MORPHOMETRIC VARIABLES FROM THE HYDROGRAPHIC SUB-BASIN OF RIO ESPINHARAS, PB / RN / PE, WITH USE OF GEOTECHNOLOGIES

.

ABSTRACT

The relief forms, terrain differences, soil type and flora are the most important indicators for the description of a river basin or drainage network. By means of morphometric analysis, it is possible to verify the basin hierarchy, river length, perimeter, drainage density, slope, among others.

The objective of this study was to perform a morphometric characterization of the sub-basin (SBH) of the Espinharas river, the intensity of land use and the proposition of mitigating measures for the main problems identified in the field trips.

The SBH of the river Espinharas extends over a surface of about 3,330 km². Data from the Shuttle Radar Topography Mission (STRM) was processed in Geographic Information System (GIS); QGIS and GRASS were used. For the generation of the slope maps, the "r.slope.aspect" module was executed, starting with the slope in percentage.

The drainage area of the SBH of the Espinharas river extends through thirty-one (31) municipalities, covering the states of Paraíba, Rio Grande do Norte and Pernambuco. SBH is classified as a 5th order branching basin with dendritic pattern. According to the values of the coefficient of compactness (2.68) and shape factor (0.32), the SBH has an elongated shape, which is not conducive to flooding. The Circularity Index (0.14) is low. The altitude of the SBH varies from 128 m to 1195 m, with a mean altitude of 661.6 m.

As for the intensity of land use, the low intensity of use prevailed, followed by the medium-high intensity, meaning that most soils are at rest, although with degraded soil characteristics, due to previous agricultural use. The main problems identified in the field trips are related to the incorrect use of permanent preservation areas, irregular deposition of solid and liquid waste and deforestation.

Keywords: QGIS, GRASS, caatinga, semiarid

1. INTRODUCTION

The relief forms, terrain differences, soil type and flora are the most important indicators for the description of a river basin or drainage network. By means of morphometric analysis, it is possible to verify the basin hierarchy, river length, perimeter, drainage density, slope, among others. These data make it possible to investigate the vulnerability to flood occurrence, understanding of the hydrological cycle, water availability, deflution, infiltration and sub- and superficial flow [1]

Thus, the morphometric characteristics are important references for regional restructuring proposals, with a focus on decision-making in relation to projects involving physical

UNDER PEER REVIEW

resources in the region, and environmental planning. In addition, understanding of hydrological behavior, and the development of resource management due to anthropogenic, economic and socio-environmental actions have been recurrent in sustainability studies [2].

Nowadays, the morphometric characterization of hydrographic basins (BH) can be done with the integration of information in a Geographic Information System (GIS) environment, either manually or automatically [3, 4]

The information on altimetry is represented by the Digital Terrain Model (MDE), which can be classified as any digital representation of a continuous variation of the relief in space, in which the altimetric data correspond to both the surface of the soil and the elements present on the surface (vegetation, buildings) [5].

The data source used comes from the Shuttle Radar Topography Mission (SRTM) mission, an international project led by the National Aeronautics and Space Administration (NASA) and the National Geospatial Intelligence Agency (NGA), which aimed to obtain (USGS,[6]), generating high resolution elevation data, making it possible to analyze, compare and update information in a given area, such as: morphometric parameters, flood control, drainage, soil conservation, reforestation among others [7].

The intensification of anthropization on the use of soil in the Brazilian semi-arid region has caused the degradation of water resources, loss of biodiversity, extraction of vegetation, together with climatic factors, has dramatically altered the hydrological processes of rainfall-deflution-sediment production [8]

Vegetation cover plays a fundamental role in the hydrological behavior of watersheds, as it assists in the infiltration of water into the soil. Reducing excess water loss superficially, maintaining erosion rates on an acceptable scale [9]

Silva et al.[10] reinforce that the removal of vegetation, in addition to discharacterizing the original environment, interferes in the water balance of the watersheds, compromising the water supply and the sustainability of the most varied life forms, notably in the northeastern semi-arid region.

