SEVEN publicações acadêmicas

MORPHOMETRIC ANALYSIS AND ENVIRONMENTAL PLANNING: AN EDUCATIONAL APPROACH IN SCIENCE AND MATHEMATICS TO UNDERSTAND THE GEOMORPHOLOGICAL PROCESSES IN THE WATERSHED OF THE ÁGUA DAS ARARAS, CORNÉLIO PROCÓPIO AND SANTA MARIANA STREAMS, PARANÁ, BRAZIL

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ABSTRACT
The article develops a detailed morphometric analysis of the Água das Araras Stream Hydrographic Basin, located in the regions of the municipalities of Cornélio Procópio and Santa Mariana, in Paraná. The research focuses on the geomorphological characterization and dynamics of the processes that model the relevance and drainage network of the basin. Based on quantitative methods such as areal, linear, hypsometric and river planning analysis, the research aims to clarify the structural factors and environmental constraints that shape the basin. The study seeks not only to identify the natural potential and aspects of environmental vulnerability, but also to suggest management actions that enable more effective and sustainable territorial planning. This work presents an important resource for future disciplines in favor of the preservation of water resources, in addition to strengthening the interdisciplinary understanding of geomorphological processes and their relevance to sustainable development. As well as the application of this knowledge in environmental education, especially in the Teaching of Geography, Science and Mathematics. In addition, morphometric analysis shows a powerful tool for interdisciplinary teaching in Geography, Science and Mathematics, promoting a practical understanding of natural processes and their impacts. The study concludes by emphasizing the relevance of the basin for environmental education and the need for conservation policies to ensure the sustainability of local water resources. The study concludes by highlighting the need for preservation policies and the importance of the watershed as an educational resource to foster environmental awareness.

Keywords: Morphometric Study. Vulnerability. Watershed. Teaching.

INTRODUCTION

Since the nineteenth century, with the systematization of scientific geography by Humboldt and Ritter, geographers began to classify geography from various perspectives, applying and developing multiple methodologies and methods with the sole objective of understanding the interrelationship between the production of geographic space and natural phenomena. Many other geographers continued their systematization studies with an emphasis on descriptive methods, aiming to understand environmental phenomena. Calculations and measurements were used to express these processes, always with the aim of holistically understanding the Earth's physical systems.

Christofoletti (1980), when defining phenomena of systems, observed that the main difficulties lie in enumerating the elements and their relationships, clearly demonstrating the scope of the system. Emphasizing the totality of systems that interest geographers, understanding that a phenomenon does not act in isolation, but works within an environment as part of a larger whole, the universe.

This work seeks to address some issues related to the hydrographic system of the Araras Creek basin, arising from the following questions: Does the Araras basin have a plan capable of highlighting its full potential? Does the Araras basin have the physical data necessary for effective environmental planning?

The main objective of this work is to gather morphometric data from the Araras Creek watershed, taking into account the theoretical precepts of the analyses presented by Christofoletti (1980). To this end, data related to river hierarchy, areal analysis, linear analysis and hypsometric analysis will be prepared; in addition to the necessary mappings for the physical diagnosis. The quantitative analysis represented in the morphometric parameters allows the interpretation of the phenomena occurring in the hydrographic basins. Geomorphological science does not abstain from the need to use quantitative methods to evidence its processes, which from the point of view of direct observation become imperceptible, using such methods of application to capture what our eyes cannot reach.

According to the results obtained, the Água das Araras Stream basin demonstrates considerable structural conditioning combined with morphoclimatic and planialtimetric processes, which will be reported below.

Morphometric analysis seeks to gather quantitative data that provide an objective geomorphological view, often necessary for the diagnosis and planning of physical phenomena in the context of watershed studies.

In this sense, Lana, Alves and Castro (2001, p. 122) explain that:

> In order to obtain quantitative data to differentiate homogeneous areas within a watershed, the morphometric analysis method is used, which consists of the characterization of morphological parameters, such as: hydrographic density, drainage density, channel gradient, sinuosity index, among others. Such parameters explain the physical indicators of the basin, characterizing its homogeneities.

Santos & Sobreira (2008) used the morphometric parameters analyzed as a subsidy for the diagnosis of areas with environmental vulnerability, especially in relation to erosion, considering the data obtained valuable for the environmental planning and zoning of the watershed.

Milani & Canali (2000, p. 150) state that

> The application of morphometric analysis facilitates the understanding in an integrated way of the hydrogeomorphological processes that occur in a hydrographic basin, even when its structuring is complex, or has undergone anthropogenic interventions, because, from a global analysis, it is possible to sectorize its elements and identify the isolated participation of each one.

In watershed studies, it is always necessary to produce knowledge about the physical aspects of the study area, which will contribute to a more accurate and assertive analysis of the processes and phenomena under development there. Thus, Teodoro *et al.* (2007, p. 137) indicate that

> The morphometric characterization of a watershed is one of the first and most common procedures performed in hydrological or environmental analyses, and aims to elucidate the various issues related to the understanding of local and regional environmental dynamics.

In this way, combining several morphometric data clarifies the differentiations of homogeneous areas. Indicating physical factors in order to denote environmental changes, being important for the survey of information on environmental vulnerability in watersheds.

Christofoletti (1972, p. 26) also contributes by stating that:

> [...] Statistical techniques are important in many stages of the research, providing the basis for sampling, analyzing the significance of the data and establishing correlations. It is also symptomatic that analysis and experimentation in geomorphological studies are carried out by applying principles and concepts admitted in other sciences, making it definitively integrated into the interdisciplinary scientific movement of our time.

