and study area.



Source: Prepared by the authors.

3.2 ANALYSIS OF MORPHOMETRIC INDEXES

Initially, a database was created to store the information. The adopted projection was the UTM (Universal Transverse Mercator) in time zone 22 and Reference Datum WGS (World Geodetic System) 84. The extraction of isolines was possible through the generation of a Numerical Terrain Model (NTM) with an SRTM image, obtained by the USGS website (United States Geological Survey, 2022).

Using the vector editing tool, it was possible to carry out the delimitation of the Campestre creek watershed, as recommended by Sperling (2007) and using isolines extracted from the SRTM image (Shuttle Radar Topography Mission). With the help of the most recent Landsat 8 images, its drainage network and the springs were defined. To determine the morphometric information, the parameters shown in Frame 1 were adopted.

Frame 1: Morphometric parameters.

Parameters	Equation
Form factor (kf)*	$Kf=\frac{A}{L^2}$
Drainage density (Dd)**	$Dd=\frac{Lt}{A}$
Sinuosity index (Is) ***	$Is=\frac{100\ x\ (Cab-L)}{P}$
Roundness index (Ic)****	$Ic=\frac{12,57\ x\ A}{P}$
Compactness coefficient (Kc)*	$Kc=0,28\ \frac{P}{\sqrt{A}}$

*VILLELA; MATTOS (1975); **RAY; FISCHER (1960); ***STRAHLER (1952); ****SCHUMM (1956);
Source: Prepared by the authors.

Such parameters need fundamental information, such as: Watershed Area (A), Basin Perimeter (P), Length of the main watercourse (L), Total length of the watercourse (Lt) and Axial length of the watershed (Cab). The resulting values of these parameters were obtained through metric operations and class measures.

3.3 LAND USE AND OCCUPATION

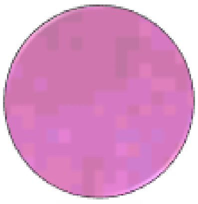
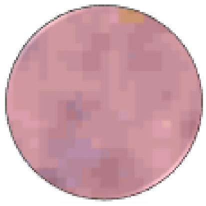
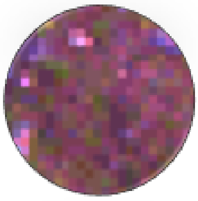
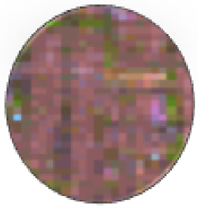
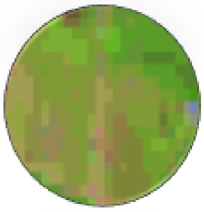
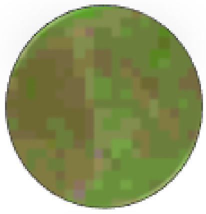
The satellite images used were obtained through the website of the National Institute for Space Research (INPE, 2022). Images from the LANDSAT 5 and LANDSAT 8 satellites, from the years 1990, 2005 and 2021, respectively, were imported. The bands used for LANDSAT 5 satellite were 3, 4 and 5, TM sensor and for LANDSAT 8 were 4, 5 and 6, OLI sensor. The purpose of choosing three different years is to assess the changes that have occurred in the basin.

To search for the images, close periods were established, intending to obtain similarities in the characteristics of the region. Images from the following periods were defined: June 1990, June 2005 and July 2021. When importing into the Spring program, the images were registered, and image contrast was applied to improve visualization. The bands used for 2021 were 4(B) 5(G) 6(R) and, for 2005 and 1990, 3(B) 4(G) 5(R).

With the watershed delimited and after clipping, segmentation was performed with similarity 5 and pixel area 30 for the LANDSAT 5 images. For the LANDSAT 8 satellite images, similarity 30 and pixel area of 30 were used. These parameters denoted the best performance in grouping similar regions for the study area.

After segmentation, the Battacharrya classification method was applied, with an acceptance threshold of 99.9%. This collection of information includes four thematic classes, which are: built-up areas, soil, dense vegetation and undergrowth. The training and capture of image samples occur according to the interpretation key that can be seen in Frame 2.

