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Papers

Drainage Network Planning and Analysis Based on Image Segmentation - an Application in the Bandeirinha Stream - Formosa, State of Goiás, Brazil

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Abstract

The present research aimed to demonstrate the feasibility of using image segmentation for better drainage extraction, automated drainage network hierarchization and main channel definition based on Horton (1945). The test area for the applications was the Bandeirinha Stream Hydrographic Basin (BSHB), which is located in the municipality of Formosa, in the state of Goiás, Brazil. The study used the Shuttle Radar Topography Mission (SRTM), with a spatial resolution of 1" x 1" (one arc second). The SRTM segmentation was performed using the Python language ODR_Obia algorithm, inserted with a QGIS plugin. Through the QGIS platform, the ODR_Hidro plugin was used to perform the delimitation of the BSHB, the extraction of the drainages and the definition of the main channel. The results were validated in the field and evaluated from the manual definition of the main channel. That was done using both the data produced by the application and the drainage data contained in the vector base of the topographic maps of the Army of Geographic Service (AGS), at the scale of 1:100,000 and 1:25,000. From the results obtained, it can be inferred that the ODR_Hidro model used for the delimitation of the BSHB, the automated hierarchization of the drainages and the definition of the main channel from the segmented SRTM image is very efficient. The field validation demonstrated its effectiveness by proving the existence of first-order drainages which are not mapped on the DSG chart at a scale of 1:100.000. This leads to the conclusion that the use of the proposed tools and the inclusion of image segmentation, aiming for the extraction of drainage network and geomorphometric characterization of watersheds, can efficiently contribute to the provision of morphometric data.

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INTRODUCTION

The studies related to the physical aspects of watersheds (WS) as spatial units are increasingly frequent and provide important information for environmental planning and management of water resources. It would be impossible to conceptualize fluvial geomorphology without mentioning a few established authors, who have provided valuable contributions to the field of geomorphology.

Davis (1899) introduced the watercourses in three main structures (young, adult and senile phases), according to their evolution. Leopold and Wolman (1957) presented these terminologies: straight, meandering and braided rivers. Schumm (1963) developed a classification based on description and interpretation, related to stability (stable, erosive, depositional).

More recently, authors like Kondolf and Piegay (2016), Marçal et al. (2017) Brierley et al. (2019) and Fryirs et al. (2019), have discussed the importance of classifying drainages, in order to facilitate the analysis of fluvial processes.

Historically, the watershed of a river was conceptualized by the authors Maksoud (1961), Bigarella et al. (1970), Christofoletti (1980) and Leal and Tonnello (2016), as a topographically defined area, drained by a main watercourse, or connected system of watercourses, which has a simple outlet from which the entire effluent flow can be discharged.

The importance of studying drainage patterns, for their capacity of providing information related to relief characteristics and long-term transformations are highlighted by Silva et al. (2020); Lavor et al. (2020) and Bertolini et al. (2021).

Initially, the hierarchy process of the drainage network was done manually. Later, with the advent of the Geographic Information Systems - GIS, other procedures were added, using orbital products such as SRTM - Shuttle Radar Topography Mission. (LEITE et al., 2012). Among automated procedures, it is worth mentioning the data model of ArcHidro which was incorporated into ArcGIS 10. QGIS introduced the QGIS *Hydrological Applications*. However, this article hopes to demonstrate another model based on the process of segmentation, applied to SRTM images, based on Horton's model of hierarchization.

The usage of geotechnological tools for morphometric analyses has been presented by many authors: Tretin et al. (2015) mentioned better agility in gathering and processing data; Scheren Robaina (2019) explained the use of Geographic Information Systems and Terrain Digital Models. In the literature of this area, we can also identify researchers that attempted to automatically classify the terrain, integrating topographical data, amongst which we highlight: Padilha and Souza (2017), who identified the morphometric characteristics of Rio Carapá in Mato Grosso; Magalhães and Rodrigues (2020), who analyzed the morphometry of Rio Santo Antônio and Ribeirão Grande, in Serra da Canastra, Minas Gerais; Bertolini (2021) analyzed the indicator for maturity from morphometric indexes in the hydrographic area of Várzea no Rio Grande do Sul.

The segmentation of satellite images consists of discriminating and subdividing the objects of interest contained therein (FERREIRA et al., 2013). Several authors have used the segmentation of images for studies in watersheds, aiming to analyze issues linked to vegetation cover, such as Romstad and Etzelmüller (2009), Cavalli, et al. (2013) and Doubrawa et al. (2014). However, only the study by Oliveira (2019) used this technique for hierarchizing drainage networks.

This paper aims to develop, test and validate the drainage network hierarchization and the automated definition of the main channel, based on Horton (1945), using the hydrological model ODR_Hidro, indicated by Oliveira (2019), which proposes the use of SRTM image segmentation to obtain better quality in the hierarchized drainage network. In order to achieve this, statistical analysis was applied, considering the standard deviation model and the differences found in calculated samples for each of the coordinates in the E axis and N axis, using the statistic Mann-Whitney *U* test in order to evaluate the differences in coordinates for the discovered bifurcations. Such positional analyses have already been utilized by Santos et al. (2015).