Considering the above, the aim of this work was to perform a morphometric characterization of the SBH of the Espinharas river, to analyze the intensity of soil use and to suggest mitigating measures for the areas with the greatest intensity of use, using geospatial tools.

2. MATERIAL AND METHODS

2.1 Hydrogeographic characterization of the study area: the sub-basin of the Espinharas river

The SBH of the Espinharas river extends on a surface of about 3.330 km ² and is surrounded to the southeast by the SBH of the river Taperoá and to the southwest by the Pajeú river, one of the tributaries of the São Francisco river, SBH of the Piancó river and the Hydrographic Region from the Middle Piranhas to the west, and the SBH from the Seridó River to the east. Its area is bounded between coordinates 643003 and 733003 Easting and 9300000 and Norwich 9100000 (Figure 01).

UNDER PEER REVIEW

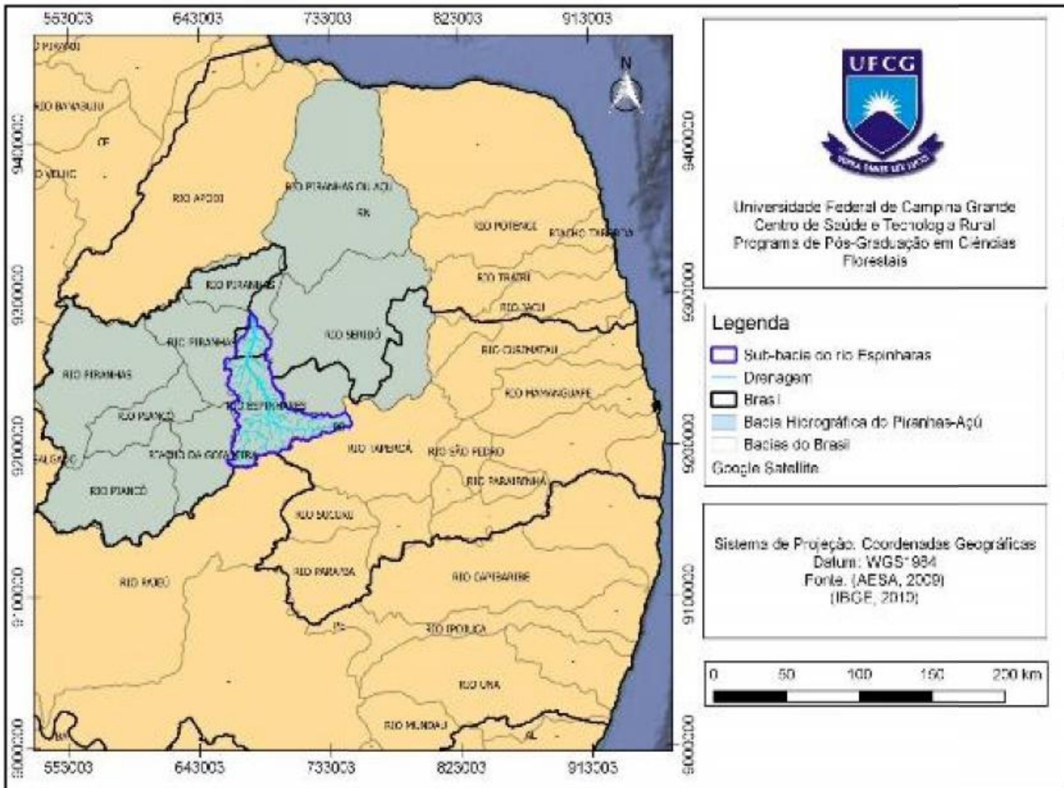


Figure 01. Schematic map of the BH of the Piancó-Piranhas-Açu river and SBH of the Espinharas river, Northeast of Brazil. Source - (BRAZIL, 2010).

The main river of the SBH is Espinharas, formed by the confluence of the Cruz and Flour rivers in the urban area of the municipality of Patos-PB. The river of the Cross is born in the municipality of Imaculada-PB and follows in the southwest-northeast direction towards the municipality of Patos-PB.

