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MORPHOMETRY OF HYDROGRAPHIC BASINS PLACED IN THE URBAN AREA OF DOURADOS – MS – BRAZIL

MORFOMETRIA DAS BACIAS HIDROGRÁFICAS INSERIDAS NA ZONA URBANA DE DOURADOS – MS

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ABSTRACT

The morphometric characterization of watersheds has great importance and appliance for the prediction of phenomena such as floods. The objective of this study was to delimitate and characterize morphometrically the hydrographic basins that encompass the urban area of the Municipality of Dourados / MS – Brazil, which derived from estimated physical variables obtained by applying a license-free GIS software. Based on a Digital Elevation Model (DEM), the following microcatchment characteristics were determined: area, perimeter, slope, altitude, and watercourse orders. Four morphometric parameters that express a direct or inverse relationship with the water quantity factors of a hydrographic source were calculated and analyzed, being them: compactness coefficient, shape factor, circularity index, and drainage density. By comparing the studied basin results, it was observed that Água Limpa, Água Boa, and Laranja Azeda basin streams are more susceptible to flooding, especially considering the measurement factor and drainage density.

Keywords: physiographic; susceptibility; microcatchments.

RESUMO

A caracterização morfométrica de bacias hidrográficas tem grande importância e aplicação para previsão de fenômenos como enchentes e inundações. Este trabalho teve como objetivo delimitar e caracterizar morfometricamente as microbacias hidrográficas que abrangem o perímetro urbano do Município de Dourados/MS, a partir da estimativa de parâmetros físicos que foram obtidos através de um sistema de informações geográficas (SIG) livre. A partir do Modelo Digital de Elevação – MDE, foram determinadas as características físicas das microbacias, sendo elas: área, perímetro, declividade, altitude e ordem dos cursos d'água. Foram calculados e analisados quatro parâmetros morfométricos que expressam uma relação direta ou inversa com fatores de quantidade de água de uma bacia hidrográfica, sendo eles: coeficiente de compacidade, fator de forma, índice de circularidade e densidade de drenagem. Comparadas as bacias em estudo, verifica-se que nas Bacias dos córregos Água Limpa, Água Boa e Laranja Azeda há maior susceptibilidade a enchentes, principalmente levando-se em consideração o parâmetro fator de forma e densidade de drenagem.

Palavras chave: fisiográficos; suscetibilidade; microbacias.

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1. INTRODUCTION

Water is a limited natural resource. It has fundamental importance for both human survival and society development. The concern about the proper management of water resources has been increasing over the years due to the occurrence of problems related to the quality and quantity of water available for human consumption (MIOTO et al., 2014).

In this context, the watershed is defined as a natural water catchment. It is usually an area of land where the surface water flows down from the higher ground to rivers that eventually wind up in an exit point.

The hydrological behavior of a watershed happens in the function of its geomorphological characteristics such as relief, area, drainage systems, soil, among others (SANTOS et. Al.,2012; TONELLO et al., 2006; TUCCI, 1997). Therefore, the physical and biotic characteristics of a basin have an important role in the process of the hydrological cycle due to its influence over infiltration, amount of water produced also known as flood, evapotranspiration, surface and sub-surface flows, among other factors (TEODORO et al., 2007).

The Brazilian Law nº 9.433/1997 established The National Water Resources Policy and created The National System of Water Resources Management, incorporating principles and patterns for the management of water resources in addition to adopting watersheds as a territorial unit of study and management (BRASIL, 1997). For this reason, the watershed management has been increasingly incorporated as territorial boundaries for the environmental management. Since then it has become one of the first procedures to be performed in hydrological and environmental analyses (CAMPOS, 2010; CARDOSO et al., 2006).

The morphometric watershed characterization includes the characterization of physiographic parameters, which are physical indicators of the basin, meaning that there is a great application as an indicator for the prediction of phenomena such as floods and erosion (VILLELA; MATTOS, 1975; CARDOSO et al., 2006). Therefore, the evaluation of the water potential turns out to be a fundamental instrument for the management of river basins, allowing the formulation of action plans for the environment in order to promote the conservation and sustainable use of natural resources (TONELLO, 2005).

Consequently, the morphometric characterizations of watersheds are of the utmost importance for environmental studies, especially when the environment under discussion has been undergoing through significant changes in its water courses, due to its important roles within the ecosystem (PINTO JÚNIOR; ROSSETE, 2005).

According to Magesh et. al. (2013), remote sensing provides a reliable source to elaborate the preparation of various thematic layers for morphometric analysis. The authors also state that the geographic information system (GIS) has been useful to assess various parameters of the basin, providing a flexible environment and a powerful tool to establish, interpret, and analyze the spatial information related to watershed.

In this way, this article aims to characterize the morphometry of the watershed from the urban perimeter in Dourados/MS-Brazil as well as to estimate physical characterizations through open and / or free geo-technologies.

2. MATERIAL AND METHODS

2.1. Study site

According to the IBGE census (IBGE, 2010), in 2010 Dourados held a population of approximately 215,000 inhabitants, being the second most populous city in the state of Mato Grosso do Sul, Brazil. The region is located in the Center-South of Mato Grosso do Sul and the population represents 14% of the total number of inhabitants of the State.

The Köppen climate classification is Cwa, a temperate climate that indicates dry winter and rainy summer. The average temperature of the coldest month is below 18°C and the hottest is above 22ºC. Additionally, according to EMBRAPA, the average annual precipitation ranges from 1400 mm to 1700 mm, being the rainy season from October to March, yet, it defines the basin soils as dystroferric Red Latosol.

The study site comprises the watershed from the urban perimeter of the Municipality of Dourados/MS. This is an area of great environmental interest, since there has been an increment of human occupation in recent decades without proper planning and some areas have been constantly damaged by floods (TAMPOROSKI et al., 2012).

The sub-basins of the urban perimeter have its sources located in the municipality of Dourados/MS and their outlet, the rivers-Rio Brilhante and Dourados (Figure 1).