According to Antonelli & Thomaz (*apud* Teodoro *et al.*, 2007), by combining morphometric data collected in a locality, several environmental and physical parameters can be highlighted, indicating the changes that occurred in the structure of the locality studied. In addition to resorting to the feasibility of data capable of demonstrating vulnerability.

The hydrological behavior of a basin refers to its geomorphological, morphoclimatic and planialtimetric characteristics, with regard to shape, relief, area, geology, drainage network, soil, etc.

Fernandes (1999 *apud* ATANASIO, 2004) notes that the name hydrographic basin refers to natural geographic compartments delimited with watersheds, which is superficially drained by a main watercourse and its tributaries.

Barrella *et al*. (2000) determines that it is a set of lands drained by a river and its tributaries, formed in the higher regions of the relief by water dividers, where rainwater either drains superficially forming streams and rivers, or infiltrates the soil for the formation of springs from the water table, which will also feed the drainage networks. The surface waters drain to the lower parts of the terrain, forming streams and rivers, and the headwaters are formed by streams that spring up in steep terrain of the mountains and mountains and as the waters of the streams descend, they join other streams, increasing the volume and forming the first rivers, these small rivers continue their paths receiving water from other tributaries, forming larger rivers until they flow into the ocean.

The formation of the hydrographic basin occurs through the unevenness of the terrain that guides the watercourses, the course follows the lower areas until it flows into the ocean, as designated by Barrella *et al*. (2000). Following a system segment, where precipitation occurs in the higher areas, filling the cavities and traveling to the lower areas.

Guerra & Guerra (1997, p. 76) It determines that the hydrographic basin is "a set of lands drained by a main river and its tributaries".

> [...] In longitudinal depressions, there is a concentration of rainwater, that is, of the surface runoff table, giving the concentrated water table – the rivers. The notion of hydrographic basin naturally requires the existence of headwaters or springs, watersheds, main watercourses, tributaries, sub-tributaries, etc. (Guerra & Guerra, 1997, p. 76).

The authors state that in the longitudinal depressions where rainwater is concentrated, it is conducive to surface runoff activities, where the concentrated water table is assigned – the rivers, called headwaters.

The current Brazilian legislation conceptualizes the hydrographic basin as being a basic unit of water resources planning, regardless of the size of the drained area and that the springs are supplied by small basins called headwaters.

By analyzing the processes and forms through a geomorphological study, we will be inquiring one of the most important themes researched. Because it represents one of the sectors that is responsible for the flow of materials when it is trained.

Conceptualizing strands Christofoletti (1980, p. 26) designates that:

> Slopes means inclined surface, not horizontal without presenting any genetic or locational connotation. The slopes can be subaerial or submarine, and may result from the influence of any process, and, in this broad sense, they cover all the component elements of the earth's surface, being formed by the wide variety of internal and external conditions.

In this sense, Christofoletti (1980) points out that the processes that occur inside the Earth's mantle and also on its surface, triggering changes, are called endogenetic strands, acting in the modification of existing slopes due to subterranean forces, which can be: orogenies, epirogesis and volcanism; and the exogenetic strands, which act through external factors causing modifications in the earth's surface, which can be through weathering, transport, deposition, mass movements and ablation.

Such endogenetic and exogenetic factors are responsible for sculpting the shapes of the earth's surface, being able to raise a mountain to the formation of valleys "sculpting landscapes".

According to Jan Dylik (1968 *apud* Christofoletti, 1980, p. 01) "the slope is a three-dimensional shape that was modeled by the processes of denudation, acting in the present or in the past, and representing the dynamic connection between interfluve and the valley bottom".

Many were the elements used in the evaluation of Jan Dylik (1968) to propose the definition of slope, the natural discontinuities (terraces, pediments, cliffs); upper limits; internal limits and flow. Several actions that are predisposed in the system that are brought about by these changes called gradation, degradation or pleasing.

Morphogenetic processes are also responsible for changes in relief, acting in isolation, entering the category of weathering or weathering processes, which cause the fragmentation of rock structures producing debris. The movement of regoliths (gravitational movements that cause the movement of particles) that can occur in the form of crawling (slow and imperceptible movement of debris); solifluxion or mud flows (flows of water and mud that, together with the debris, cause the waterproofing of some soils); avalanche (can be made up of ice or rocky fragments, causing the free fall of materials in order to obtain speed capable of destroying several targets); landslides (displacements of masses caused by a large flow of water in terrain of greater slope, in rainy seasons); landslides (displacements of blocks of land).

In this sense, we can highlight that many factors of disorder often occur on slopes (steep terrain) capable of being degraded by physical, chemical and biological factors. Physical factors stand out: water action (and its evaporation and freezing processes, etc.), humidity and temperature variations; Chemical factors: pressure and temperature of the rocks; Biological factors: action of living beings (such as bacteria or animals, whether decomposing or excrement) among others. Such disorder factors can cause changes in the relief.