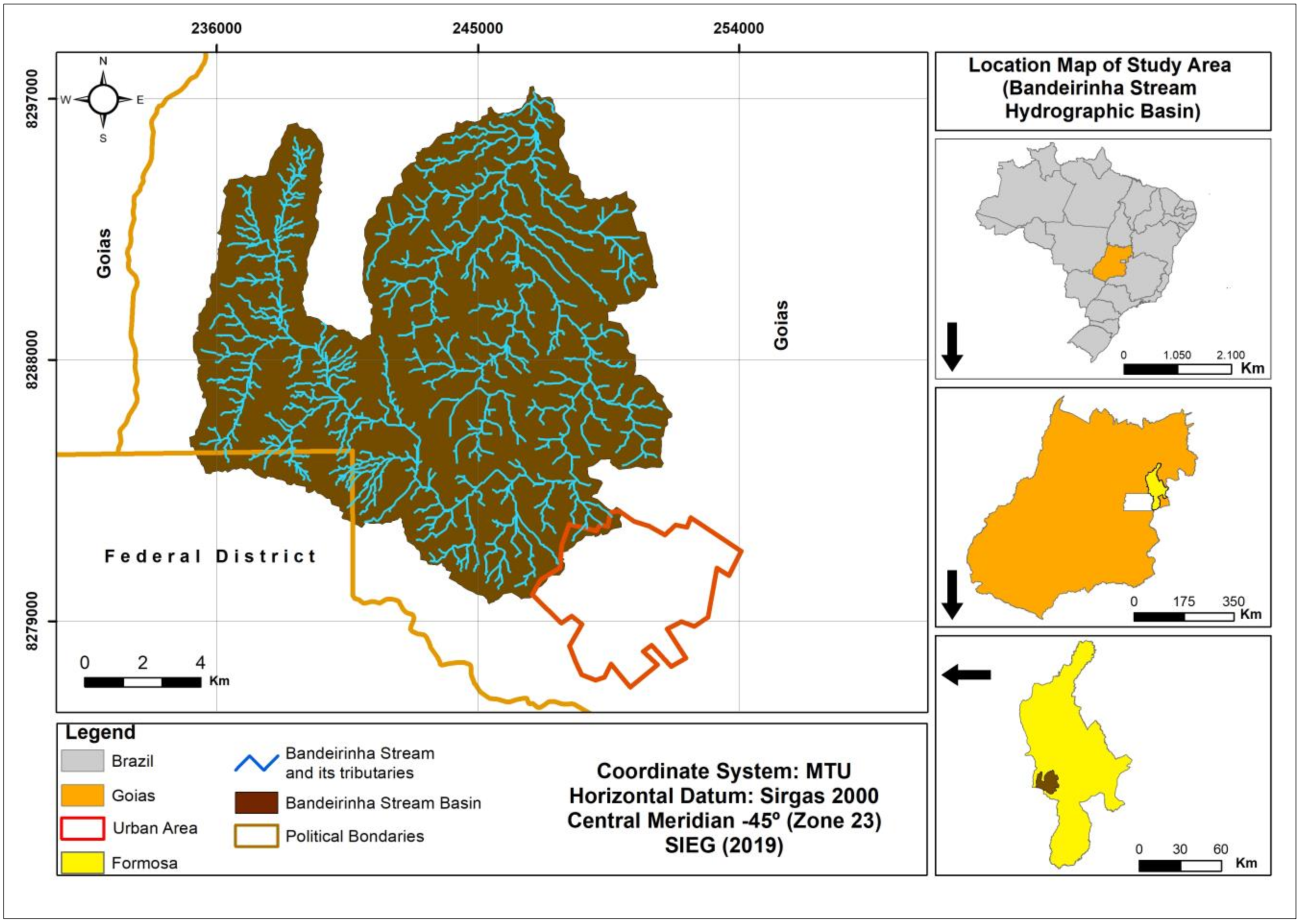
MATERIALS AND METHODS

The study area is the Bandeirinha Stream Hydrographic Basin BSHB (Figure 1), located in the central meridian (-45º), zone (23), between coordinates MTU N-8284826.96 and E-235380.96 and coordinates MTU N-8297454.09 and E-247147.25, occupying more than 180 km² of surface extension and approximately 92 km of perimeter. The highest part of the basin is located between the Maranhão River Plateau, the Federal District Plateau, and the Rio Preto/Paranã Divisor Plateau. The lower part of the basin belongs to the Vão do Paranã geomorphological unit. The BSHB is a sub-basin of the Paranã River, which in turn belongs to the Tocantins/Araguaia basin.

The Bandeirinha stream source is located near the border of Goiás state with the Federal District and has an altitude of 1,212 m. Along its course, the Bandeirinha stream is marked by hilly terrain. The stream is of fundamental importance to the municipality and is the city's main drinking water source. The sanitation company of the State of Goiás - SANEAGO (OLIVEIRA, 2019) does its capture. Saneago is a Brazilian company, concessionaire of basic sanitation services in Goiás.

According to Pimenta et al. (2015a), three types of soils are found in the Bandeirinha stream watershed: red and red-yellow latosols, cambisols and neosols (Figure 2). The geology, also seen in Figure 2, consists of the Bambuí group, including the Paraopeba subgroup, which is represented by the upper Neoproterozoic metasedimentary sequence. This sequence is characterized by glaciogenic sedimentation, followed by three regressive megacycles developed in metamorphic rocks with little resistance to erosion, such as siltstones, argillites and limestones (PIMENTA et al., 2015a).

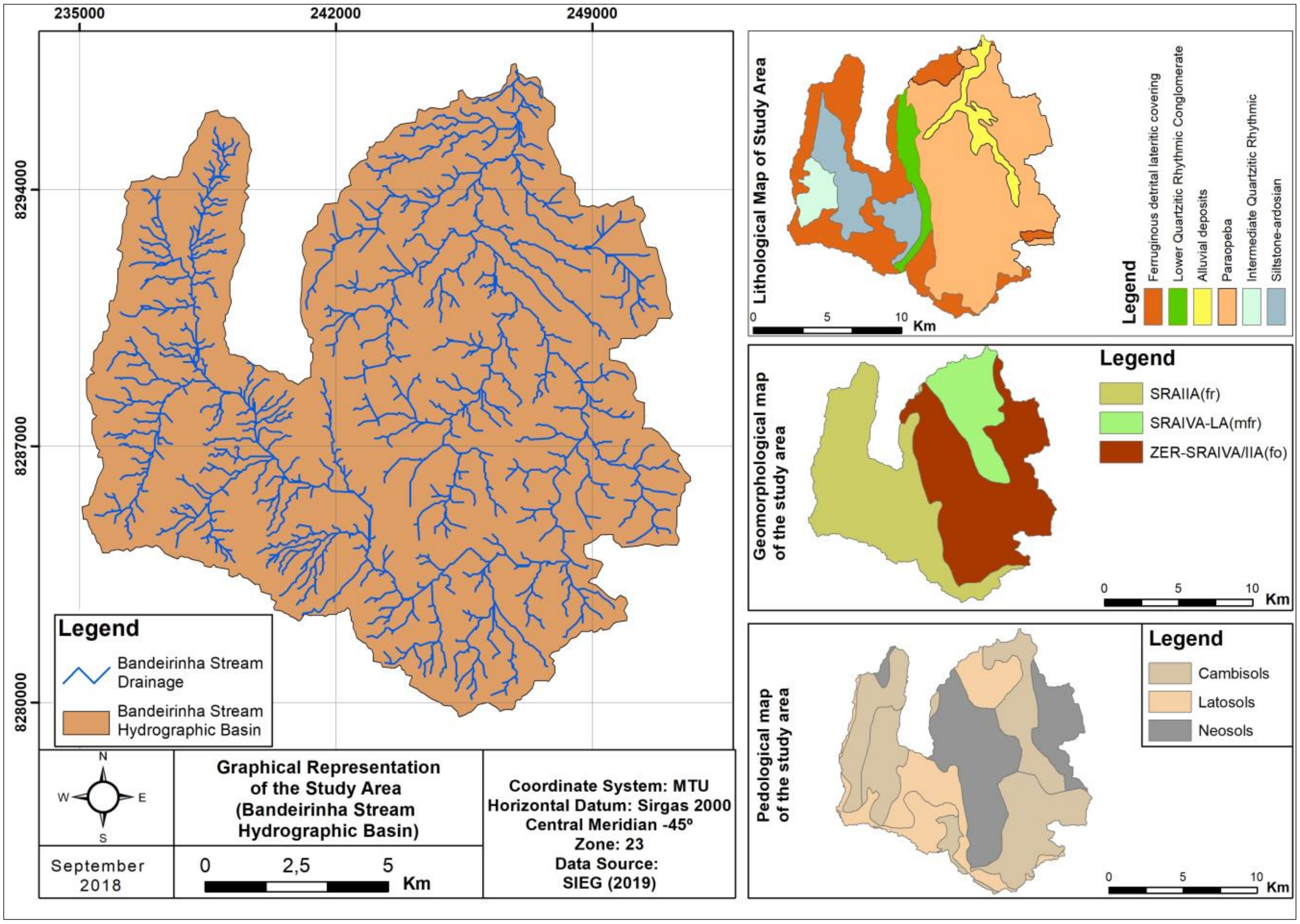
Figure 1 – Location Map of Study Area



Source: Oliveira (2019).