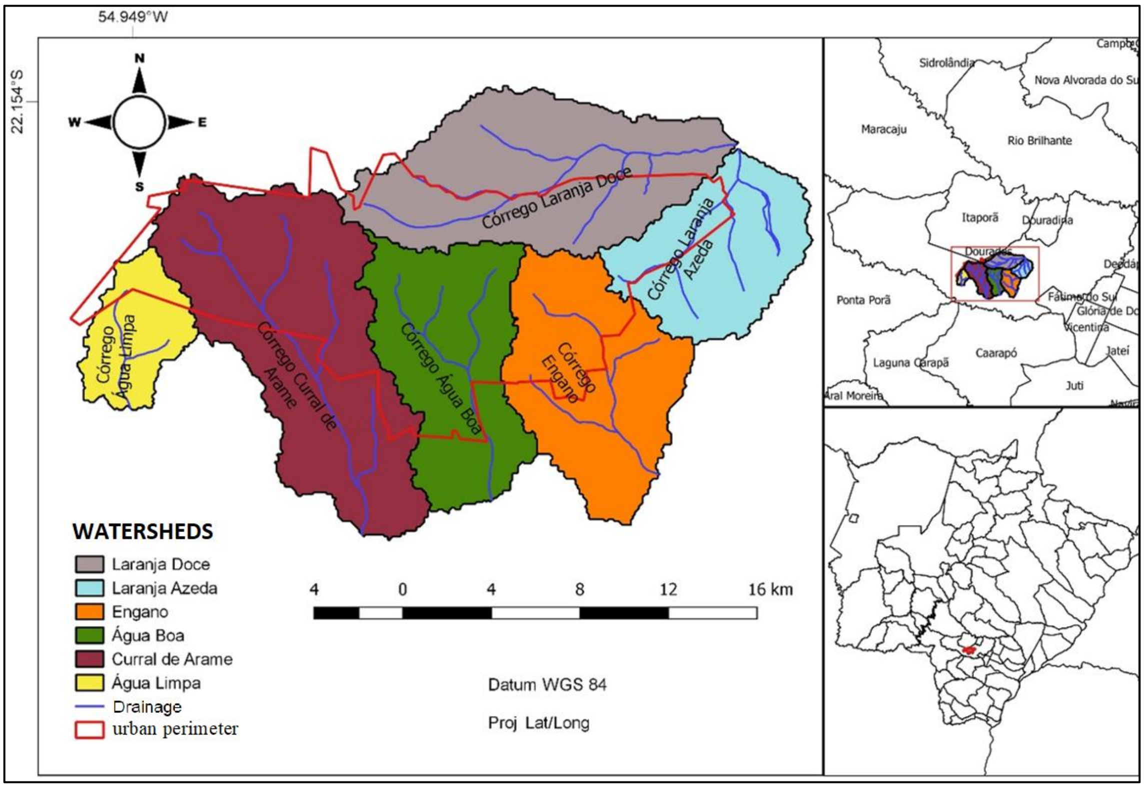

Figure 1 - Location of the Watershed of the urban perimeter in Dourados/MS.

2.2. Data acquisition

For this research, altimetry data were used as Digital Surface Model (DSM), Shuttle Radar Topography Mission - SRTM (USGS, 2015), orbit-224/75 point with a resolution of 30 m, and Dourados official topographic map with 1:100,000 scale, developed by The Brazilian Army Geographic Service (DSG) in which all of them were converted into WGS-84.

The vector data (points, lines and closed lines) and sensitive flood areas in shapefile format (ESRI, 1997) are basically representing the political administrative limit from the state of Mato Grosso do Sul and the municipality of Dourados, in which they were obtained in the Brazilian Institute for Geography and Statistics (IBGE, 2016). These data were used to delimit the study site to be developed in a map.

2.3. Processing of Digital Surface Model (DSM)

Several studies had proven the accuracy of the Shuttle Radar Topography Mission - SRTM data, just as Rodriguez et al. (2006), Santos et al. (2006), and Correa et al. (2017), for example. There are some undesirable peculiarities about these data such as sensitivity to any objects present on the surface of the land or even the antennas, buildings, and changes in vegetation cover (GROHMANN, 2015).

Although such objects are in the earth's surface, their inclusion can unfortunately disrupt the perception of the surface to obtain topographic imprint information (FARR et al., 2011).

For this reason, the free software algorithms such as r.in.gdal.qgis and r.fill.fir were essential to aid in filtering and minimizing the negative effects of all surface and relief.

The process of automatic delineation for DSM was carried out using hydrological modeling algorithms in the GRASS installed in QGIS 2.14.0 (2016). The routines performed for hydrological modeling consisted in the preparation of the stream segments, directions of drainage, and the influence of the basin area, making it possible to do the calculation of the surface and the area perimeter.

Initially, the objective was to remove spurious elevations and the DSM SRTM data cells by applying the plugin Fill, available on the free SIG QGIS 2.14.0 (QGIS DEVELOPMENT TEAM, 2016). After correcting DSM in order to remove the pixels that could compromise the flow of water, it was determined the preferred direction of flow on the surface using the tool Flow Direction, which sets the stream for each pixel in only one direction within eight possible paths related to the nearby pixels.

The acquisition of the accumulated flow on the surface was defined with the Flow Accumulation algorithm, which consists of the representation of the flow segments by pixels selected in the previous step. In this stage, it is already possible to define the basins mouth, thus obtaining the contribution area upstream of that point. For the automatic delimitation of the basins, the Watershed algorithm was used and in this step, it was also possible to extract the drainage network for the study areas.

As the basins are obtained in a raster file (pixel), it was necessary to convert them into the vector format (polygon) to perform the calculations of area and perimeter.

The mouth was defined in order to select a contribution area that covered the maximum urban perimeter and the perennial urban streams taken as main water courses.

In order to verify the consistency of the limits obtained, the official topographic base of the study area was used through the Dourados - MS Chart (DSG, 1979), an image of the satellite Landsat 8 UTM (USGS, 2015), orbit 224, color composition RGB 542 and date of passage September / 2016. In the program QGIS 2.14.0 (QGIS DEVELOPMENT TEAM, 2016), the automatic delimitation of the studied basins was compared with the topographic map of the municipality as the basis of the photointerpretation, analyzing whether the basins covered the main water courses and their tributaries.