Frame 2 - Interpretation key for understanding the classes used in land use and occupation.

INTERPRETATION KEY				
Class	**Description of uso**	**Images Google Earth**	**LANDSAT 5 3(B) 4(G) 5(R)**	**LANDSAT 8 4(B) 5(G) 6(R)**
Soil	Areas that do not have vegetation cover. Vegetation transition areas.			
Built-up Areas	Waterproofed areas, residences, industries and highways.			
Dense Vegetation	Large grouped vegetation.			
Undergrowth	Agriculture and pasture areas.			

Source: Prepared by the authors.

At the end of the land use and occupation classification, a final cut of the basin area was carried out, to perform the calculation of the selected parameters. Subsequently, a post classification was performed.

4. RESULTS AND DISCUSSIONS

4.1 MORPHOMETRIC ANALYSIS

The morphometric analysis resulted in the information presented in Table 1.

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Table 1: Result of the morphometric parameters.

Analyzed morphometric parameters	Results
Basin hierarchical order	3ª
Basin axial length - km	8,6
Basin area (A) - Km²	32,45
Basin perimeter (P) - km	22,81
Main Channel Length (L) - km	7,95
Total length of channels (Lt) - km	22,06
Form factor (Kf)	0,51
Drainage density (Dd) - km/km²	0, 68
Sinuosity index (Is) - %	7,5
Roundness index (Ic)	0,83
Compactness coefficient (Kc)	1,12

High susceptibility
Medium susceptibility
Low susceptibility

Source: Prepared by the authors.

With the method used, it was possible to find a value of 0.68 km/km² for the drainage density (Dd), which, according to França et al. (1968), classifies its drainage system with greater infiltration power and low surface runoff, as the value is less than 1.5 km/km². This value found is in line with other studies, such as Vale and Bordalo (2020) and Pereira et al. (2017), who obtained results of 0.66 km/km² and 0.35 km/km² for their watershed, respectively.

The value found for the Form Factor parameter (Kf) of the Campestre creek watershed is 0.51 which, according to Villela and Matos (1975), presents medium susceptibility to floods, as it is within the range of 0.50 - 0.75. This index shows that a basin with a low form factor value is less prone to flooding than a basin that has the same size, but with a larger form factor (VILLELA; MATTOS, 1975).

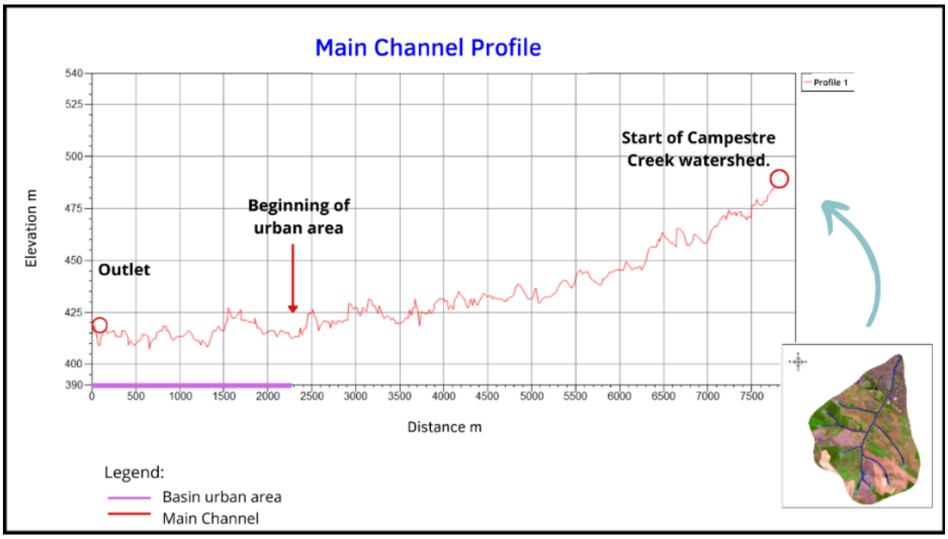
For the circularity index (Ic), whaterseds with values below 1 have narrow and elongated geometry, and values approaching 1 have circular geometry, which makes the basin more susceptible to flooding (BARROS, 2016). The result of the Circularity Index found for the Campestre creek watershed was 0.83, which indicates that the basin is geometrically circular and highly susceptible to flooding.