The geomorphology consists of the Flattening Regional Surface IV-A - SRAIVA, starting point of the Vão do Paranã formation in the State of Goiás, specifically in the axis Porangatu - Crixás (LATRUBESSE; CARVALHO, 2006). The predominant vegetation belongs to the cerrado biome, which corresponds to more than 23% of the Brazilian territory (MARTINS et al., 2015). According to Köppen's classification, the study area belongs to the tropical climate domain, having two well-defined seasons Aw and variations to high altitude tropical climate CWa (OLIVEIRA et al., 2018).

Figure 2 - Physical aspects map of the study area.



Source: Oliveira (2019).

METHODS

For the development of this research, the following data and software were used: SRTM image, obtained from the United States Geological Survey (USGS) website with 30 m spatial resolution; topographic maps of the Army Directorate of Geographic Service (ADGS), at scales 1:100,000 and 1:25,000. The SRTM segmentation was performed using the Python language ODR_Obia algorithm, inserted with a QGIS plugin. For watershed delimitation, drainage extraction, drainage network hierarchization, and main course definition, the ODR_Hidro model was used. The model consists of a script, implemented in Phyton language, accessed through the QGIS platform, used for delineating geomorphometric features of watersheds. For the remaining procedures, the software packages QGIS v 2.18.19 and ArcGIS Desktop Advanced - Esri v 10.5 were used.

In order to evaluate and identify the better scale for the generated drainage network, we utilized data from Oliveira et al. (2020), wherein the bifurcation coordinates created by the drainage network were compared, using ODR_Hidro, to the same bifurcations extracted from IBGE maps in the scales of 1:100.000 and 1:25.000.

After data acquisition, clipping and definition of the reference system (SIRGAS 2000 MTU, Zone 23S), the SRTM was treated using ArcGIS 10.5. The fill sink tool was applied to correct possible spurious errors, thus generating the consistent digital elevation model (DEM) of the study area. After that, the DEM was segmented. The following extraction of the drainage network, the delimitation of the BSHB and the ordering of the drainage network were performed in a fully automated way using ODR_Hidro (OLIVEIRA, 2019) and having the segmented DEM as a product.

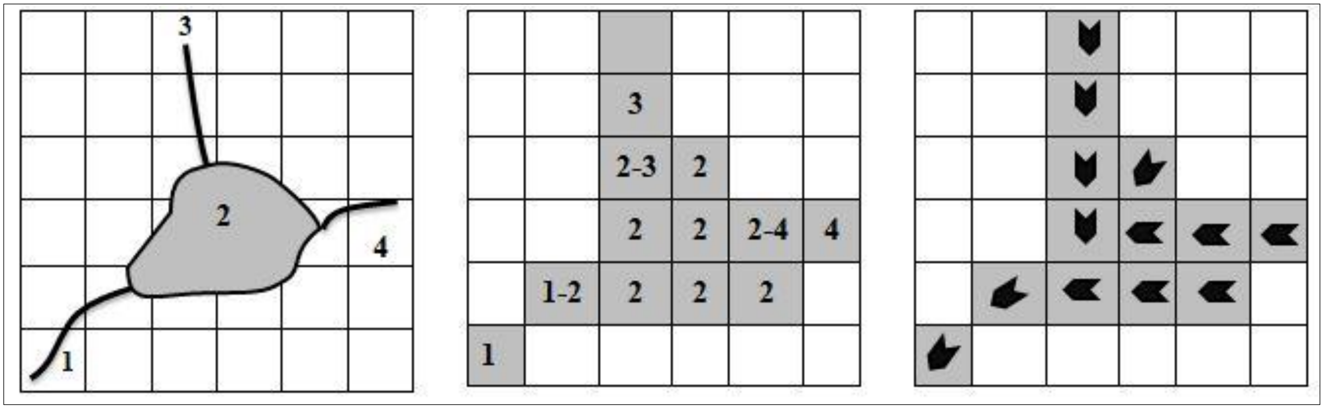
SRTM Segmentation

Before performing the segmentation, the ODR_Obia algorithm checks the size and the possibility of the image being segmented into a single scene. If necessary, ODR_Obia adjusts the image to start the segmentation process. If the image size is compatible with the prerequisites set in the TA Baatz Segmenter algorithm, as proposed by Baatz and Schaрe (2000), the segmentation is performed. However, if the image exceeds the established prerequisites, ODR_Obia (OLIVEIRA, 2019) will slice the image into several tiles to perform the segmentation of each tile. After the segmentation of all tiles, a "Merge" is performed to join all tiles, making the attributes of the average altimetry of each pixel available in raster and vector formats (OLIVEIRA, 2019). After that, the user loads the SRTM image and provides the parameters for segmentation in ODR_Obia.

Extraction, channel ordering and main channel definition

The extraction and ordering of the channels were performed using the fill sinks methodology proposed by Wang and Liu (2006). This was done to eliminate the possible spurious errors and correct possible failures, both in the filling and in the elevation removal. The Deterministic Infinity - D∞ model (Figure 3), proposed by Tarboton (1997), was used to determine the direction and accumulation of the flow in the SRTM segmented image. It is based on the segmentation pixels, which contain the average altimetry. In order to determine the accumulation flow raster (Figure 3), the ODR_Hidro model also uses the Deterministic Infinity - D∞ algorithm. The method is based on the estimation of the catchment area and is defined as the sum of the surface areas of the cells where runoff contributes to a point in question (FERNANDEZ et al., 2012).

Figure 3 - Representation of the cumulative flow with the D∞ algorithm



Source: Adapted from Sobrinho et al. (2010).