2.4. The morphometric of the watershed

The results obtained through the MDS, the physical characteristics of the sub-basins were determined as being the basin area, perimeter, slope, altitude, and order of watercourses. Afterward, four morphometric parameters were used to express a direct or inverse relation with water quantity factors of a watershed, being compactness coefficient, shape factor, circularity rate, and drainage density.

The methodology used for the determination of these parameters was based on the proposal established by Cardoso et al. (2006), analyzing the morphometric parameters through geoprocessing software for an eventual description of the physical behavior of the river basins.

2.4.1. Coefficient of compaction

The compactness coefficient (Kc), the first physical parameter to be calculated, is related to the shape of the basin to a circle (Equation 1). According to Villela and Mattos (1975), this coefficient is a dimensionless number that varies according to the shape of the basin. The more irregular the basin, the greater the compactness coefficient. A minimum coefficient equal to unity would correspond to a circular basin shape. For an elongated basin, its value is significantly higher than 1. In the interpretation of the capacity coefficient (Kc) as follows: $1.00 \leq Kc < 1.25$ - basin with a high propensity to floods; 1.25 ≤ Kc <1.50 - basin with a medium tendency to large floods; Kc ≥ 1.50 - basin not subject to large flooding, according to Schimitt and Moreira (2008). The Kc was determined based on the following equation:

Equation 1:

$$\mathbf{Kc} = \mathbf{0,28}\frac{\mathbf{P}}{\sqrt{\mathbf{A}}}\,(1)$$

In which: Kc – coefficient of compactness, P – basin perimeter (m), and – drainage area (m ²)

2.4.2. Factor of form

Thereafter, the shape factor of the basin (F) was calculated, which relates the shape of the basin to a rectangle, corresponding to the ratio between the mean width and the axial length of the basin (from the estuary to the furthest point of the ridge) (Equation 2). The shape of the basin as well as the shape of the drainage system can be influenced by some characteristics, mainly by geology. They can also act on some hydrological processes or on the hydrological behavior of the basin. Flood-susceptible basins have values close to/or greater than 0.5, a basin with a low form factor is less subject to flooding than another of the same size, but with a higher form factor (CARDOSO et al., 2006; VILLELA; MATTOS, 1975).

The shape factor was determined using the following equation:

Equation 2:

$$\mathbf{F} = \frac{\mathbf{A}}{\mathbf{L}^2}\ (2)$$

In which: F – form factor, the basin –drainage area (m ²) and L – shaft length (m) basin.

2.4.3. Circularity rate

The circularity rate (Ci), Equation 3, relates the area of the basin to the area of a circle, it tends to the unit as the basin approaches the circular shape and decreases as the form becomes elongated (ANDRADE et al., 2008).

Equation 3:

$$\mathbf{Ic} = \frac{\mathbf{12{,}57.A}}{\mathbf{P}^2}\,(3)$$

In which: Ic – rate of circularity, A –drainage area (m ²) and P – perimeter (m).

2.4.4. Drainage density

The drainage system is formed by the main river and its tributaries. According to Oliveira et al. (2010), drainage density (Dd) indicates the level of development of the drainage system of a river basin. This parameter indicates the highest or lowest speed with which water leaves the watershed. Therefore, refers to the index that indicates the development drainage system degree, providing an indication of drainage efficiency in the basin. It is expressed by relationship between the sum of the lengths of all existing drainage channels (perennial, intermittent and temporary) and basin total area.

The rate was determined by using equation 4:

Equation 4:

$$\mathbf{Dd} = \frac{\mathbf{Lt}}{\mathbf{A}}\ (4)$$

Whence: Dd – drainage density (km/km ²), (Tt) – total length of all channels (km) and A – drainage area (km ²).

The drainage patterns are related to the spatial layout of the river courses, being influenced by the nature and the arrangement of the automatic categories, slope, altitude range, and the geological and geomorphological evolution of the region. From the geometric point of view, they have the following drainage patterns (CHRISTOFOLETTI, 1980): dendritic (regions of sedimentary structures with rocks of uniform force), trellis (regions of homogeneous structures, wind structures and anticlinal crests), parallel (regions with strong structural control and steep slopes), radial (can develop on various ramming and structures) with the centrifugal and centripetal ring settings (with hard layers and fragile structures), Figure 2.

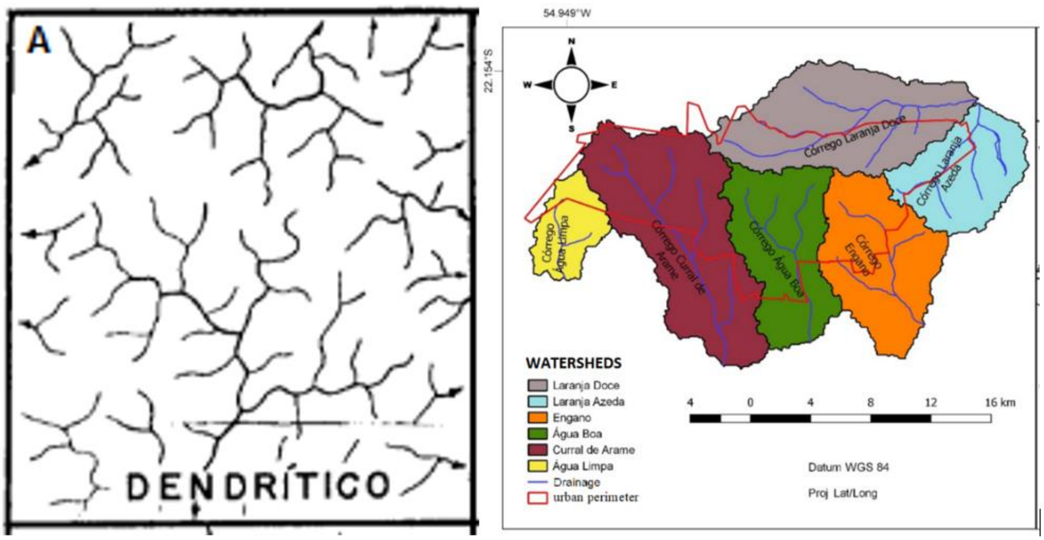

Figure 2 - (a) drainage pattern according to Christofoletti (1980); (b) drainage that covers the urban perimeter of Dourados/MS - Brazil.