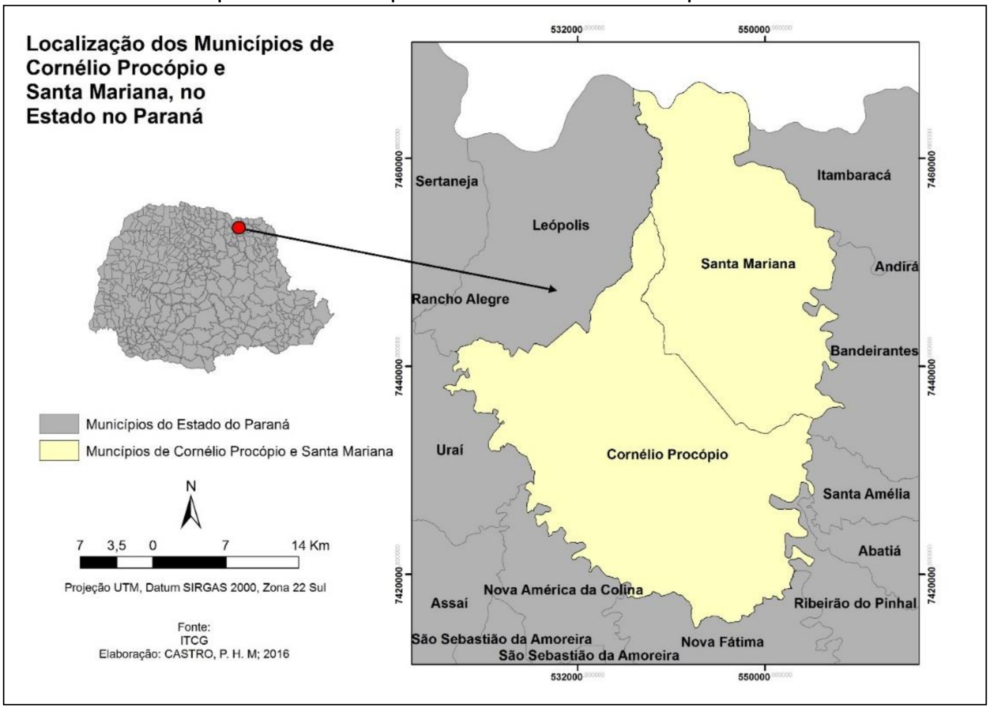
LOCATION OF THE STUDY AREA

The source of study (Hydrographic Basin of the Água das Araras Stream) has its source in the city of Cornélio Procópio, located in the Pioneer North of Paraná (Figure 1), with an estimated population according to the demographic sense of the IBGE 2010 (IPARDES, 2015) of 46,928 inhabitants, gentile procopenses, with a territorial area of 634,100 km².

The first occupations in the north of Paraná had as participants farmers from São Paulo, Mineiros, Northeasterners and Northerners (IBGE, 1971 *in* IPARDES, 2015). The origin of Cornélio Procópio took place in the mid-1920s, when Colonel Cornélio Procópio made a donation of five thousand bushels of land located in the locality where the municipality is today, to his son-in-law Francisco Junqueira. These lands were transformed into allotments that soon had their occupation due to the fertility factor, especially the settlers from São Paulo who came with the intention of planting coffee.

Soon after the construction of the SP-PR railroad, there was a new flow of migration, visibly from São Paulo and Minas Gerais. In 1931, the railway station was inaugurated, named in honor of Colonel Cornélio, who gives his name to the city.

Figure 1. Location Map of the municipalities of Cornélio Procópio and Santa Mariana – PR.



Elaboration: Castro, 2016. Organization: Authors, 2016.

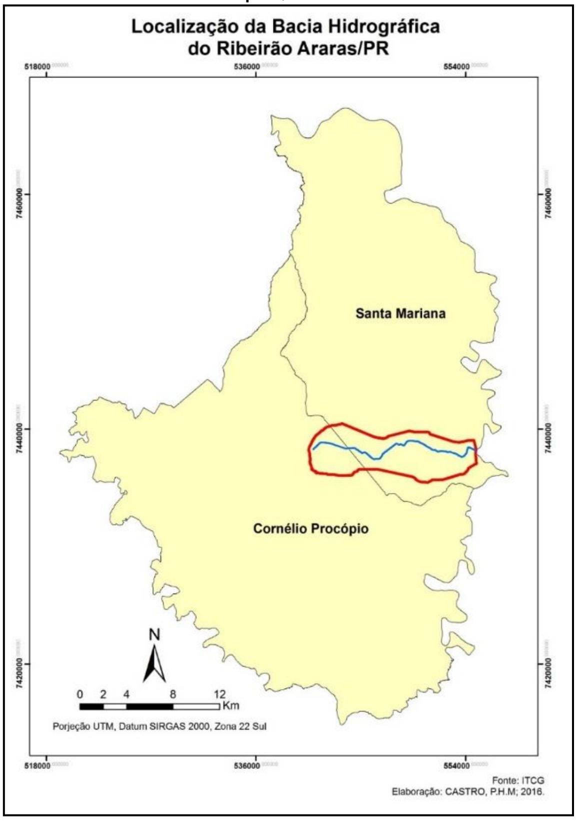
The mouth of the basin under study is located in the municipality of Santa Mariana (Figure 2) located in the north of Pioneiro do Paraná, containing a population of 12,435 inhabitants according to the 2010 census (IBGE *in* IPARDES, 2015), with a territorial area in Km² of 427,193, where the gentile is Santa-marianenses.

This municipality was formed in 1934, being a small village on land belonging to Francisco Junqueira (IBGE, 1971 *in* IPARDES, 2015), due to the great fertility of the lands, a large number of outsiders from different regions migrated to the locality in search of land. In October 1938, the administrative and judicial district of Santa Mariana was created.

With its expansion and its vast development on the coffee culture, little by little the city of Santa Mariana presented itself in a position to emancipate itself in a political and administrative way.

According to old citizens of the locality, the name Santa Mariana was a tribute to the wife of Francisco Junqueira, former owner of the land.

Figure 2. Map of the Location of the Hydrographic Basin of the Água Araras Stream in relation to the municipalities of Santa Mariana and Cornélio Procópio, Paraná.



Elaboration: Castro, 2016. Organization: Authors, 2016.

The Água das Araras Stream is a tributary of the Laranjinha River, between its course it has the Atlantic Forest of preservation where today is located a park called Mata São Francisco where it crosses. Its headwaters are located at the coordinates Latitude: -

23° 9'45.95"S. Longitude: -50°35'58.37"W, and its mouth is at the coordinates Latitude: -23° 9'48.00"S Longitude: - 50°27'51.10"W.