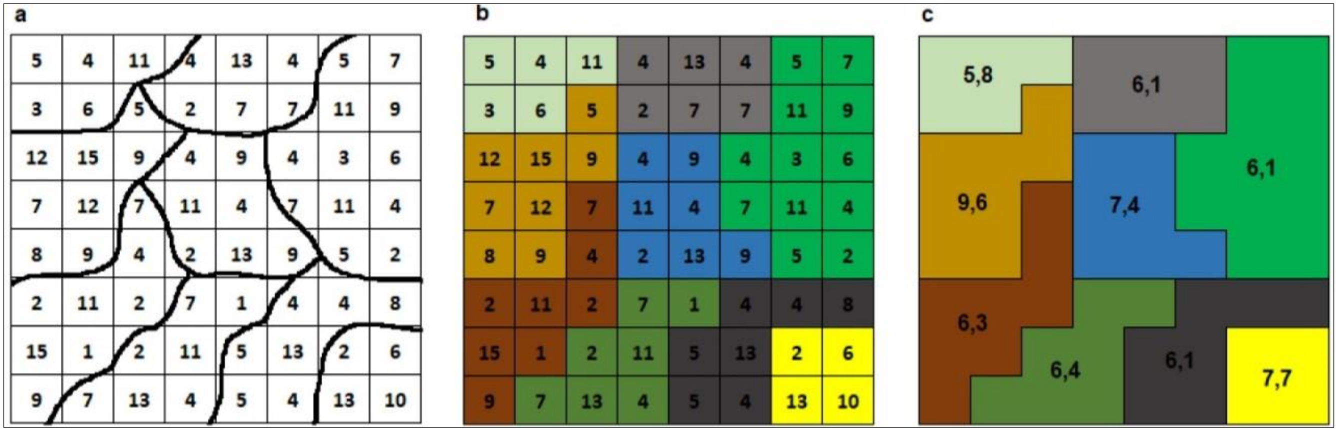
In order to estimate flow directions for the calculation of the accumulated areas with continuous passages of 3 x 3 mobile windows, considering the highest slope of their neighbors, ODR_Hidro uses the Deterministic Infinity - D∞ method (FERNÁNDEZ et al., 2012). The value of the catchment area is confronted with a threshold, which represents the minimum area necessary for the definition of the channels, from which the drainage lines will be started. When using ODR_Hidro, the "filled_file" threshold for channel network densification allows a network with a higher or lower number of channels to be generated (OLIVEIRA, 2019). High threshold values generate less dense drainage networks and lower values produce denser drainage networks. The delineated channel network is divided into segments, with each one being part of a stream with start and end points coordinates (TARBOTON, 1997). Based on Horton's (1945) model, the ODR_Hidro used the filled_file threshold for determining the main channel.

Basin delimitation

For the delimitation of the basin, the segmented SRTM was used. The segments altimetric quotas average values are extracted in function of the grouping of the closest neighbor pixels with the central pixel, using similarity criteria (in this case, closest altimetric quotas). Thus, each segment takes the average of the altimetric coordinates values where it overlaps in the original image.

For a better understanding of the segmentation process, Figures 4 A, B and C present a scheme of an image showing the stages of its segmentation. Figure 4A shows the intersection of segmentation within any binary grid while figure 4B shows the process of grouping these pixels. Figure 4C shows the definition of these segments, assuming the average of the grouped pixels within each segment.

Figure 4 - (A) segmentation intersection with an image; (B) image pixels grouped by the segmentation; and (C) segments assuming the average of the pixels within each grouping.



5	4	11	4	13	4	5	7
3	6	5	2	7	7	11	9
12	15	9	4	9	4	3	6
7	12	7	11	4	7	11	4
8	9	4	2	13	9	5	2
2	11	2	7	1	4	4	8
15	1	2	11	5	13	2	6
9	7	13	4	5	4	13	10

Source: Oliveira (2019).

The procedure for delimiting the basin chosen for this research started with the identification of its mouth, which must be marked on the raster data. The basin limit surrounds all the springs and water courses. The hilltops were determined using the value of the average of all pixels that overlap the segments that were grouped, always observing the drainages flow direction (OLIVEIRA, 2019). It should be stressed that the segmentation changes the value of each pixel based on the values of neighboring pixels, so the value to be used is the average of the pixels that make up the segment. Thus, all pixels that compose the same segment or object in the segmented image will have the same value, providing greater accuracy to the segmented DEM (OLIVEIRA, 2019).

After obtaining the results, the information validation stage was initiated. Superposition of the topographic chart vector data with ODR_Hidro vector data was performed. Additionally, field visits were carried out to verify the existence of the drainages mapped by ODR_Hidro and to identify the divergent points, that is, the bifurcations contained in the ODR_Hidro maps that were not present in the AGS topographic chart at the scale of 1:100.00.

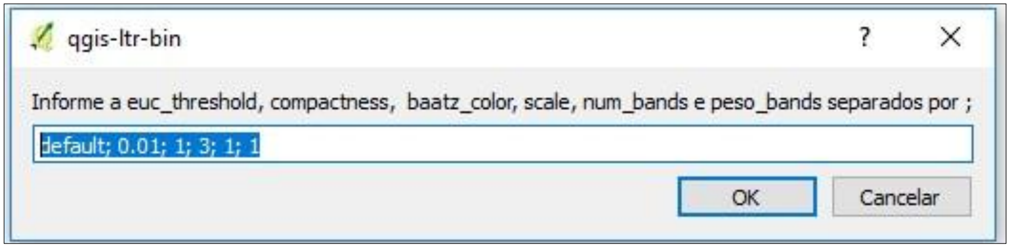
The procedure was carried out with the use of a pair of dual-frequency geodesic GPS receivers - L1/L2, which enabled the collection of field data referring to the coordinates of channels bifurcations. These points coordinates were identified and stored in a database that already contained the coordinates extracted from the AGS maps. The data collected *in loco* allowed a comparison between both coordinates - field data and AGS maps. The drainages obtained from the ODR_Hidro model were superimposed on the drainages contained in the vector base of the AGS topographic maps, MI - 2216 - FORMOSA-SD-23-Y-C-V and MI - 2272 - VILABOA-SD-23-Y-C-II, 2nd Ed. 2006, scale 1:100,000, in order to verify if the drainages mapped by ODR_Hidro were compatible with the drainages in the maps. After this verification, some drainages mapped by the ODR_Hidro model that were not in the vector base of the AGS chart were selected. The E and N coordinates of the bifurcations of the drainages contained in the AGS topographic maps in vector format were extracted using the Feature Vertice To Point function of ArcGIS.

RESULTS AND DISCUSSION

Segmented Srtm Using Odr_Obia

With the input thresholds set (Figure 5), the "compactness - shape parameter (0.01)" provided better clustering of the pixels, representing less compact and more spread-out objects. The scale factor (1.3) determined the average size of the object to be created resulting from the segmentation. The higher the assigned value, the larger the segments produced and, consequently, the smaller the quantity of segments created. However, a lower value assigned for this parameter means that smaller segments are created in larger quantities. It is worth noting that the new drainage channels generated by ODR_Hidro were identified and validated in the field (Figure 6 A, B and C).

Figure 5 - Thresholds used to segment the SRTM.



qgis-ltr-bin

Informe a euc_threshold, compactness, baatz_color, scale, num_bands e peso_bands separados por ;

default; 0.01; 1; 3; 1; 1

Source: Oliveira (2019).

Besides the validation, the generated data were verified by means of comparison with the ADGS topographic chart. The production of the new segmented image, properly modified by the segmentation scale factor, brought the average value of the grouped pixels assigned to each segment. The grouping of these pixels allowed the separation of the altimetry classes, which were transformed into homogeneous segments by joining the average altimetry of the grouping of the respective pixels.

Figure 6 - (A) Coordinate collection in drainage mapped by ODR_Hidro; (B) Coordinate collection in bifurcation mapped by ODR-Hidro; (C) Coordinate collection at the junction of two bifurcations.

Source: Oliveira (2019).