2.4.5. Gradient and altitude

The Digital Elevation Model (DEM) can be used as an input to the origin of the map of gradient and altitude. It is noted that there is a decline rate in the river basins generated and it can be compared to the classification according to Embrapa, Table 1.

Declivity (%)	Discrimination
0 – 3	Flat relief
3 – 8	Low wavy relief
8 – 20	Wavy relief
20 – 45	Strongly wavy relief
45 – 75	Mountainous relief
> 75	Strong mountainous relief

Table 1 - Classification of gradient.

The terrain slope is expressed as the altitude variation between two points of the terrain in relation to the horizontal distance that separates them. The gradient classes were separated into six distinct intervals, as suggested by Embrapa (1979).

2.4.6. Order

The classification of the order of the watercourses can be performed through the criteria introduced by Horton (1945) or Strahler (1957). In this context, in the determination suggested by Strahler, the smallest channels without tributaries are considered as the first order, extending from the source to the confluence. The second order channels are those that originate from the confluence of two-first order channels and only receive first order tributaries. According to Strahler (1964), the first-order rivers correspond to the sources which the volume of water is still low. The second-order rivers correspond to the junction of two first-order rivers and the third-order rivers, the junction of two of the second, and so on, forming a hierarchy.

3. RESULTS AND DSISCUSSION

Morphometric characteristics of watersheds present in the urban perimeter of Dourados-MS are represented in Table 2.

	1	2	3	4	5	6
Geomorphological Characteristics	Stream Água Limpa Watershed	Stream Curral de Arame Watershed	Stream Água Boa Watershed	Stream Engano Watershed	Stream Laranja Azeda Watershed	Stream Laranja Doce Watershed
Area (Km^2)	26.13	116.15	70.67	74.67	54.07	96.28
Perimeter (km)	26.16	63.92	49.66	44.91	39.43	53.06
Compacity's Coefficient (Kc)	1.43	1.66	1.65	1.46	1.5	1.51
Form factor (F)	0.49	0.37	0.48	0.31	0.56	0.24
Circularity Index (Ic)	0.48	0.38	0.36	0.47	0.44	0.43
Maximum declivity (%)	30.26	33.91	49.31	34.24	27.32	29.42
Average declivity (%)	3.21	3.63	4.02	3.77	3.14	3.57
Minimal declivity (%)	0.59	0.61	0.6	0.6	0.59	0.61
Maximum Altitude (m)	458	486	465	445	451	479
Average Altitude (m)	417	421	406	399	397	416
Minimum Altitude(m)	368	341	347	336	346	334
Watershed Order	2	3	3	2	2	3
Drainage density (Km/Km^2)	0.76	0.51	0.57	0.5	0.6	0.5

Table 2 - Watersheds physical characteristics in the urban area of Dourados-MS-Brazil.

Analyzing the compactness coefficient (Kc), it can be affirmed that all studied basins show little susceptibility to flooding under normal precipitation conditions presenting values > 1.40, which means normal intensity and longer duration. In this way,the compactness coefficient presents the value far from the unit.

As for the circularity rate (Ci), the basins analyzed showed a value below (0.51), which is an indication that they do not have a circular shape, thus a tendency to elongate shape, favoring the fluvial flow. This rate may possibly be applyed to smaller river basins, since the large basins can present different directions of their contributors, generating an area that tends to become less circular due to the range of their headwaters in circular shaped basins and will have greater possibilities of rainfall to occurs simultaneously in all its length, concentrating a large volume of water in the main tributary (GEORGIN et al., 2015).

Moreover, the shape factor (F) indicates the tendency of the basin as being subject to flood of the analyzed basins. Only three values were lower than 0.50, in other words, the basins of Curral de Arame, Engano and Laranja Doce streams have suggested low rate to floods. The basins of Água Limpa, Agua Boa and Laranja Azeda stream had values close to/or higher than 0.50, indicating a medium tendency to floods, according to (VILLELA; MATTOS, 1975).

Data from Dourados - MS civil defense and the shape of the wetlands (Figure 3), elaborated by the Geographic Service Directorate of the Brazilian Army (DSG, 1979), confirm the study notes, since the districts that are affected by the factor rainfall caused by the floods are those located within the Água Boa, and Laranja Azeda basins, with the Cachoerinha, Campo Dourado and Jardim Climax districts being the most affected by the high intensity rainfall, due to the disorderly occupation without planning on the banks of the streams (DOURADOS AGORA, 2015).