The river Farinha is born in the municipality of Salgadinho-PB where it travels around 70 km, until it meets the river of the Cross, to form the river Espinharas. On the border of the states of Paraíba and Rio Grande do Norte, the Espinharas River flows into the Piranhas River, in the municipality of Serra Negra do Norte-RN, near the municipality of Jardim de Piranhas-RN and the municipality of São Bento-PB.

According to Alvares et al. [11] in the SBH area studied, the climates Bsh and Aw 'are characterized. The Bsh type is defined as a hot and dry climate, with summer rains and with annual rainfall around 500 mm and an annual average temperature of 26 ° C; the Aw type is present in the western central portion of the subbasin, presenting a warm and semi-humid climate with summer-autumn rains, with a rainfall of around 500 mm, an average annual temperature of 27 ° C and extending through the southeast portion of the sub-basin [12,13].

The soils are generally shallow, stony, of crystalline origin and very vulnerable to erosion, predominantly of the following types: Luvisols Chromic and Neosol Lithole [14]

UNDER PEER REVIEW

The vegetation present in the study area is composed of small woody species, endowed with spines and, usually, deciduous leaves that lose their leaves in the dry period, with a marked presence of cactaceae and bromeliaceae [10].

According to SUDEMA [15], the Open Arboreal Arboreal Caatinga (CAAA) is present in most of the studied area, characterized by sparse vegetation with some arboreal individuals with a mean height of 3m, with herbaceous and cactaceous vegetation, being high degree of degradation in the flat relief areas.

The vegetation is classified as Closed Arboreal Shrub Caatinga (CAAF) and is found on the slopes of hills and mountains [16]. This vegetation has as characteristics the predominance of arboreal individuals.

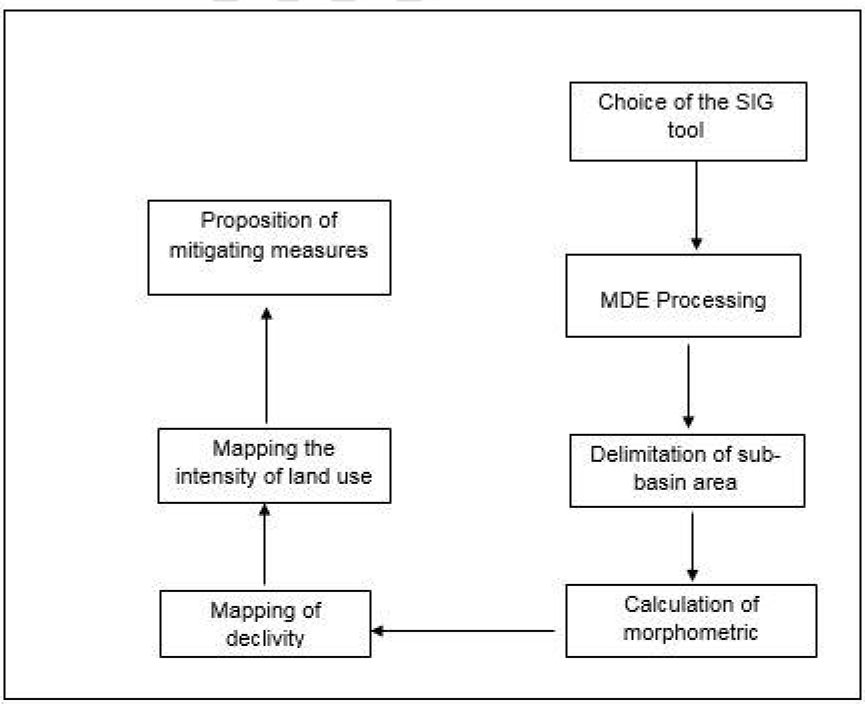
2.3 Materials used

- Planialtimetric Letters from SUDENE, edited in 1985 and scanned in 1996; (SB.24 - Z - A - VI), Serra Negra do Norte - RN (SB.24 - Z - B - IV), Piancó - PB (SB.24 - Z - C - III) and Ducks-PB (SB.24-Z-D-I).
- SRTM MDE covering scenes 07_w038_1arc_v3.tiff.aux; s08_w038_1arc_v3.tif.aux;
- QGIS software including add-ons and GRASSGIS.
- Landsat 8 satellite images, resolution 30m, bands 2, 3 and 4, orbit, point 216/064, 215/065 and dates 06/08/2017, 08/15/2017 respectively.