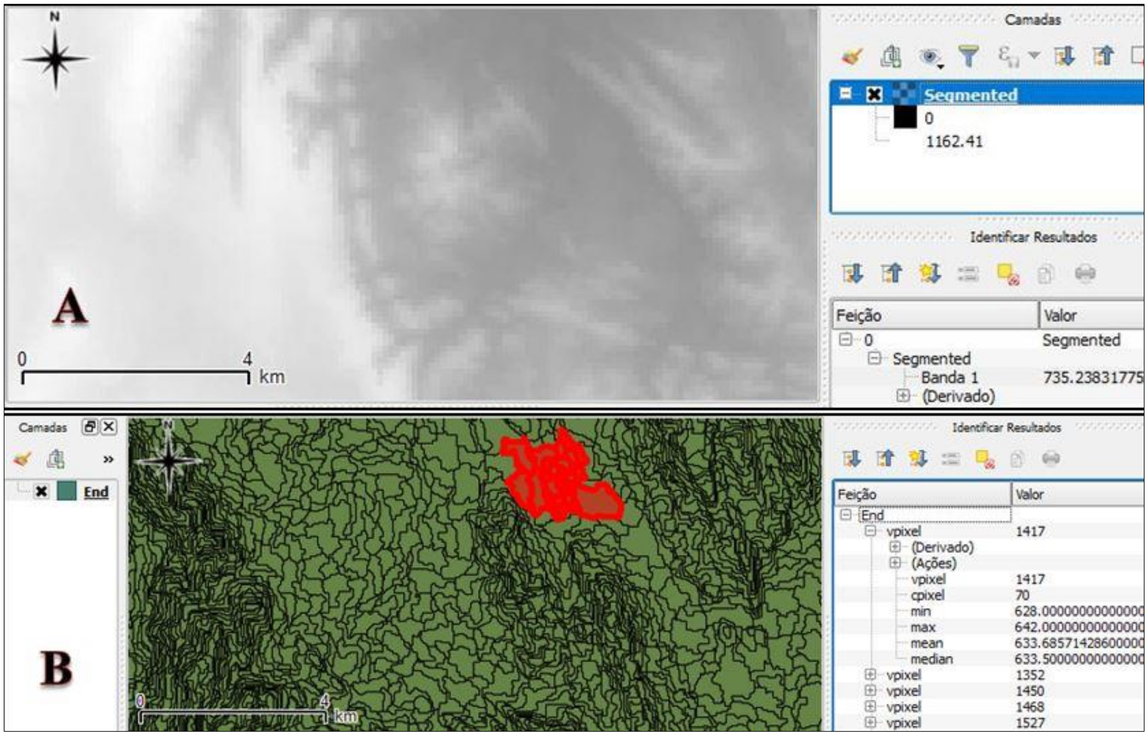
The production of a new raster image through segmentation of the SRTM made it possible to improve the raster image used for mapping with ODR_Hidro. Using the segmented image, the model possibly mapped at a better scale than that of 1:100,000, which is compatible with the original SRTM. That is evidenced by the number of drainages mapped that were validated in the field, as well as its comparison with the ADGS chart.

The field validation occurred through the collection of points in loco, in order to obtain the coordinates of the bifurcations and the photographic record of the points collected. For the fieldwork, a Topcon Hiper dual frequency (L1/L2) GNSS receiver and the Topcon Tools software were used to process the collected points. The points collected were processed and adjusted to the SIRGAS UTM 2000 reference system, zone 23, for which the precision established for processing followed specifications contained in the Technical Standard for Georeferencing Rural Property (NTGIR).

The image was segmented after the introduction of the segmentation parameters (Figure 5), which resulted in two files, one raster and one vector (Figure 7 A and B). Using field validation and the ADGS topographic chart as comparison parameters, the thresholds chosen for the segmentation provided the objects that most closely resemble the reality of the terrain. Usually, images are attributed a value weight from zero, where zero implies disregarding the image for the segmentation process. In this case, the image was considered as having a weight value of 3.

The altimetric values of the new segmented DEM obtained from the raster segmentation brought with it the average value of the grouped pixels assigned to each segment. The grouping of the pixels after the classification resulted in the separation of altimetric classes, which were transformed into homogeneous segments composed by joining the average altimetry of the grouping of the respective pixels. The generated raster (Figure 7 A) and vector (Figure 7 B) files brought the altimetric values of the new segmented DEM which were used in the processing for channel extraction and basin delimitation. However, for the extraction of these objects, only the raster image was used, which brings with it the average pixel value of the already segmented image.

Figure 7 (A) Segmented SRTM raster image; (B) Segmented SRTM vector image. Both have corrected altimetry.



Feição	Valor
0	Segmented
Segmented	
Banda 1	735.23831775
(Derivado)	

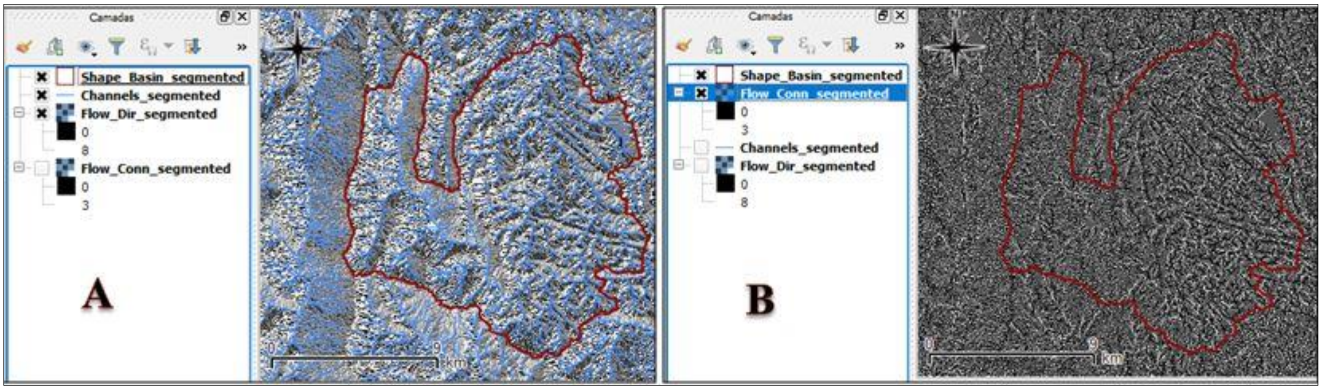
Feição	Valor
End	
vpixel	1417
(Derivado)	
(Ações)	
vpixel	1417
cpixel	70
min	628.000000000000
max	642.000000000000
mean	633.685714286000
median	633.500000000000
vpixel	1352
vpixel	1450
vpixel	1468
vpixel	1527

Source: Oliveira (2019).

CHANNELS AND BANDEIRINHA STREAM HYDROGRAPHIC BASIN

After the SRTM segmentation, the ODR_Hydro model defined the flow directions for the calculation of the accumulated areas, what is known as "accumulation flow". It started from the highest elevation and considered the highest slope of its neighbors (Figure 8 A and B).