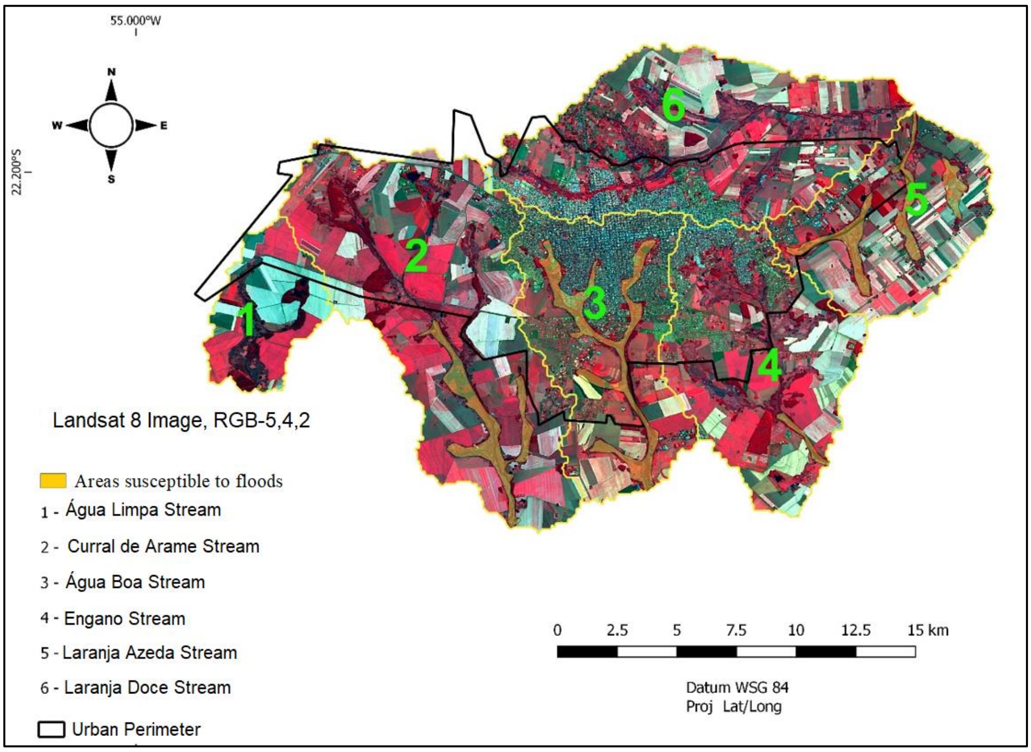

Figure 3 - Areas susceptible to floods, The Brazilian Army Geographic Service (DSG), database (1979), map topographic vector Dourados-MS-Brazil.

According to Tamporoski (2012), susceptible areas to floods gets worse by high trash volume on the slopes, resulting in the obstruction of the drainage networks, and with the garbage and heavy rains they end up in the houses of the residents, causing serious problems to the population near the stream mouth. The lack of investments in environmental education and the population lack of interest make the situation even worse (DOURADOS AGORA, 2015).

The drainage density is another factor that contributes to the indication of the development degree of the drainage system of a basin. These values substantially aid river basin management planning.

All river basins presented drainage deficiency, according to the low rates shown in table 2. The drainage density found in the hydrographic basins of the studied streams ranged from 0.50 to 0.76 km / km². According to Villela and Mattos (1975), this rate can range from 0.50 km / km² in basins with poor drainage to 3.50 km / km² or more in well-drained basins, indicating, thus, that the studied basins have poor drainage.

A high drainage density describes a highly branched basin that responds relatively quickly to a certain amount of rain; according to Linsley et al. (1975), a low drainage density reflects in a slow hydrologic response from the drainage basin. Borsato and Martoni (2004) report that densities of low drainage are usually seen in soils which are whether resistant to erosion or very permeable from whence the relief is smooth.

The drainage system, according to Strahler's hierarchy, showed a degree of third-order branching in the flood season. The order of less than or equal to 4 is common in small river basins and reflects the direct effects of land use. Therefore, the more branched the network, the more efficient the drainage system (STRAHLER, 1964).

In terms of macro and micro drainage in the urban perimeter, the basins of the study presented poor drainage density, which implies difficulties in the drainage of rainwater with great intensity at certain times of the year, causing flooding in some risk areas (COTA et al., 2014).

It is observed that the pattern is a dendritic type, according to figure 2, also called arborescent, considering that it presents similar development to the configuration of a tree (CHRISTOFOLETTI, 1980).

Analyzing the slope of the hydrographic basins (Figure 3), all of them presented an average slope with values ranging from 3.14 to 4.02%, indicating a smooth wavy relief, which is consistent with the topography found in the region.

The gradient map of the analyzed basins can be observed in Figure 4.

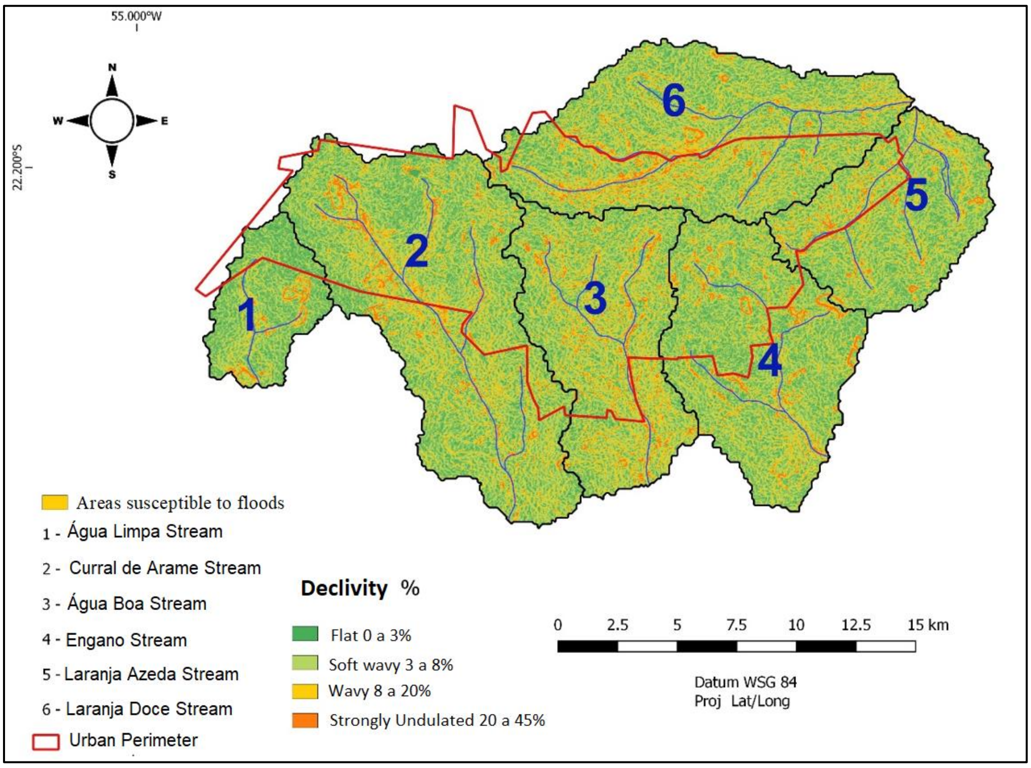

Figure 4 - Classification of gradient according to Embrapa (1979).