The headwaters of the Água das Araras Stream have two evident drainages, located about 1 km upstream of the area of the Mata São Francisco State Park. More precisely in the vicinity of the Arthur Hoffig Exhibition Park (Figures 3 and 4).

Figure 3. Landscape of the headwaters area of the Araras springs.

Photo: Authors, 2016.

Figure 4. Landscape of the headwaters area of the Araras springs.

Photo: Authors, 2016.

The headwater area of the springs has a small riparian forest around the drainage (Figures 5 and 6), with a predominance of monoculture plantations. With rotational crops of corn, soybean and wheat (Figure 4).

Figure 5. Aspects of the headwater area of Araras springs.

Photo: Authors, 2016.

Figure 6. Presence of riparian vegetation, but below what is necessary.

Photo: Authors, 2016.

In the photos (Figures 5 and 6) it can be seen that there is a riparian forest composed of various trees, in addition to an extension of grass around the spring, but fragile to protect the drainage.

According to the website Agencia Ambiental Pick-upau (2016) environmental panorama (an article of 05-09-2007), a farmer donates 15 thousand seedlings for planting around the source of the Araras and its tributaries, for the sake of protection, of the predisposed seedlings 5 thousand were planted on his property and the other 10 thousand according to the report would be planted on the day of the tree of the year announced, The purpose of the action is to reforest the stream from the source to mitigate the degradation caused by the extensive presence of monocultures.

The region of Cornélio Procópio and Santa Mariana has a subtropical climate with average temperatures in accordance with the climatic typology, they do not have well-defined drought situations, rainfall is distributed, however, it may have situations of high rainfall on occasions of extreme events.

According to the classification proposed by Köppen, the region can be classified as a Humid Subtropical Climate, which has a warmer monthly average of less than 22° C and the coldest month below 18 °C, without dry season, mild summer and severe frosts, which are too frequent. Distributing in the higher altitude lands of the mountainous areas. And the humid Subtropical Climate has warmer monthly averages above 22° C and in the coldest month below 18 °C, presenting undefined dry seasons, hot summers and less frequent frosts.

The cities of Santa Mariana and Cornélio Procópio, located in the State of Paraná, are located under the Third Plateau of Paraná (Maack, 2012) and can be called the Guarapuava Plateau, being developed in terrains dating from the Mesozoic era, consisting of strata of São Bento Inferior or Botucatu sandstones with flows of basic lavas, forming mainly Basalts.

The geological constitution of the third plateau is formed by the sandy-clayey pedestal, in addition to the presence of the Esperança and Poço Preto formations, of the Rio do Rastro group, and the São Bento Inferior or Botucatu sandstone formations (Maack, 2012).

The third plateau has its entire extension with large lava flows originating from the process of Gondwanic volcanism from the post-Triassic to the Eo-Cretaceous (Maack, 2012) and even through tectonic rifts. Composed of a multitude of elevations preponderant of the Vulcanization processes, plateaus, plateaus of the water dividers and orographic lines

Such specifications of traap flows (mainly basalts) plus the presence of weathering processes caused the clayey, rich and fertile soil that designated the occupation process of Santa Mariana (SM) and Cornélio Procópio (CP), as well as in the other cities of the third plateau of Paraná.

METHODOLOGICAL PROCEDURES

Geomorphology being a science that studies the reliefs and seeks to understand and characterize the topographic modeling of a region, which were certainly established due to a series of processes, ChristofolettI (1980, p. 01) highlights processes as "being a sequence of regular and continuous actions that develop in a relatively well-specified way and leading to a determined result". In this case, endogenous and exogenous processes are the network of systems capable of forming and modifying the soil base, modeling and diversifying the Earth's crust.

Because it is an open and branched system, all the other components are influenced by such continuous actions, and these act in the dissimilarity of the systems of their universe.

For Christofoletti (1980, p. 01):

> The analysis of forms and processes provides knowledge about the aspects and dynamics of the current topography, under the various climatic conditions, making it possible to understand the forms sculpted by destructive forces and those originated in depositional environments.

With the analysis of the relief and its constituents we can report moments of formation, providing the possibility of analysis of the conditions of the past reigning at that time with regard to the predominant climatic types in such regions studied, considering that the layers of deposition in the relief are sources of information and records of the acting processes that predisposed the relief in which it can currently be analyzed.

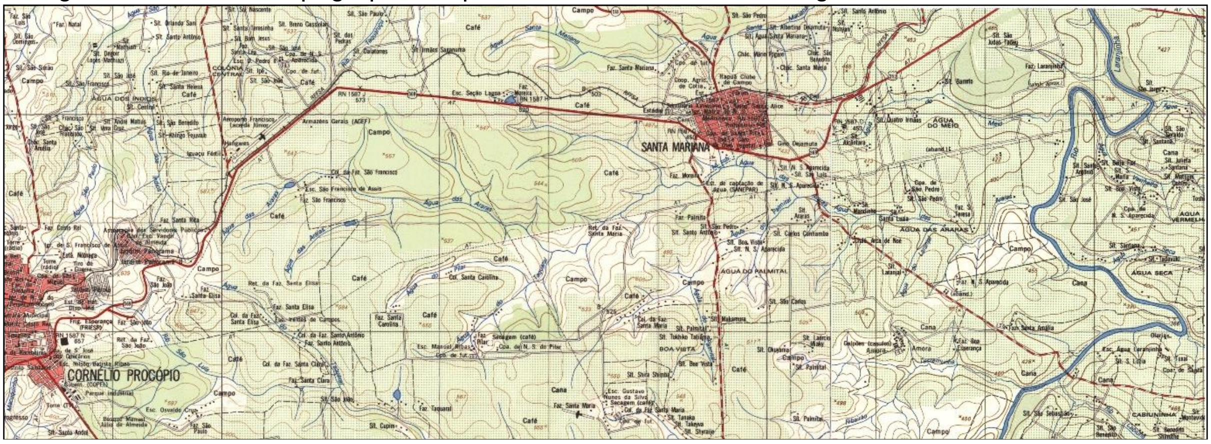
The process of morphometric characterization of a basin becomes one of the most routine procedures used in environmental analyses, such research elucidates the objective of issues related to caring, and executing ways of controlling the place in relation to vulnerability and conflicting anthropological exercises.