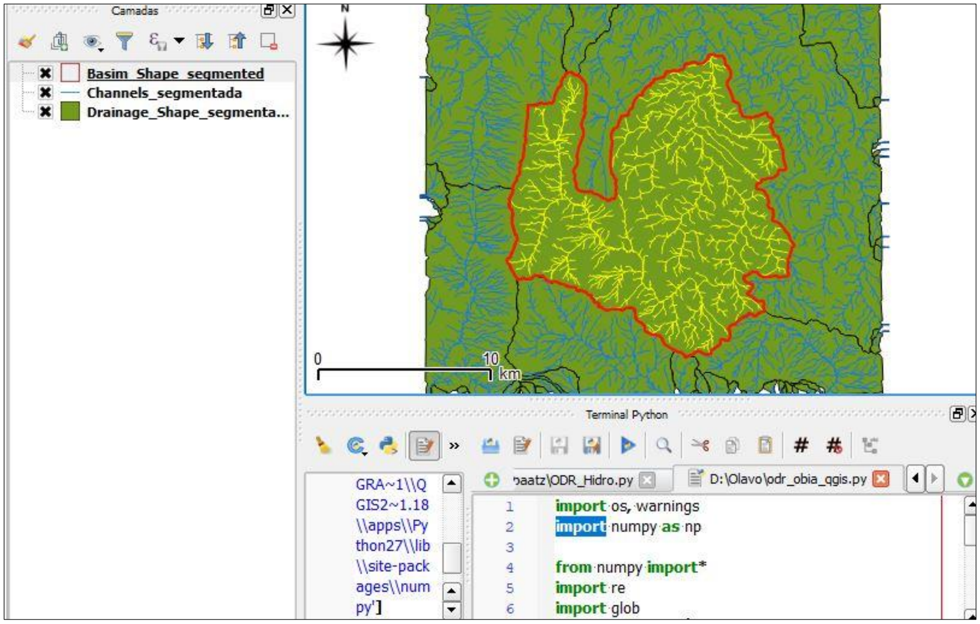
Figure 8 - (A) Raster image of the flow direction indicator; (B) Raster image of the cumulative flow indicator.



Source: Oliveira (2019).

As pointed out by Fernandez et al. (2012), the flow direction is based on the estimation of the catchment area, which contributes to the sum of the surface areas of the cells in which the runoff flows to a specific point. It is worth noting that the results of the flows are necessary to perform the ordering of the channels. The extraction of the channel network made by the model was topologically consistent, considering that all drainage segments are obligatorily touching each other and also present a common node in their affluent, as shown in Figure 9.

Figure 9 - Drainage generation from the segmented image.



```
GRA~1\\Q
GIS2~1.18
\\apps\\Py
thon27\\lib
\\site-pack
ages\\num
py']
```

```
import os, warnings
import numpy as np

from numpy import*
import re
import glob
```

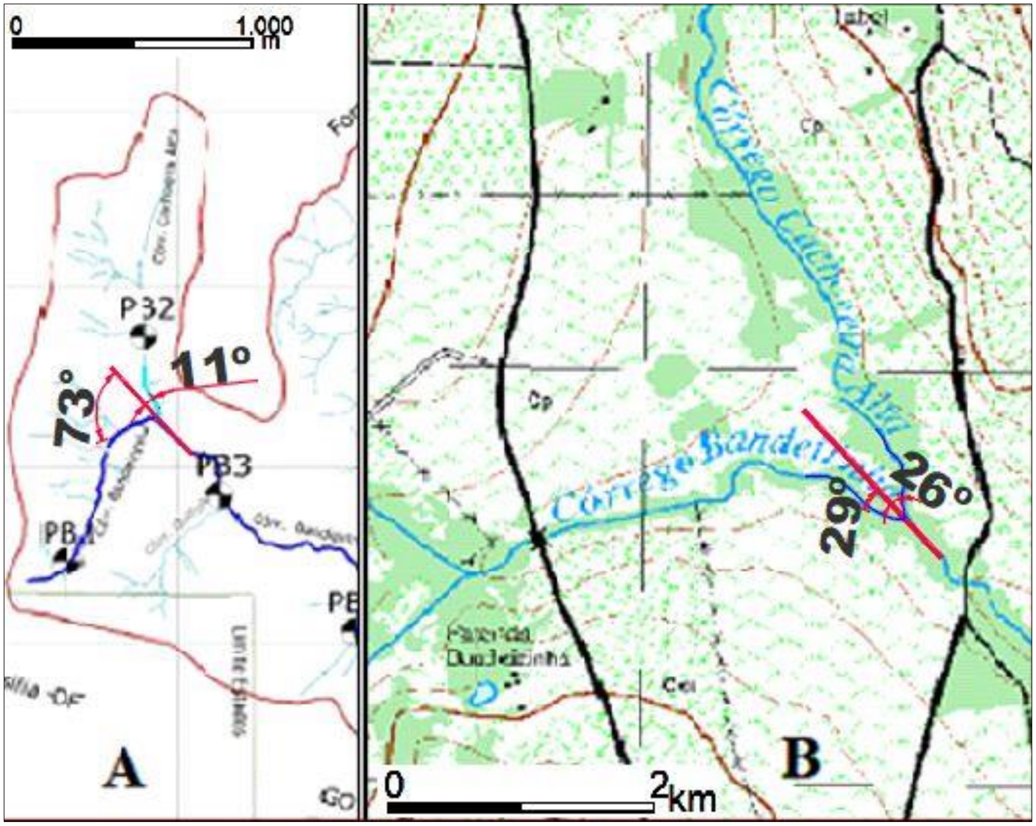
Source: Oliveira (2019).

In the analysis and definition of the Main River, it can be seen that the drainage network pattern is predominantly dendritic (Figure 9), which proves that it does not present structural control, Christofoletti (1980). The concept of the smallest angle was, then, used to define the main channel (HORTON, 1945) and the application presented another configuration, obtaining a much higher density of channels. Possibly, these channels could be linked to a better mapping scale than the scale informed in the mapping of the two ADGS topographic maps in vector format, MI - 2216 - Topographic Map FORMOSA-SD-23-Y-C-V and MI - 2272 - Topographic Map VILABOA-SD-23-Y-C-II, 2nd ed. 2006, both at scale 1:100,000. The study also pointed out divergences in the definition of the main channel in comparison with the definition given in the studies of Pimenta et al., (2015b), which shows the left channel, highlighted in dark blue, as the main one (Figure 10 A and B).

Horton (1945) established the criteria to determine the smaller order according to the greater angle of confluence, while the same order number from its source consigns the main river. However, if the two channels present the same angle the main channel will be defined by the criteria of length. Therefore, the channel of higher order will always be the one that presents the greatest length from its source to its mouth (HORTON, 1945).

According to the method prescribed in Horton (1945), the left channel has 73º and 29º in Figures 10 (A) and 10 (B), respectively, while the right channel angularly measured 11º and 26º respectively, which demonstrates that the right channel is the main one in both Figures.

Figure 10 - (A) BSHB produced by Pimenta et al. (2015b), with Bandeirinha stream in dark blue; (B) Bandeirinha stream indicative on ADGS chart.