In terms of surface speed in Água Boa-stream basin in comparison to the others, under the same conditions of vegetation cover, soil class, and rainfall intensity, for example, a greater predisposition to degradation is suggested.

In this context, the average slope of a river basin is relevant in planning, both for compliance with legislation and to ensure the efficiency of man's interventions in the environment. Also, it has an important role in the distribution of water between the surface and underground drainage, among other processes.

According to Vilella and Mattos (1975), the high altitudes tend to receive more amount of precipitation. In addition, the loss of water is smaller. In these regions, precipitation usually exceeds evapotranspiration leading to a water supply that maintains the regular supply of the aquifers responsible for the sources of watercourses.

Figure 5 shows the altimetric map of the areas under study, representing the average relief of each basin and showing the variation of the elevation of several terrains.

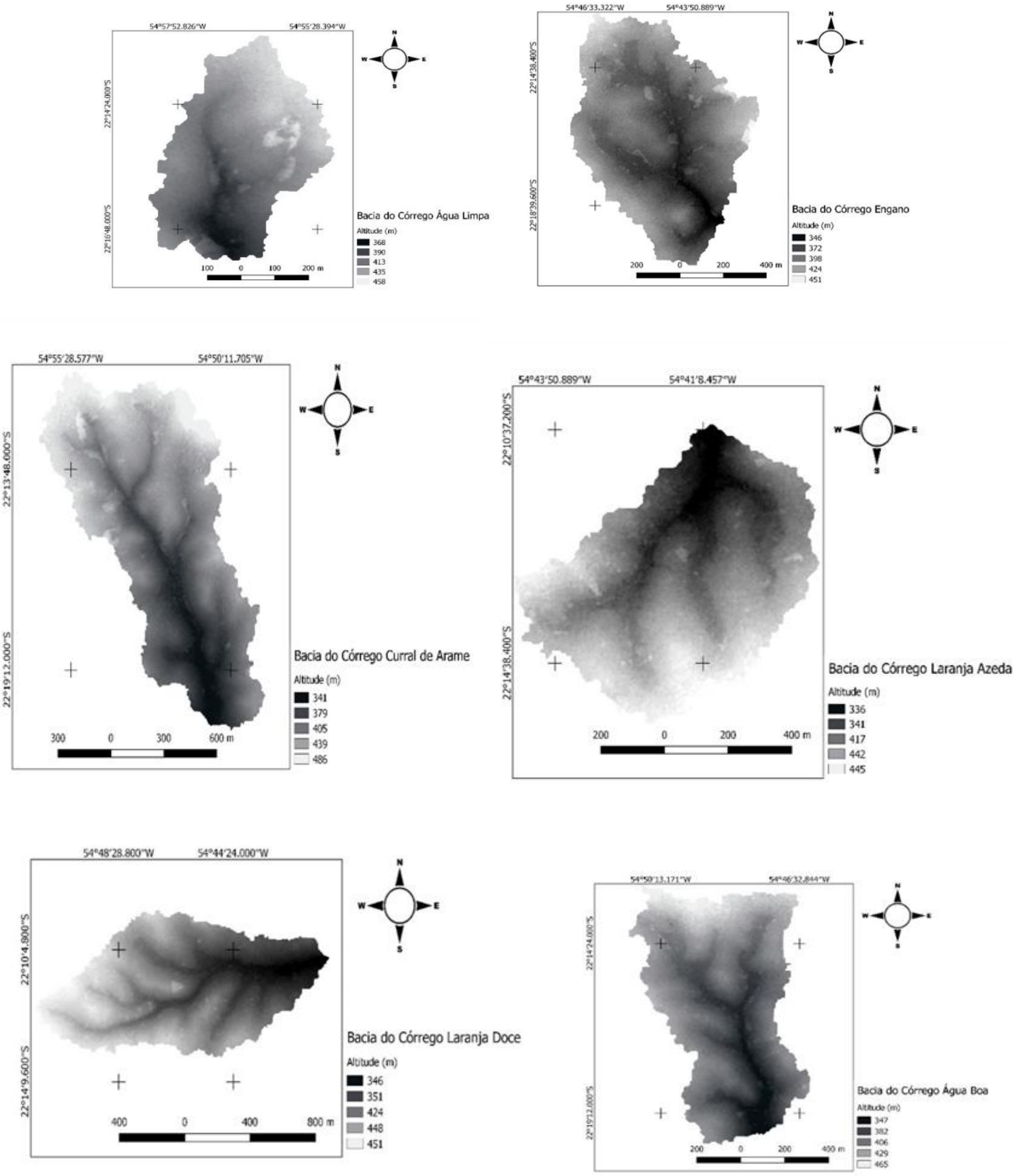

Figure 5 - Watersheds Altimetric map in the urban perimeter of Dourados-MS-Brazil.

It is possible to notice that the drainage areas of the basins are included between 333 to 486 m, with a large part of the area located between the altitudes of 340 and 440 m, showing average altitudes ranging from 397 to 421 m. In the altitude analysis of the basins, the watershed of the Curral de Arame stream was highlighted with a high altitude when compared to the others, having a maximum of 486 m and a minimum of 341 m, with an average of 421, favoring the flow and thus increasing the chances of floods due to poor drainage.

Therefore, analyzed basins, there is a greater susceptibility to floods in the watersheds of Água Limpa, Água Boa, and Laranja Azeda streams, mainly by the parameter form factor. The values of the morphometric analysis of the streams of Laranja Doce, Engano and Curral de Arame indicate a few tendencies to floods when compared with the acceptable rates proposed by the verification of the parameters. Data of the

Dourados - MS civil defense confirm the notes of the study, due to the fact that the neighborhoods that are harmed by the rain factor caused in the floods are those located within the basins Água Boa and Laranja Azeda, in other words, the most affected districts by high-intensity rains are Cachoerinha, Campo Dourado and Jardim Climax (DOURADOS AGORA, 2015).