Cristofolletti (1972) attributes that many studies can be carried out based on statistical methods, which are interconnected with the scientific representations of today.

The following items were used for the morphometric research in question:

- Topographic map of the Brazilian Institute of Geography and Statistics (IBGE) UTM projection, Cornélio Procópio Folha SF.22-Z-C-I-2 (MI-2759-2) and Bandeirantes Folha SF.22-Z-C-II-1 (MI-2760-1) scale 1:50,000 (Figure 7);
- Digital Camera; GPS for field support; Curvimeto; Planimeter.

Figure 7. Mosaic of Topographic Maps for the delimitation of the Água das Araras Stream Basin.



Fonte: adaptado IBGE, 1990 (Folha SF.22-Z-C-I-2, MI-2759-2); IBGE, 1991 (Folha SF.22-Z-C-II-1, MI-2760-1).

Based on the observations and studies of Campos (2006) and Campos *et al.* (2012) for the morphometric analysis of the Água das Araras stream, where the numerical terrain models (NTM'S) will be used, where they will be given through the cartographic parameters that the geoprocessing systems attribute to us.

In this research, the indices necessary for the analytical study of a hydrographic basin will be attributed, namely (Ross, 1992; Christofoletti, 1980, p. 102-117; Tricart, 1965; Derruau, 1965, Horton, 1945) the fluvial hierarchy, linear analysis, areal analysis and hypsometric analysis.

Since the focus of this work refers to a morphometric analysis, the following steps were predestined to achieve this goal:

Using a Planialtimetric map, the basin and its tributaries will be delimited, where the drainage map will be prepared, making use of the topographic maps of Cornélio Procópio and Santa Mariana, available on the IBGE website, at a scale of 1:50,000 (Campos & Stipp, 2006).

For the hierarchization of the drainage of the area, they will be based on the concepts of Machado (2004) using Horton's formula of 1945 presented by Strhaler in 1952 (*apud* Christofoletti, 1980). Thus hierarchizing the tax courses of the basin.

The length of the main course is measured beyond its tributaries, and the entire area drained by the rivers constituting the Água das Araras basin. Afterwards, the altitudes of the mouth were ascertained using the curve and the planimeter.

For the analytical study of the hydrographic basin, the hydrographic studies addressed in the four items are used, according to Ross (1992), Cristofoletti (1980), Tricart (1965), Derruau (1965) and Horton (1945 *apud* Christofoletti, 1980), the fluvial hierarchy, linear analysis, areal analysis and hypsometric analysis.

The formulas listed for the hydrographic analysis of the Água das Araras stream, in accordance with the items mentioned above, based on the studies by Campos (2006) and Campos & Stipp (2006):

Bifurcation Ratio expressed by the formula (*Rb*):

$$Rb = \frac{Nw}{Nw + 1}$$

where *Rb* is the forking relation; *Nw* is the number of segments of a given order, and *Nw+1 is the number of segments of the order immediately above;*

Weighted bifurcation ratio (*Rpb*): For this index, the *Rb* of each set of two successive orders is multiplied by the total number of channels involved in this relationship; then, the total sum of the products obtained is divided by the total sum of channels found in the basin. The average value found is the weighted bifurcation ratio.

Ratio between the average length of the channels of each order (*Rlm*):

$$Rlm = \frac{Lmw}{Lmw - 1}$$

where *Rlm* is the ratio between the average channel lengths; *Lmw* is the average length of the channels of each order, and *Lmw-1* is the average length of the channels of the next lower order;

Length of the main river: distance from the mouth to the farthest source from it.

Extent of the surface path expressed by the formula (*Eps*):

$$Eps = \frac{1}{2Dd}$$

where *Eps* is the length of the surface path and *Dd* is the drainage density.

Channel gradient expressed by the formula:

$$G = (H - h)X\left(\frac{100}{L}\right)$$

Where H is the altitude of the spring, h is the altitude of the mouth and L is the length of the course.

Sinuosity index expressed by the formula (*Sin*):

$$I\sin = \frac{L}{Lt}$$

where *Isin* is the index of sinuosity; L is the length of the main river and, Lt is the length of the basin axis;

Average Channel Length Expressed by Formula (*Lm*):

$$Lm = \frac{Lu}{Nu}$$

Where Lm is the average length of rivers; Lu is the total length of the rivers and Nu is the total number of rivers;

Basin Area (A):

It refers to the entire area drained by the river system as a whole, supplied in m^2 or km^2, mainly;

Shape of the basin expressed by the sentence (*Ff*):

$$Ff = \frac{A}{L2}$$

Where Ff is the form factor; A is the area of the basin and L is the length of the shaft.