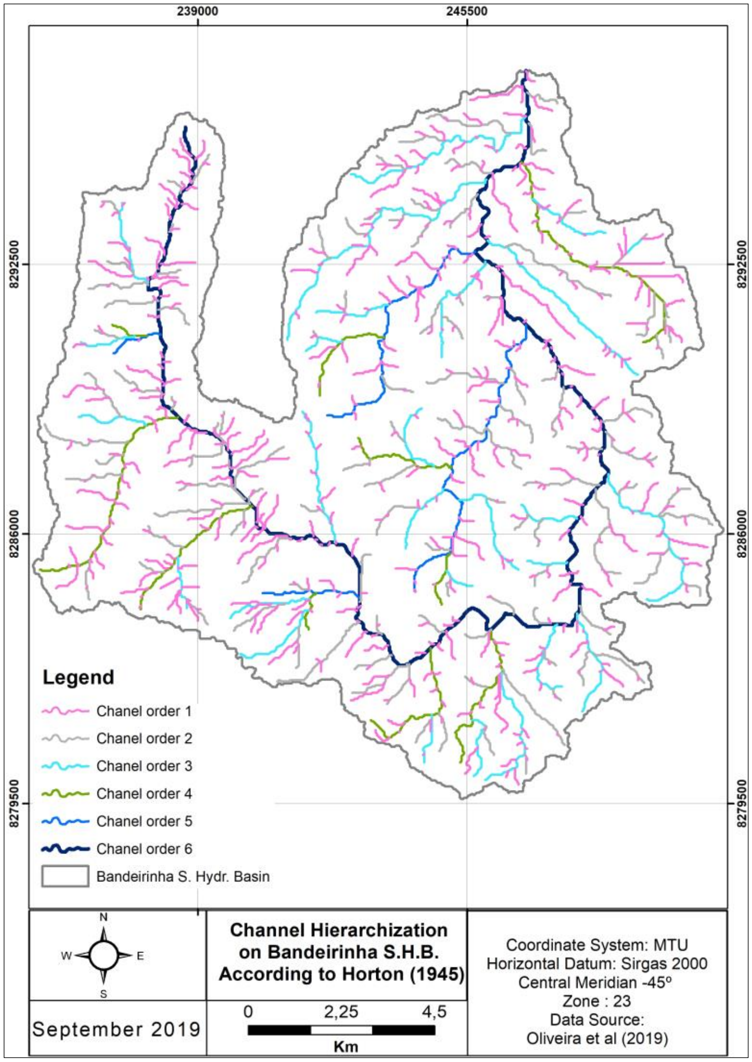
Source: Oliveira (2019).

Following the parameters proposed by Horton (1945), the BSHB channels were generated using the ODR_Hidro model and hierarchized (Figure 11), reaching the sixth order. Following the hierarchization criteria, the point that called a lot of attention was the confluence of the last channel of order 4 with the channel of order 6 (Figure 11). In the topographic chart (Figure 10 B), the bifurcation of these two channels originated two toponyms, the right channel being named Cachoeira Alta stream and the left one Bandeirinha stream. Evidently, it is known that in a topographic map, there is no information about their toponyms, nor about the definition of a main course, a task that must be performed when the objective is to study the basin morphometry, using the data that are mapped according to its scale. However, visually, the two channels shown in the ADGS chart have similar angulations, inducing the reader to define the Bandeirinha stream as the main channel. In this sense, the angular measurement, observed in Figure 10 (B), put an end to this indecision, which had already been presented in the study by Pimenta et al. (2015a).

Following the criteria proposed by Horton (1945) and observing the 4th order channel segment (Figure 11), named Bandeirinha stream, and comparing it with the 6th order channel segment (Figure 11), named Cachoeira Alta stream, also considering, from the last confluence, and extending a line from downstream to upstream, the channel that presents a greater angle is the one of a smaller order. In this sense, measuring the angles formed by these two segments (Figure 12 A) puts an end to any doubt. The angle of the left channel measured 52º and the angle of the right channel measured 0º, confirming that the right channel is the main one.

With the help of the "filled_file" threshold used in ODR_Hidro, which allows the generation of a larger or smaller number of channels, Figure 12 B shows corroboration with this information. The hierarchy observed in Figure 11 shows that the right channel, extracted by the ODR_Hidro model, is the main channel segment. It is also observed that this channel is the one with the greatest distance between its spring and mouth. In addition, it also has the largest drained area and the highest altitude (1,212m) of the main spring (Figure 11).

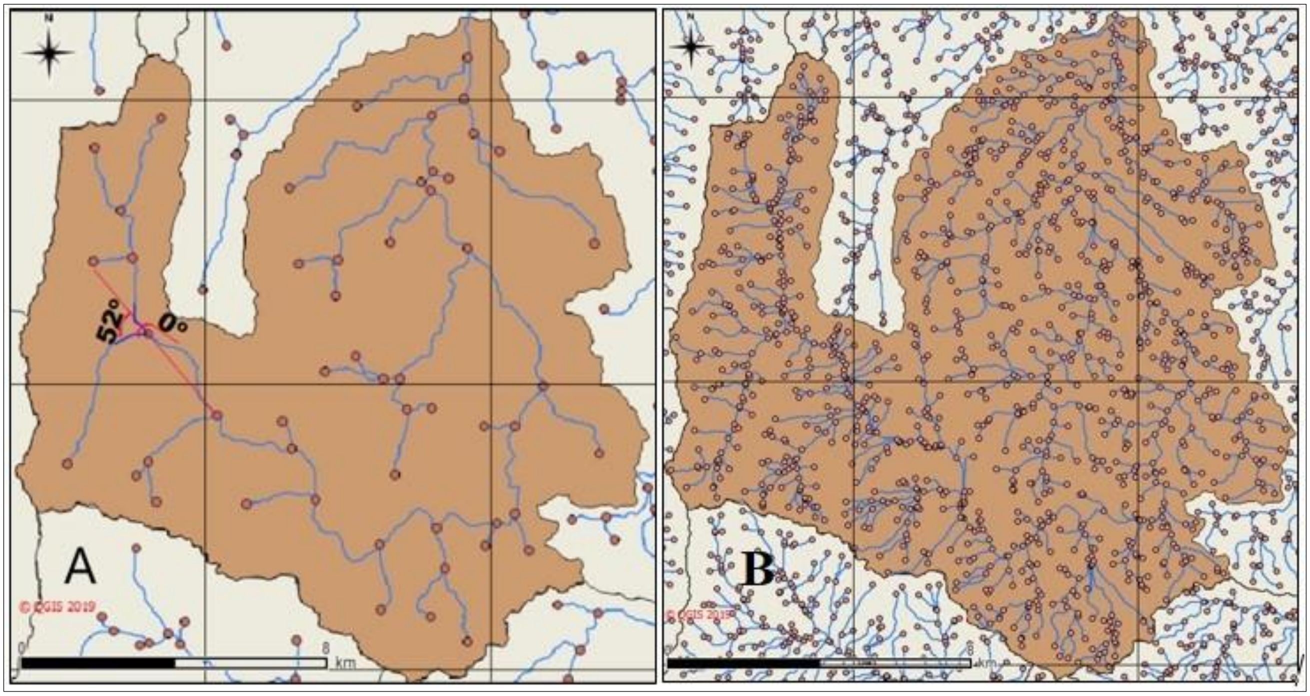
Figure 11 - Bandeirinha Stream Hydrographic Basin with hierarchized drainage network.



Source: Oliveira (2019).