2.4 Methods used

2.4.1 Steps for the development of work

The accomplishment of the research comprised the following stages (Figure 02):



UNDER PEER REVIEW

Figure 02. Flowchart of the methodological steps.

For the development of the proposed work, it was important a bibliographic review to deepen and contextualize some concepts such as: BH, caatinga biome???, remote sensing, geoprocessing and land use map.

The second step was selecting the software used in data processing. A limitation was the cost involved in acquiring them. However, open source programs, such as the GIS and GRASS GIS, software for processing, allowed the analysis and visualization of the data and were used to extract the morphometric characteristics.

2.4.2 MDE SRTM Processing

The SRTM MDE was acquired in GeoTIFF format from Earth Explore of the USGS website. The data corresponding to scenes 07_w038_1arc_v3.tif.aux; s08_w038_1arc_v3.tif.aux with a resolution of 1 arc of a second, which corresponds to approximately 30 meters, referenced to DATUM WGS84.

The model was used for extraction of the morphometric characteristics, the APP of the water courses and top of hill with the aid of the tools QGIS and compliments. The processing of the data contained in the MDE comprised the following stages:

- STRM mosaic composition (Raster > miscellaneous > mosaic);
- Mosaic reprogramming for flat coordinates, referenced to the Sirgas2000 Datum, Zone 24 South (Raster > Projections > Redesgin);
- Clipping involving the study area (Vector > Geoprocessing tool > crop);
- Filling of regions without data in the SRTM MDE using the “r.fillnulls” module, which operates with the Spline Adjustment Algorithm [17], implemented in SIG GRASS.

2.5 Sub Basin delimitation and morphometric variables

The delimitation of the sub basin began with the obtaining of the hydrological attributes in the QGIS GIS.They were executed by the GRASS complement "r.watershed"[18]. This module derives maps of flow accumulation, drainage direction, drainage location and BH boundary.

Then, the flow direction map and the drainage network were generated with a Thershold = 5000.The "Single Flow Direction" algorithm was selected and inserted into the "r.water.outlet" algorithm for delimitation of the SBH from the point considered as exudative in the coordinates UTM E = 679171.64 and N = 9288383.11, previously chosen on the "Stream" map.

The "r.stream" modules were used to make the drainage network map and the flow direction for the following determinations: (1) hierarchy of the drainage network by the algorithm "r.stream.ordere"; (2) SBH, number and length of rivers of each order and drainage density, using the algorithm "r.stream.stats".

2.6 Slope map

For the generation of the slope maps, the "r.slope.aspect" module was executed, starting with the slope in percentage.

UNDER PEER REVIEW

The slope map was submitted to the "r.reclass" algorithm to compartmentalize the result into classes, constituting six themes, at different intervals with values as percentage suggested by EMBRAPA [19], according to Table 01.

Table 01. Classes of slope, according to Embrapa [19].

Declivity (%)	Classes
0 - 3	Plan
3 - 8	Soft wavy
8 - 20	Wavy
20 - 45	Strongly wavy
45 - 75	Mountainous
> 75	Strongly hilly

2.7 Intensity of use of SBH soils

With the aid of the coverage map, a pre-analysis of the different land cover patterns was performed. After the pre-processing of the images, visual and supervised classifications were performed. For the visual method, the first step was the processing of the images. The second stage consisted of the vector representation of each identified theme, rasterizing on a mask previously generated with definition of the polygon of the basin.