The sinuosity index (Is) is distributed by classes and, according to Christofoletti (1980), channels with Is >20% are considered very straight, between 20-29% are straight, from 30 to 39.9 are rambling, from 40 to 49.9 % are windy and values greater than 50% are very windy. For the Campestre creek watershed, the index found was 7.5%, being considered as very straight, with high susceptibility to flooding.

For the coefficient of compactness (Kc), the result found was 1.12, being classified as circular. According to Lobo et al. (2021), the watersheds of Barbosa and Barbosinha streams, also located in the city of Lins, has a compactness coefficient of 1.19.

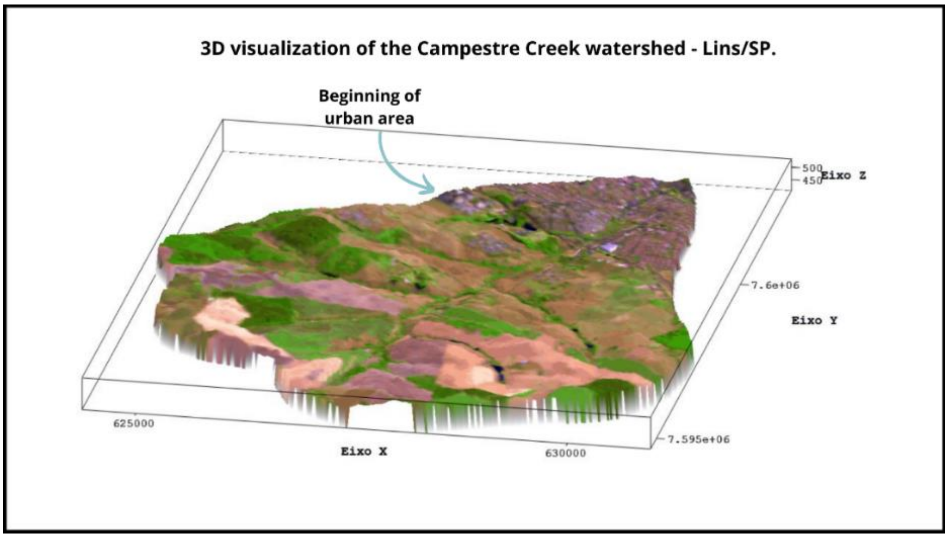
The longitudinal profile of the main channel can be seen in Figure 2, where it's beginning to its outlet is marked. It can be seen in the profile that, from the beginning of the basin to the beginning of the urban area, around 2,358 m, there is a decay of the channel, thus indicating a place with a high slope. From 2,358m, it can be seen that the area does not undergo major changes related to the slope, which contributes to the accumulation of water in times of rain due to its flow rate, which explains the occurrences of floods in its outlet, which is the point of confluence with the Barbosa and Barbosinha streams. This can be seen in Figure 3, which contains a 3D view of the basin area.

Figure 2: Longitudinal profile of the main channel in the Campestre creek watershed.



Source: Prepared by the authors.

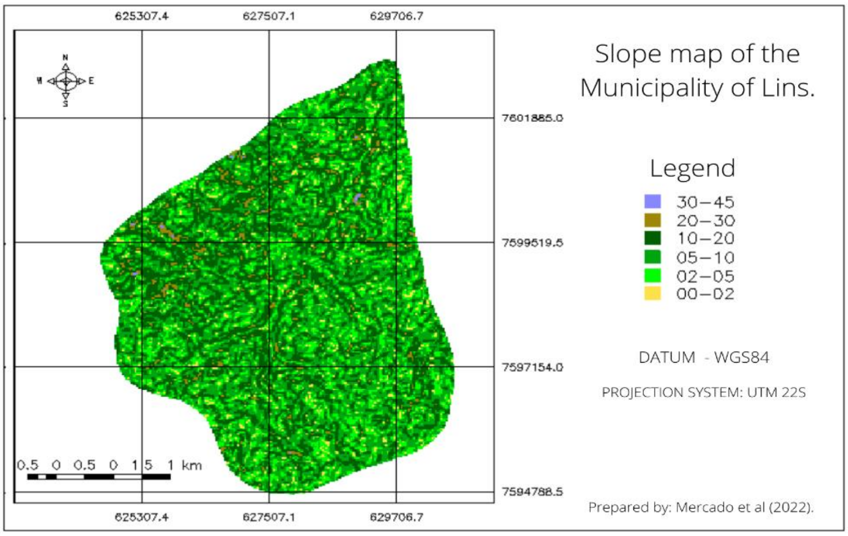
Figure 3: 3D view of the Campestre creeck watershed.