Examining the positional configuration of the BSHB drainage network, it is possible to observe a conflict in Figure 13C, between channels generated by ODR_Hidro and existing channels in the scale of 1:100.000 (Figure 13 A – in magenta). However, the drainage network generated in the scale of 1:25.000 (magenta), shows quite a coincidence with the cartographic base in the scale of 1:25.000.

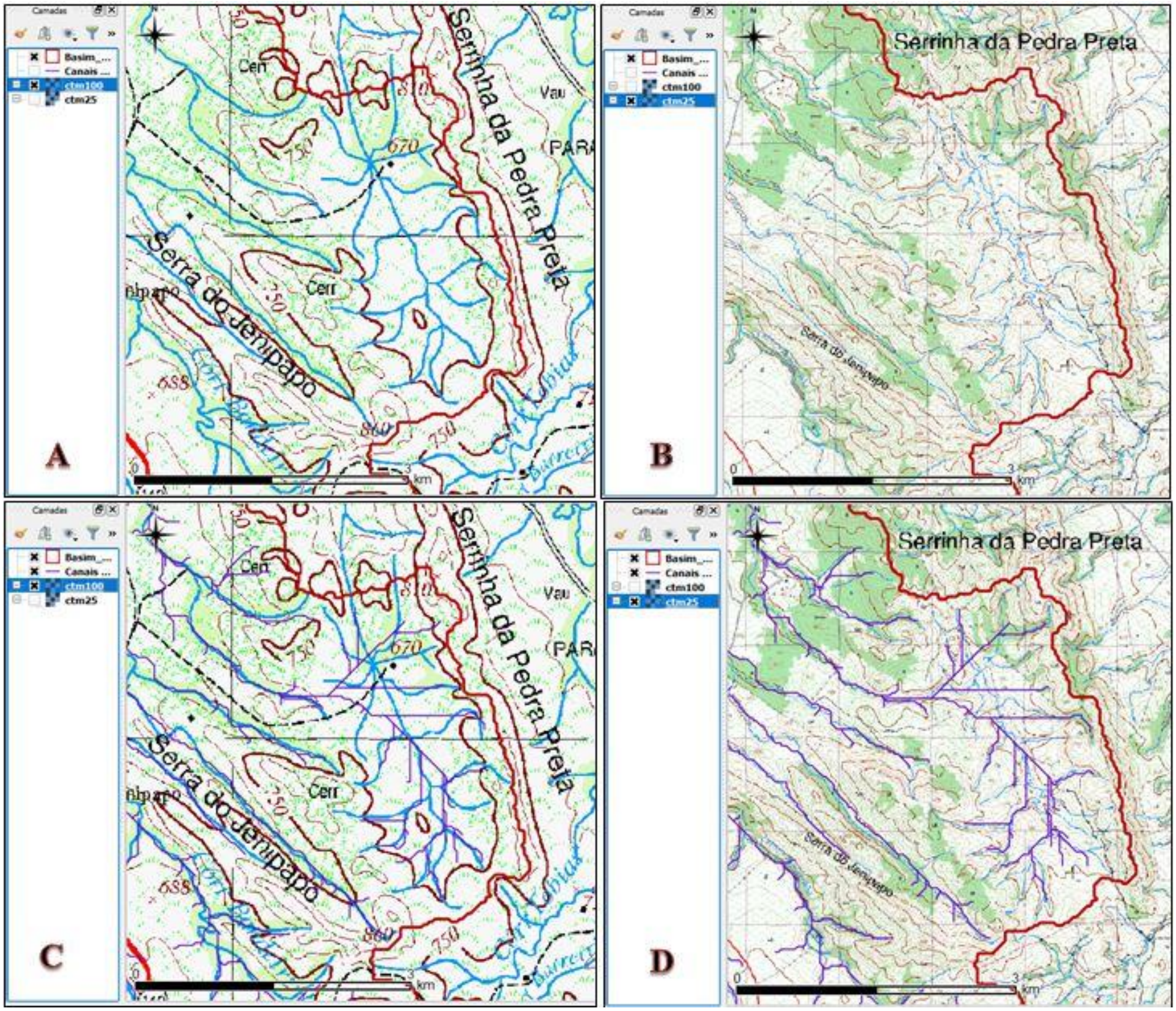
Figure 12(A) - Bandeirinha Stream Hydrographic Basin and channel network with angular measurement of two channels; (B) Bandeirinha Stream Hydrographic Basin and channel network extracted with ODR_Hidro and definition of the right channel as the main one.



Source: Oliveira (2019).

Examining the positional configuration of the BSHB drainage network, shown in the scales of 1:100.000 (Figure 13 A) and 1:25.000 (Figure 13 B), there is an overlap in the channels (in dark blue) mapped with the ODR_Hidro, superimposed in the respective Figures 13 C and D, in addition to the indication of the BHCB boundary (red line). Conflict can be seen in Figure 13 C, between the channels generated by the ODR_Hidro and the channels mapped in the 1:100,000 scale chart. However, in the 1:25,000 scale map (Figure 13 D) this conflict is non-existent, which can corroborate the quality of ODR_Hidro for mapping drainage networks from large-scale products.

Figure 13 - (A) Topographic chart at scale 1:100,000; (B) Topographic chart at scale 1:25,000; (C) Channels overlaying the topographic chart at scale 1:100,000; (D) Channels overlaying the topographic chart at scale 1:25,000



Source: Oliveira (2019).

It is now evident that the ODR_HIDRO model, using the SRTM segmented raster image, can contribute effectively to obtaining geomorphometric data. Comparing the process for obtaining the data listed in this research using, for example, the free software QGIS, the advantages are numerous. On one hand, QGIS does not perform the procedure in an automated way, nor associates the extraction of geomorphometric data. It ties them directly to a segmented raster image, the purpose of which is to obtain the drainage network, the extraction of the basin and the final calculation of the basin area. On the other hand, the use of the raster image segmented by ODR_Obia and the use of the ODR_Hidro model takes the process in a fully automated way. These new tools only need two user interventions: indicating the location where the DEM is stored and in the raster where the basin outflow is located. With these two interventions, they can start the process of extracting the geomorphometric data. In this sense, the applied methodology can be considered a new proposal for the extraction of geomorphometric indices.

CONCLUSIONS

The application of the ODR_Obia and ODR_Hidro tools, developed and used for segmentation, delimitation of the basin, extraction of the channels and other calculations, proved to be very efficient, due to the following aspects: despite using SRTM with a 30 meters spatial resolution, the model was able to generate channel density compatible with the scale of the ADGS 1:25,000 topographic chart; the ordering and analysis of the drainage network employed in this research allowed us to clearly define the main channel, and verify that it does not present structural control, since the drainage network presents a predominantly dendritic pattern; the method makes the process of obtaining geomorphometric data from smaller scale products more precise.

The use of the ODR_Hidro model, with the use of segmented raster images, besides accelerating, qualifies the process for obtaining geomorphometric data. It may become in the near future an important tool to help and speed up geomorphometric studies for research involving watershed analysis.

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AUTHORS CONTRIBUTION

The three authors participated in all stages of the work. The first author, under the guidance of the others, carried out all the field research and writing of the article.