Circularity index expressed by the formula (*Ic*):

$$Ic = 12{,}57\,X\left(\frac{A}{P}\right)$$

where Ic is the roundness index, A is the area of the basin and P is the perimeter of the basin;

Compactness Index expressed by the formula (*Kc*):

$$Kc = 0,28X\left(\frac{P}{\sqrt{A}}\right)$$

where *Kc* is the compactness index, *P* is the perimeter of the basin in km and *A* is the area in km²;

River density expressed by the formula (*Dr*):

$$Dr = \frac{N}{A}$$

Where *Dr* is the density of rivers; *N* is the number of channels; *A* is the basin area;

Drainage density (*Dd*): correlates the total length of the channels with the area of the watershed. The formula *Dd = Lt/A is applied*, where *Dd* is the drainage density; *Lt* the total length of the channels and *A* the area of the basin;

Maintenance coefficient expressed in the formula (*Cm*):

$$Cm = \left(\frac{1}{Dd}\right)X1.000$$

where *Cm* is the maintenance coefficient and *Dd* is the drainage density.

Maximum altimetric amplitude of the basin (*Hm*): altimetric difference between the altitude of the mouth and the altitude of the highest point of the topographic divide;

Relief ratio expressed in the formula (*Rr*):

$$Rr = \frac{Hm}{Lb}$$

Where *Rr* is the relief relation; *Hm* is the maximum topographic amplitude and *Lb* is the length of the basin;

Roughness index expressed in the formula (*Ir*):

$$Ir = HxDd$$

Where *Ir* is the roughness index; *H* is the altimetric amplitude and *Dd* is the drainage density.

Compactness Index expressed in the formula (*Kc*):

$$Kc = 0{,}28X\left(\frac{P}{\sqrt{A}}\right)$$

Where *Kc* is the compactness coefficient, *P* is the perimeter (*m*) and *A* is the drainage area (m2).

Through these variables, Campos & Stipp (2006) and Stipp; Fields; Caviglione (2010) propose the creation of a table of results necessary for the systematization of the data.

From a UTM projection base, a mosaic of scale 1:38.461 was taken, thus, in an analog way, the physical data of the basin area were obtained, then first delimiting the water dividers (Figures 8 and 9).

Figure 8. Data collection analogously.

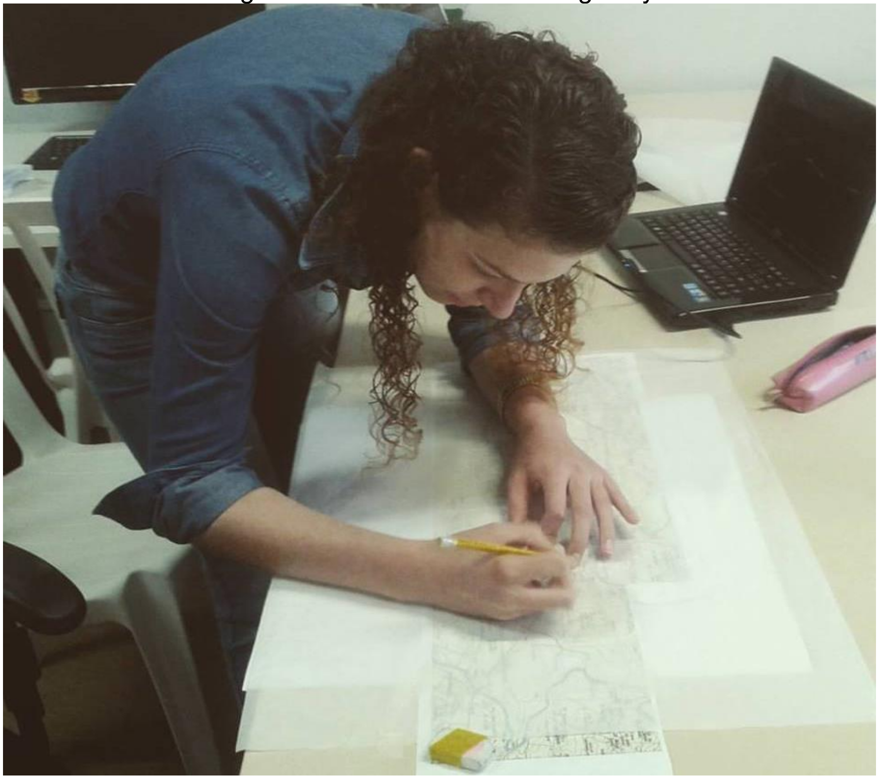


Photo: Authors, 2016.

Figure 9. Acquisition of physical data using analog methods – topographic map.

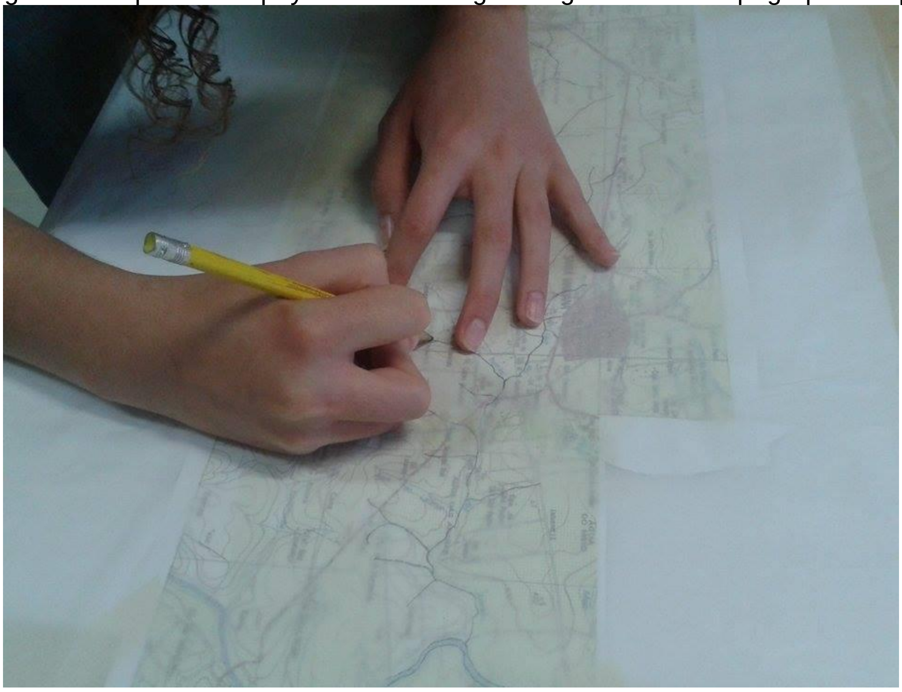


Photo: Authors, 2016.