Source: Prepared by the authors.

Another characteristic analyzed in the watershed under study was the slope present in the area, which can be seen in Figure 4, where the most present classes are from 5 to 10%, from 10 to 20% and from 2% to 5%.

Figure 4: Slope map in percentage of the Campestre creeck watershed.

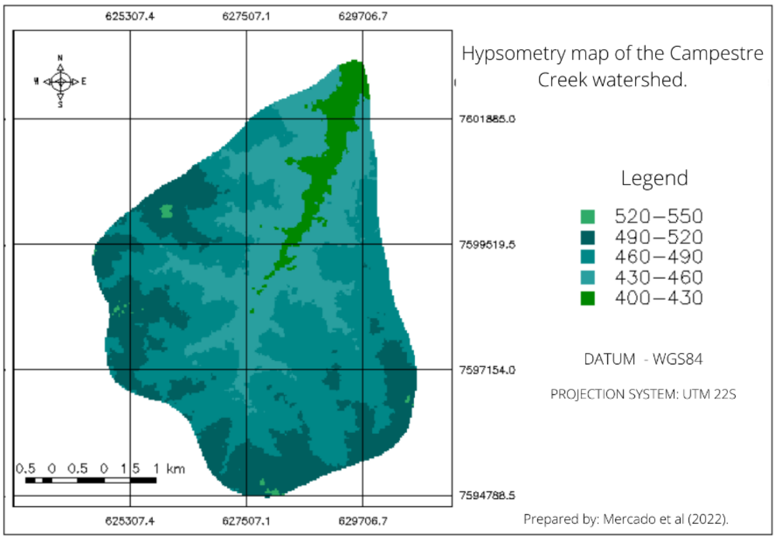


Source: Prepared by the authors.

The most present relief class, from 5% to 10%, has an area of about 13.71 km², followed by 10.41 km² located in the 10% to 20% class and 6.25 km² belonging to the 2% to 5% class. The other classes, from < 2%, from 20% to 30% and > 30%, have an area of 1.26 km², 0.74 km² and 0.03 km², respectively. The relief present in the Campestre creek watershed can be considered as gently undulating, but with more undulating regions.

In Figure 5, the altimetry of the site can be seen, where 14.68 km² of the total area of the watershed is inserted between elevations 460 and 490, followed by 8.27 km² that is present between 430 and 460, and the area of 7.59 km² which is located between 490 and 520. The altitudes from 400 to 430 and from 520 to 550 have the smallest amount of area, being 1.79 km² and 0.12 km², respectively.

Figure 5: Hypsometric map of the Campestre creeck watershed.



Source: Prepared by the authors.