The subjects chosen for used map were based on field sampling. Three samples were selected previously for the thematic class. For automatic classification, the likelihood method (Maxlike) was used. Ten samples of each class were verified, considering the training based on the labeling formulated in the visual interpretation of the image and related knowledge of the study area.

This classification, with respect to the semi-arid Northeast, behaves in a peculiar way, considering the reality of the areas used for agriculture, which, due to the incorrect management, presented with various degrees of degradation. In order to classify the intensity of land use, six (06) levels of intensity were used, varying from very high to very low intensity according to the methodology adapted from Lima [20] Table 02). After the classification of soil cover levels, the field data were cross - referenced, for further characterization of the different spots of soil use intensity of SBH of the Espinharas river.

Table 02. Level of intensity of land use and its characteristics.

Intensity of use of the soils	
Level	**Features**
Very high intensity	High deforestation with exposed, stony, eroded and unsuitable soils for agriculture
High Intensity	High population density, presence of minifundia, semi-open and low density vegetation, presence of invasive plants in abandoned and regenerated areas
Average high intensity	Agriculture
Average Intensity	Open-cut shrub caatinga spots interspersed with rocks in an undulating relief area
Low Intensity	Area of arboreal shrub caatinga and areas at rest due to low productivity
Very low current	Area of closed tree caatinga (T4) and soil covered with organic material

UNDER PEER REVIEW

Source. Adapted from Lima [20].

2.8 Proposals for mitigation for types of degradation and levels of intensity of land use in APP and AUR

For the preparation of the proposals, a number of documents on the assessment of environmental impacts at the basin level were drawn up, mainly the Environmental Protection Guide of the German Federal Ministry for Economic Cooperation and Development (BMZ) [21]; Book of Consultation for Environmental Assessment of the World Bank [22]; (WORLD BANK [23].

The themes discussed and the proposals presented are directly related to the environmental problems identified in the field activities, with reference to the Espinhas river SBH area.

3. RESULTS AND DISCUSSION

3.1 Delimitation of SBH of the river Espinharas

The SBH drainage area of the Espinharas River extends through thirty-one (31) municipalities; twenty five (25) in the State of Paraíba, three (03) in the State of Rio Grande do Norte and three (03) in the State of Pernambuco (Table 03).

Table 03. Municipalities comprising the SBH of the Espinharas river.

County	Area (km²)	Area (%)	Population	Imediate geographical region
Areia de Baraúnas-PB**	95,61	2,87	1.908	Patos
Assunção-PB	6,23	0,19	3.732	Campina Grande
Brejinho-PE	3,73	0,11	7.464	Afogados da Ingazeira
Cacimba de Areia-PB*	235,48	7,07	3.673	Patos
Cacimbas-PB**	72,25	2,17	7.035	Patos
Catingueira-PB	0,47	0,01	4.905	Patos
Desterro-PB	0,2	0,01	8.196	Patos
Imaculada-PB**	95,85	2,88	11.659	Patos
Ipueira-RN	0,79	0,02	2.190	Caicó
Itapetim-PE	0,19	0,01	13.932	Afogados da Ingazeira
Junco do Seridó-PB	2,01	0,06	6.934	Campina Grande
Mãe D'água-PB*	178,69	5,37	4.044	Patos
Malta-PB	18,28	0,55	5.679	Patos
Maturéia-PB*	80,74	2,42	6.283	Patos
Passagem-PB*	114,64	3,44	2.338	Patos
Patos-PB**	508,28	15,27	104.716	Patos
Paulista-PB	2,58	0,08	12.117	Pombal
Quixaba-PB**	106,87	3,21	1.834	Patos
Salgadinho-PB**	155,24	4,66	3.752	Patos
Santa Luzia-PB	13,89	0,42	15.145	Patos
Santa Teresinha-PB**	248,05	7,45	4.612	Patos
Santa Terezinha-PE	0,54	0,02	11.411	Afagados da Ingazeira
São Bento-PB	0,49	0,01	32.651	Catolé do Rocha –