With the use of the curve, the measurement in centimeters of the channels I, II, III and VI was performed and the chart scale was applied.

For the perimeter calculation: the area of the basin was multiplied by the scale and transformed into kilometers.

For drainage area: with the use of the Planimeter, measurements were made in the composition using the measured scale of 1:38.461.

Sinuosity index: emphasizing the formula of the same, with the main river divided by the axis of the basin.

Drainage area: with the use of the altimeter, measurements were taken and converted into km^2.

The other calculations of the systematized information were spreadsheets according to the methodology proposed by Campos *et al.* (2012).

RESULTS AND DISCUSSIONS

Table 1, a data systematization table, demonstrates the fluvial hierarchy proposed by Horton (1945) and the relationship between the number of channels and the length of the channels in each order of the Araras Watershed, developed by Campos & Stipp (2006). We can observe the presence of 39 first-order channels, 9 second-order channels, and one third-order channel, plus the main course, totaling 49 channels.

Table 1. Number of channels and length of channels in each order of the Araras basin.

Channel Order	No. of Channels	Length of Canals in km
First	39	33.07646 Km
Second	9	19.2305 Km
Third	1	6.15776 Km
4th	1	17.69206 Km

Source: Adapted from Campos & Stipp, 2006.

Table 2 of calculations aims to demonstrate the morphometric parameters of the Araras Hydrographic Basin. Table proposed by Campos & Stipp (2006). In it we can observe the numbers obtained with the quantification of the equations previously arranged, with regard to the axis of the basin, length of the main channel, average length of the channels, drainage density, density of the rivers, extension of the surface course, sinuosity index, relief ratio, roughness index, maintenance coefficient, form factor, compactness index, circularity index, maximum and minimum altitude, altimetric amplitude, total length of the channels, number of channels, main gradient and in addition to these items, table 2 delimits the relationship of segments, bifurcation relationship between them, quantifies according to Horton (1945) the right and left tributaries of the study area and their average lengths and bifurcation index.

Table 2. Morphometric Parameters of the Hydrographic Basin of the Água das Araras Stream.

DATA OBTAINED	BASIN
Perimeter	36.92256 Km
Drainage Area	47.59 km²
Eixo goes to Bacia	16.15 Km
Main Channel Length	17.69206 Km
Average Channel Length	1.55422 Km
Drainage Density	1.6002685544 km/km2
River Density	1.02963 canals/km2
Extension Surface Path	31,24
Sinuosity Index	1,087
Relief Ratio	14.67 m/Km
Roughness Index	379,263 m/(Km/Km2)
Maintenance Coefficient	62,489 m2/m
Form Factor	0,182
Compactness Index	1.49856 m/m2
Circularity Index	0,428
Maximum Altitude	609 m
Minimum Altitude	372 m
Altimetry Amplitude	237 m
Total Length of Channels	76,15678 Km
Number of Channels	49

Number of Springs					49		
Main Channel Gradient %					1,34%		
Basin Order					4th Order		
Order	Number of segments			Fork ratio	Average length of the channels	Relationship between the average channel length index and the bifurcation index	Relationship between the average length of the channels
	D	And	T				
First	25	14	39	4,33	848,11 m	0	0
Second	7	2	9	9	2.137,22 m	0,28	2,520
Third	1	0	1	1	6,157.76 m	2,881	2,881
4th	1		1	1	17,692.06 m	2,873	2,873

Source: Adapted from Campos & Stipp, 2006

The 1st order channels along the entire area of the basin show a system with good surface drainage, mainly due to the type of soil existing in the study area, derived from basalt, with high percentages of clay in its composition. However, asymmetry in the distribution of drainage is perceived, possibly due to structural and planialtimetric constraints.

With a Form Factor expressed by the index of 0.182, close to 0, it indicates an elongated hydrographic system, characteristic of drainages in plateau areas, where vertical dissections are even more intense.

With a sinuosity index of 1.087, they fit the characteristics of plateau drainage, with little sinuosity, defined mainly by structural constraints. Indices above 2.0 characterize drainage with meandering formation, commonly found in regions of low slopes, more characteristic of plains.

The altimetric amplitude of 237m (Table 2) demonstrates a cohesive slope not so flat providing a better distribution of the watercourse, also resulting from the factor expressed by the Form factor.

Indicating that the data collected inhibit possible environmental disasters such as floods, environmental vulnerability and the occurrence of natural risks of siltation. However, it is necessary to study the natural anthropic risks given that the Água das Araras stream has several monoculture plantations.

The basin demonstrated through the results, to have a considerable structural condition, resulting from its lithology, allied to the morphoclimatic and planialtimetric processes.

THE APPLICATION OF MORPHOMETRIC ANALYSIS IN THE TEACHING OF GEOGRAPHY, SCIENCE AND MATHEMATICS

The morphometric analysis of a hydrographic basin, such as the Água das Araras Stream, opens a significant opportunity for interdisciplinary teaching, involving areas of Science, Geography and Mathematics. This study, by developing the physical characteristics and processes that shape the natural environment, allows students a deeper understanding of ecological interactions and the consequences of social actions on environmental resources.