It was observed that the compactness coefficient and the circularity index of the studied areas expressed distanced values of the unit (1), usual for longer-shaped basins, indicate a medium probability of flood peaks in these basins. The form factors obeyed, mainly in Córrego Laranja Doce and Curral de Arame watersheds, corroborate this statement. The rainfall varied from values below 41 mm (July) to greater than 174 mm (December), with 1.410 mm being the annual average in the region (ARAI et al., 2010).

4. CONCLUSIONS

The integrated analysis of the morphometric parameters of a hydrographic basin allows a broader evaluation of how it would respond to rainfall events. It also enables the adequate planning and environmental management of the area, being able to guide in the management and territorial organization, as well as subsidize environmental studies about the use of its water resources in order to identify possible areas susceptible to floods.

It is verified that in the Água Limpa, Água Boa and Laranja Azeda watersheds, there is a higher susceptibility to flooding, especially considering the parameter form factor and drainage density.

5. REFERENCES

ANDRADE, N. L. R.; XAVIER, F. V.; ALVES, E. C. F.; SILVEIRA, A.; OLIVEIRA, C. U. R. Caracterização morfométrica e pluviométrica da bacia do Rio Manso – MT. **Revista Geociências**, São Paulo, v. 27, n. 2, p. 237-248, 2008.

ARAI, F. K.; GONÇALVES, G. G. G.; PEREIRA, S. B.; COMUNELLO, E. VITORIANO, A. C.T. DANIEL, O. Especialização da precipitação e erosividade na bacia hidrográfica do Rio Dourados – MS. **Revista Engenharia Agrícola**, Jaboticabal, v. 30, n. 5, p. 922-931, 2010.

BORSATO, F. H.; MARTONI, A. M. Estudo da fisiografia das bacias hidrográficas urbanas no município de Maringá, Estado do Paraná. Acta Scientiarum. **Humam and Social Sciences**. Maringá, v. 26, n. 2, p, 273-285, 2004.

BRASIL, LEIS. 1.990. Lei n° 9.433 de 08 de Janeiro de 1.997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1° da Lei 8.001 de 13 de março de 1.990, que modificou a Lei n° 7.990 de 28 de dezembro de 1.989. Data da legislação: 08/01/1997 – Publicação DOU: 09/01/1.997.

CAMPOS, Y. O. **Gestão Ambiental: Complexidade Sistêmica em Bacia Hidrográfica**, 186f. Tese (Curso de Pós-Graduação em Geografia). Universidade Federal de Uberlândia., UFU, Uberlândia, 2010.

CARDOSO, C. A.; DIAS, H. C. T.; SOARES, C. P. B.; MARTINS, S. V. Caracterização morfométrica da bacia hidrográfica do Rio Debossan, Nova Friburgo, RJ**. Revista Árvore**, Viçosa, v.30, n.2, p.241-248, 2006.

CHRISTOFOLETTI, A. Geomorfologia. 2. ed. São Paulo: Edgard Blücher, 1980. P.188.

CORREA, N.F.; RIBEIRO, V. D. O.; MIOTO, C. L.; FILHO, A. C. P;. Obtenção de MDE Corrigido para Delimitação de Bacia Hidrográfica com Auxílio de Geotecnologias Livres. **Anuário do Instituto de Geociências – UFRJ**. Rio de Janeiro, Vol. 40 - 1 / 2017 p. 217-225. Disponível em: http://www.anuario.igeo.ufrj.br/2017_1/2017_01_217_225.pdf. Acesso em: 22 Dez 2018.

COTA, M. P.; GOMES, C.; NOGUEIRA, D. H.; GOLÇALES, J. V.; PEGORARO, M. S. Avaliação socioambiental do córrego Laranja Doce, Dourados MS. In: ENEPEX: ENCONTRO DE ENSINO, PESQUISA E EXTENSÃO, 8º ENEPE UFGD – 5º EPEX UEMS, 2014, Dourados. Resumo. Dourados, 2014. p. 1-23. 2017.

DOURADOS AGORA, 2015. Municípios têm prazo para encaminhar levantamento de áreas de risco para Defesa Civil. Disponível em: <http://www.douradosagora.com.br/noticias/meio-ambiente/municipios-tem prazo-para-identificar-areas-de-risco>. Acesso em: 20 ago. 2016.

DSG. 1979. Departamento de Serviço Geográfico do Exército. Carta Dourados. Escala 1:100.000. Folha SF 21-Z-B-II. Disponivel em <http://www.geoportal.eb.mil.br/mediador/rate.php?modulo=login&acao=entrar>. Acesso em: 14 jul. 2016

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. **Serviço Nacional de Levantamento e Conservação de Solos** (Rio de Janeiro, RJ). Súmula da 10. Reunião Técnica de Levantamento de Solos. Rio de Janeiro, 1979. 83p.

ESRI Inc. - ARC / INFO version 7.11. Environmental Systems Research Institute Inc. New York, 1997, 1 CD ROM.

FARR, T.G.; ROSEN, P. A.; CARO, E.; CRIPPEN, R.; DUREN, R.; HENSLEY, S.; KOBRICK, M.; PALLER, M.; RODRIGUEZ, E.; ROTH, L.; SEAL, D.; SHAFFER, S.; SHIMADA, J.; UMLAND, J.; WERNER, M.; OSKIN, M.; BURBANK, D.; ALSDORF, D. The Shuttle Radar Topography Mission. Reviews of Geophysics, v. 45, n. 2, p. 33, 2007. Disponível em < http://www.agu.org/pubs/crossref/2007/2005RG000183.shtml>. Acesso em: 10 ago. 2016.

GEORGIN, J.; OLIVEIRA, G. A.; ROSA, A. L. D. Estudo Comparativo de Índices Morfométricos Relacionados com Cheias das Bacias Hidrográficas do Alto Jacuí e Vacacaí Mirim – RS. Revista Eletrônica em Gestão e Tecnologia Ambiental, Santa Maria, v. 19, n. 2, p. 1357-1364, 2015. Disponível em: < https://periodicos.ufsm.br/reget/article/viewFile/16834/pdf>. Acesso em: 20 set. 2016.

GROHMANN, C.H. 2015. 'Radiography of the Amazon' DSM/DTM data: comparative analysis with SRTM, ASTER GDEM. Geomorphometry 2015, Poznam, Poland. Proceedings.