4.2 LAND USE AND OCCUPANCY ANALYSIS

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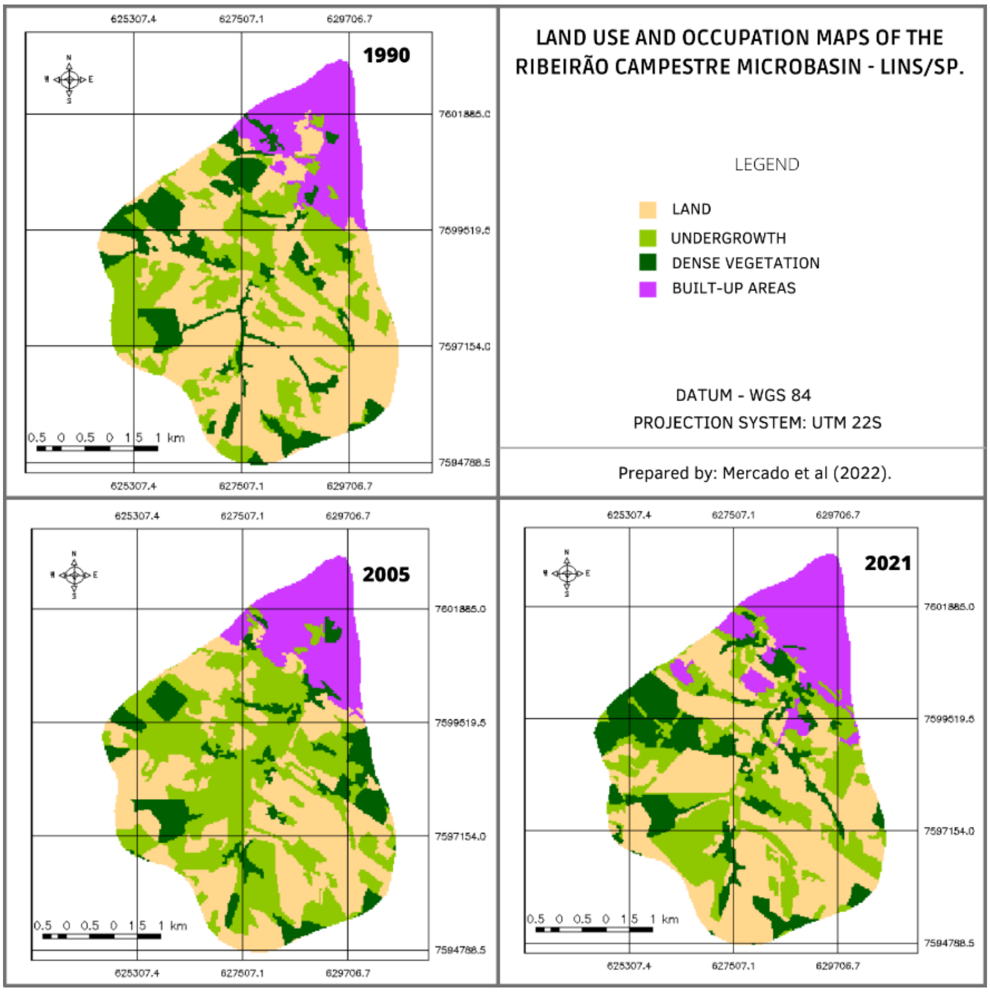
The generation of land use and occupation maps aimed to identify the changes that occurred in the Campestre creek watershed during three different years (1990, 2005 and 2021). Thus, the classification maps can be seen in figure 6.

Figure 6: Land Use and Occupation Maps of the Campestre creeck watershed.



Source: Prepared by the authors.

Using the Spring software class measurement tool, it was possible to obtain the values corresponding to the area of each demarcated use, as well as its growth over the years, compared with the initial period of analysis. The values can be seen in Table 2.

Table 2: Result of land use and occupation areas and their growth variation.

Land Use and Occupation Classes	Area (km²)			Growth Variation (%)	
	2021	2005	1990	2021-1990	2005-1990
Built-up Areas	4,87	4,4	4,28	13%	2,80%
Dense Vegetation	5,57	3,96	4,68	19%	-15,30%
Undergrowth	8,78	12,6	8,28	6%	52%
Soil	13,25	11,3	15,19	-12,70%	-25%

Source: Prepared by the authors.

Based on the results obtained, the growth of 13% of built-up areas in the period studied is remarkable. There was a 19% growth in dense vegetation areas in the comparison between 1990 and 2021, which increased from 4.68 km² to 5.57 km², respectively. The class referring to soil showed a decrease of -12.70%, from 15.19% in 1990 to 13.25% in 2021. The decrease in the area of exposed soil can also be observed.

Through the cross-tabulation methodology, it was possible to obtain the results regarding the interaction and distribution of area growth during the years 1990 and 2021. Of the total 13% growth in built-up area, 0.16 km² was on dense vegetation, 0.36 km² on the undergrowth and 0.78 km² on the ground. Another example is the soil class, which in 2021 was distributed as follows: 0.05 km² in built-up areas, 1 km² in dense vegetation and 4.35 km² in undergrowth. Table 3 shows the rest of the classes and their respective growth.