For education in Geography, the study of the river basin facilitates an in-depth understanding of the organization of geographic space and the relevant training processes. Analyzing the data collected, such as river routes and the distribution of the drainage network, helps students understand how rivers and their conduction networks shape the relief over time. Cartography is another key area here, encouraging students to construct and interpret maps of the watershed and its tributaries, identifying watersheds, altitudes, and relief configurations. These hands-on mapping activities allow students to relate physical geography to human impacts on the landscape, stimulating discussions about sustainability, soil management, and water resource management.

In the teaching of Science, this analysis enables a rich discussion about geomorphological and hydrological processes. Based on the research, students can check how a watershed contributes to the maintenance of ecosystems and the preservation of biodiversity. The hydrographic basin under study, which includes preservation areas such as the São Francisco Forest, an example of a remnant of the Atlantic Forest, provides students with a practical understanding of the importance of preserved areas and their contribution to water and soil quality. Environmental impact analyses, based on the data collected during the study, reveal how agricultural practices and land use can significantly alter the ecological balance of the watershed. Thus, the discussion on topics such as biodiversity and conservation leads students to reflect on the importance of environmental preservation as a means of ensuring the sustainability of local and regional ecosystems.

Mathematics becomes an essential link in this context, translating morphometric data into quantitative analyses that support the study. By applying calculations of area, volume and slope, students can understand in practice how mathematics applies to watershed studies. Indices such as density of variation and maintenance coefficients allow students to become familiar with data analysis and the use of mathematical equations to solve real problems. Working with river density statistics, students can interpret tables and graphs, developing the ability to analyze and compare environmental data. Mathematical simulations of water flows, based on channel gradients, offer a practical insight into how mathematical models help predict natural features and understand sustainability challenges.

Exploring these themes, the study of the Água das Araras Stream Basin promotes active and contextualized teaching, where the application of scientific and quantitative methods provides an integrated view of natural processes and human responsibilities in relation to the environment. This interdisciplinary approach in education not only strengthens students' theoretical knowledge but also fosters critical awareness of the importance of preserving and using environmental resources responsibly.

In addition, this interdisciplinary approach in the analysis of the watershed of the Água das Araras Stream allows teachers and students to make connections between the applied content and local environmental problems. Investigating the effects of soil orientation and occupation on the quality of water resources, students not only apply theoretical knowledge, but also engage in reflections on current issues of socio-environmental sustainability.

For example, studying the influence of riparian vegetation on water quality and margin stability encourages students to analyze the importance of preserved forests for maintaining nutrients and preventing degradation, which is crucial for the conservation of aquatic ecosystems. This practical analysis reinforces the understanding of how deforestation and the expansion of monoculture can generate negative impacts, promoting reflection on sustainable agricultural practices and the development of alternative land use practices that respect ecological balance. The interpretation of the indices obtained allows us to understand how different geographic and environmental variables interact and how changes in these configurations can affect the hydrological behavior of the watershed. Thus, using quantitative methods to observe and interpret physical issues, students experience the applicability of mathematics in real-world scenarios, understanding how science and mathematics work together to solve complex problems in environmental studies.

In addition, this educational proposal fosters a practical and experimental approach, where students can carry out fieldwork for data collection and comparison with theoretical studies. Collecting water samples, measuring parameters such as pH, turbidity and water flow, and comparing these data with the indices calculated in the study offer valuable empirical experience. This type of activity provides students with a tangible understanding of the geomorphological processes and hydrological interactions that were discussed in the classroom. In addition, by experiencing these processes directly, students become more critical and aware of the importance of importance.

FINAL CONSIDERATIONS

The initial questions that led to this work were quickly elucidated, and it became evident that there was no published physical data about the study area, nor a draft of environmental planning.

The geomorphological data collected about the basin and the understanding of its morphological system will provide conditions to subsidize the planning of land use and occupation in this geographical space, considering in the process its limitations and enhancing the use of physical resources with less environmental vulnerability.

Obtaining data manually in a world of technology, where there are advanced GIS'S that could give faster results, is to turn to the teaching factor. In the geography degree we will have the objective of teaching students how to carry out a morphometric analysis work, and demonstrating such a feat by hand provides us with better knowledge in addition to being a challenge for few due to their need for attention and knowledge so that there are no susceptible errors.

Using the concept of hydrographic basin as an ecosystem unit in the area of environmental planning and morphometric analysis, Villela & Mattos (1975), constituting elements of great importance for the evaluation of its hydrological behavior, thus, establishing relationships and comparisons between them and known hydrological data, it is possible to indirectly determine the hydrological values in places where data are lacking.

Christofoletti (1969) determines that the analysis of aspects related to drainage, relief and geology can lead to the elucidation and understanding of several issues associated with local environmental dynamics. It is worth remembering that none of these indices act in isolation, and should be understood as capable of simplifying the complex dynamics of the basin, which even has a temporal magnitude.

Morphometric studies in areas of hydrographic basins produce knowledge necessary for society, regarding better territorial management, directly subsidizing the management of water resources, both for public supply and for agricultural production and hydroenergy.

In short, the study of the Água das Araras Stream Basin, based on our morphometric analysis methods, is configured as a powerful tool for interdisciplinary teaching. By integrating concepts from Geography, Science and Mathematics, students can visualize the complexity of natural systems and their intrinsic relationship with human activities. With this experience, they not only broaden their theoretical understanding, but also develop an ecological awareness and environmental responsibility, which are essential to face the contemporary challenges of socio-environmental sustainability.

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