HORTON, R. E. Erosional Development of Streams and Their Drainage Basins: Hydrophysical Approach to Quantitative Morphology. Geological Society of America Bulletin. v. 56, v. 3, p. 275-370, 1945.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE (2016). Sinopse do Censo Demográfico 2010 – Brasil. Disponível em: <http://www.ibge.gov.br/cidadesat/link.php?codmun=500370>. Acesso em 14 jul. 2016.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE, Geociências, 2013. Disponível em: < http://www.ibge.gov.br/home/geociencias/.htm>. Acesso em: 6 jun. 2016.

LANDSAT 8 UTM. 2016. Imagem de Satélite. Canais 8, 5, 4, 2, Órbita 224 Ponto 075. Disponível em <http://earthexplorer.usgs.gov> Acesso em: 4 set. 2016.

LINSLEY, R. K.; KOHLER, M. A.; PAULHUS, J. L. H. **Hydrology for Engineers.** 2. ed., New York, McGraw-Hill, 1975. 482 p

MAGESH, N. S.; JITHESHLAL, K. V.; CHANDRASEKAR, N.; JINI, K.V. Geographical information system-based morphometric analysis of Bharathapuzha river basin, Kerala, India. Appl Water Sci (2013) 3:467–477. DOI 10.1007/s13201-013-0095-0

MIOTO, C. L.; RIBEIRO, V. O.; SOUZA, D. M. Q.; PEREIRA, T. V.; ANACHE, J. A. A.; PARANHOS FILHO, A. C. Morfometria de Bacias Hidrográficas Através de SIGs Livres e Gratuitos. Anuário do Instituto de Geociências – UFRJ, v. 37, p. 16-22. 2014. Disponível em: http://www.anuario.igeo.ufrj.br/2014_2/2014_2_16_22.pdf. Acesso em 10 set. 2016.

OLIVEIRA, P. T. S.; SOBRINHO, T. A.; STEFFEN, J. L.; RODRIGUES, D. B. B. Caracterização Morfométrica de Bacias Hidrográficas Através de dados SRTM. **Revista Brasileira de Engenharia Agrícola e Ambiental.** Campina Grande, v. 14, n. 8, p. 819-825, 2010.

PINTO JÚNIOR, O. B.; ROSSETE, A. N. Caracterização Morfométrica da Bacia Hidrográfica do Ribeirão da Cachoeira, MT-Brasil. Revista Geoambiente On-line, v.4, p. 38-53. 2005. Disponível em: < https://www.revistas.ufg.br/geoambiente/article/view/25872>. Acesso em: 12 set. 2016.

QGIS Development Team. 2016. QGIS 2.14.0 Essien. Geographic Information System. Open Source Geospatial Foundation Project.

RODRIGUEZ, E.; MORRIS, C. S.; BELZ, J. E. A global assessment of the SRTM performance. **Photogrammetric Engineering and Remote Sensing,** Bethesda, v.72, n.3. p. 249-260, 2006.

DOS SANTOS, A. M; TARGA, M. S.; BATISTA, G. B.; DIAS, N. W. Análise morfométrica das sub-bacias hidrográficas Perdizes e Fojo no município de Campos do Jordão, SP, Brasil. **Revista ambiente e água.** v. 7, n. 3 (2012). Disponível em: < http://www.ambi-agua.net/seer/rate.php/ambi-agua/article/view/945/pdf_744> . Acesso em: 07 abril 2019.

SANTOS, P. R. A.; GABOARDI, C.; OLIVEIRA, L.C. Avaliação da Precisão Vertical dos Modelos SRTM para a Amazônia. **Revista Brasileira de Cartografia**, Rio de Janeiro, v.58, n.1, p. 101-107, 2006.

SCHMITT, A.; MOREIRA, C. R. Manejo e Gestão Hidrográfica Utilizando o Software Gratuito Quantum-GIS. **Revista cultivando o saber**, Edição Especial, p. 125- 137, 2015.

SILVEIRA, A.L.L. Ciclo Hidrológico e Bacia Hidrográfica. **Hidrologia: ciência e aplicação.** São Paulo: EDUSP, 2001. p. 35-51.

STRAHLER, A. N. Quantitative analysis of watershed geomorphology. **Transaction of American Geophysical Union,** v.38, p.913-920, 1957.

STRAHLER, A.N. Quantitative geomorphology of drainage basins and channel networks. In: CHOW, Ven Te (Ed.). **Handbook of applied Hidrology**. New York: McGraw-Hill, 1964. p. 4.39-4.76.

TAMPOROSKI, B. R. F.; ALVES, M. A. M.; SILVA, L. F.; PEREIRA, J. G. Planejamento Urbano e as Enchentes em Dourados: a distância entre a realidade e a legalidade. **Caderno Metropolitano**, São Paulo, v. 14, n, 27, p. 217-232, 2012.

TEODORO, V. L. I.; TEIXEIRA, D.; COSTA, D. J. L.; FULLER, B. B. O Conceito de Bacia Hidrográfica e a Importância da Caracterização Morfométrica para o Entendimento da Dinâmica Ambiental Local. **Revista Uniara**, n. 20, 2007.

TONELLO, K. C. **Análise Hidroambiental da Bacia Hidrográfica da Cachoeira das Pombas**, Guanhães, MG. 2005. 69f. Dissertação (Mestrado em Ciências Florestais) – Universidade Federal de Viçosa, Viçosa. 2005.

TONELLO, K. C.; DIAS, H. C. T.; SOUZA, A. L.; RIBEIRO, C. A. A. S.; LEITE, F. P. Morfometria da Bacia Hidrográfica da Cachoeira das Pombas, Guanhães – MG. **Revista Árvore,** Viçosa, v. 30, n. 5, p. 849-857, 2006.

TUCCI, C. E. M. 1997. **Hidrologia: ciência e aplicação.** 2.ed. Porto Alegre: ABRH. 943 p.

VILLELA, S. M., MATTOS, A. **Hidrologia Aplicada.** São Paulo: McGraw – Hill do Brasil, 1975, 245p.