Table 3: Table of cross-tabulation results referring to the growth of areas from 1990 to 2021.

Land Use and Occupation Classes	Area (km²)			
	Built-up Areas of 2021x1990	**Dense Vegetation of 2021x1990**	**Undergrowth of 2021x1990**	**Soil of 2021x1990**
Built-up Areas	3,56	0,15	0,43	0,05
Dense Vegetation	0,16	2,59	0,92	1
Undergrowth	0,36	1,13	2,43	4,35
Soil	0,78	1,66	4,96	7,73
Total in 2021:	**4,87 km²**	**5,5 km²**	**8,7 km²**	**13,2 km²**
Total in 1990:	**4,2 km²**	**4,6 km²**	**8,28 km²**	**15,2 km²**

Source: Prepared by the authors.

In view of this, the decrease in the area of dense vegetation and exposed soil indicates that there is a reduction in permeable areas, which, associated with the morphometric characteristics already diagnosed, can thus negatively interfere with urban drainage issues.

5. CONCLUSION

Because it is a 3rd order basin and has the following morphometric characteristics: form factor with a value of 0.51, sinuosity index of 7.5%, circularity index of 0.83 and compactness coefficient of 1.12, the Campestre creek watershed has a circular shape and straight water channels, contributing to the classification of medium to high susceptibility to floods and inundations.

The increase in built-up areas in regions that were previously soil and vegetation indicate that the municipality is expanding. Built-up areas increased by 13% during the years 1990-2021, from 4.2 km² to 4.87 km². The area of exposed soil, which previously had 15.2 km² in 1990, became 13.2 km² in 2021, showing a decrease of 12.7% in area, which indicates that construction of new subdivisions ends up impacting the reduction of permeable areas and thus, hindering the infiltration of water.

Given the above, planning, management and environmental studies aimed at improving the quality of land use in hydrographic basins and watersheds are of paramount importance, so that strategies can be devised to prevent flooding and flooding in cases of hydrological events.

6. BIBLIOGRAPHIC REFERENCES

ALVES, W. S. et al. Geotechnologies applied in the analysis of land use and land cover (LULC) transition in a hydrographic basin in the Brazilian Cerrado. **Remote Sensing Applications: Society and Environment,** v. 22, 100495, 2021. Elsevier BV. <http://dx.doi.org/10.1016/j.rsase.2021.100495>.

BARROS, D. V. et al. Morfometria, uso e cobertura do solo como indicadores de enchentes e inundações na Bacia do Rio do Prata, Ilha do Maranhão. **Revista Brasileira de Gestão Ambiental e Sustentabilidade**, v. 3, n. 5, p. 217-226, 2016. Revista Brasileira de Gestão Ambiental e Sustentabilidade. <http://dx.doi.org/10.21438/rbgas.030511>.

CAMARA G. et al. SPRING: Integrating remote sensing and GIS by object-oriented data modelling. **Computers & Graphics,** v.20, n. 3, p.395-403, 1996.

CHRISTOFOLETTI, A. **Geomorfologia**. São Paulo: Edgard Blücher, 1980.

FRANÇA, G. V. **Interpretação fotográfica de bacias e redes de drenagem aplicada a solos da região de Piracicaba.** 1968. Tese (Doutorado em Agronomia/Solos e Nutrição de Plantas). Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, 1968.

IBGE - Instituto Brasileiro Geografia Estatística (org.). Censo. **Cidades.** Disponível em: <http://twixar.me/6vRm>. Acesso em: 21 de maio 2022.

INPE - Instituto Nacional de Pesquisas Espaciais. **SPRING:** Tutorial de geoprocessamento. Disponível em: <http://www.dpi.inpe.br/spring/teoria>. Acesso em 20 de maio de 2022.

LOBO, I. V.; LIMA, C. G. R.; LOLLO, J. A. Study of morphometry and land coverage to help urban planning in Barbosa and Barbosinha Brooks watershed, Lins - SP. **Periódico Eletrônico Fórum Ambiental da Alta Paulista,** v. 17, n. 6, p.26-39, 2021. <https://doi.org/10.17271/1980082717620213070>.

LOLLO, J. A. et al. Mudanças de Uso e Cobertura da Terra e Degradação Ambiental em Bacias Hidrográficas. *In*: AMÉRICO-PINHEIRO, J. H; BENINI, S. **Bacias hidrográficas: fundamentos e aplicações**. Tupã: ANAP, 2018, p. 15-40.

PEREIRA. B.W.F. et al. Avaliação dos índices morfométricos para a caracterização da estrutura da bacia hidrográfica do rio peixe-boi, PA. In Congresso Internacional das ciências agrárias. **ANAIS** (...) disponível em: https://cointer-pdvagro.com.br/wp-content/uploads/2018/02/AVALIA%C3%87%C3%83O-DOS-%C3%8DNDICES-MORFOM%C3%89TRICOS-PARA-A-CARACTERIZA%C3%87%C3%83O-DA-ESTRUTURA-DA-BACIA-HIDROGR%C3%81FICA-DO-RIO-PEIXE-BOI-PA.pdf >. Acesso em: 25 mai. 2022.

PREIDL, S. et al. Introducing APiC for regionalised land cover mapping on the national scale using Sentinel-2A imagery. **Remote Sensing Of Environment**, v. 240, 111673, 2020. Elsevier BV. <http://dx.doi.org/10.1016/j.rse.2020.111673>.

RAY, R. G.; FISCHER, W. A. Quantitative photography, a geologic research tool. **Photogrammetric Engineering,** v. 26, p. 143-150, 1960.

ROSA, R. Geotecnologias na geografia aplicada. **Revista do Departamento de Geografia,** v. 16, p. 81-90, 2005.

ROSSI, M., **Mapa pedológico do Estado de São Paulo:** revisado e ampliado. São Paulo: Instituto Florestal, 2017.

SANTOS, G. T.; LIMA, C. G. R.; LOLLO, J. A. Uso e Ocupação do Solo e Caracterização Morfométrica da Microbacia do Córrego São Miguel em Miguelópolis-SP. In: XVII Fórum Ambiental da Alta Paulista. **ANAIS...** XVII Fórum Ambiental da Alta Paulista, Tupã, ANAP, p.40-52, 2021.

SCHUMM, S. A. Evolution of drainage systems and slopes in badlands of Perth Amboy. **Geological Society of America Bulletin,** v. 67, n. 5, p. 597-646, 1956.

SOARES, L. S. et al. 2016 l. Análise morfométrica e priorização de bacias hidrográficas como instrumento de planejamento ambiental integrado. **Revista do Departamento de Geografia,** v. 31, p. 82-100. <https://doi.org/10.11606/rdg.v31i0.107715>.

SPERLING, M. V., **Estudos de modelagem da qualidade da água de rios.** Belo Horizonte: UFMG, 2007.

STRAHLER, A. N. Quantitative Analysis of Watershed Geomorphology. **Transactions, American Geophysical Union**, v. 38, n. 6, p. 913-920, 1957.

TUCCI, C. E. M. 1997. **Hidrologia: ciência e aplicação** 2.ed. Porto Alegre: ABRH/Editora da UFRGS, 1997.

USGS - United States Geological Survey's. **Earthexplorer**. Disponível em: <https://earthexplorer.usgs.gov/>. Acesso em Jun. 2022.

VAEZA, R. F. et al. Uso e ocupação do solo em bacia hidrográfica urbana a partir de imagens orbitais de alta resolução. **Floresta e Ambiente**, v. 17, n. 1, p. 23-29, 2010. <http://dx.doi.org/10.4322/floram.2011.003>.

VALE, J. R. B.; BORDALO, C. A. L. Caracterização morfométrica e do uso e cobertura da terra da bacia hidrográfica do Rio Apeú, Amazônia Oriental. **Revista Formação**, v. 27, n. 51, p. 313-335, 2020. Disponível em: <http://twixar.me/RDRm>. Acesso em: 10 jun. 2022.

VILLELA, S.M.; MATTOS, A. **Hidrologia aplicada**. São Paulo: Mcgraw Hill, 1975. 250p.