				São Bento
São Joao Do Sabugi-RN	13,39	0,40	6.174	Caicó
São Jose De Espinharas-PB**	709,83	21,32	4.738	Patos
São Jose Do Bonfim-PB*	153,84	4,62	3.411	Patos
São Mamede-PB	1,32	0,04	7.794	Patos
Serra Negra Do Norte-RN**	400,19	12,02	8.083	Caicó
Taperoá-PB	18,82	0,57	15.190	Campina Grande
Teixeira-PB**	89,37	2,68	14.739	Patos
Vista Serrana-PB	1,71	0,05	3.675	Patos
Total	3329,57	100,00	340.014	-

* Municipalities (04) with territorial area totally inserted in the drainage area of the sub-basin of the Espinharas river.
** Municipalities (10) with a significant portion of their territory in the drainage area of the sub-basin of the Espinharas river. ***Source of the data need to be included***

The municipalities that have the largest area of insertion in the Sub-basin are: São José de Espinharas-PB, covering an area of 709.83 km² (21.32%) and near the municipality of Patos-PB with 508.09 km² (15 , 27%). Some municipalities have a sub-category, almost inexpressive. They are: Santa Terezinha-PE with 0.54 km² (0.02%), São Bento-PB with 0.49 km² (0.01%), Ipureira-RN 0.79 km² (0.02%), Itapetim -PE 0.19 km² (0.01%), Desterro-PB with 0.2 km² (0.01%) and Catingueira-PB 0.47 (0.01 km²) (Figure 03).

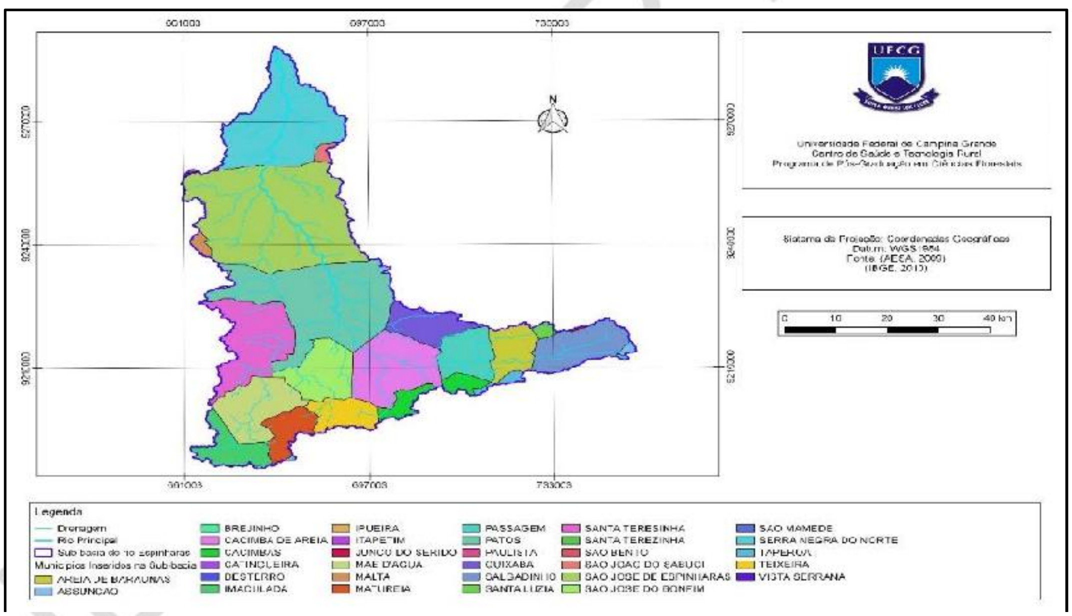


Figure 03. Map of the municipalities that are totally or partially inserted in the SBH of the river Espinharas(**Source ???)**

The remaining seven municipalities have a small part of their territory, inserted in the drainage area of the SBH under study and are part of other SBH.

Sobrinho et al. [24] observed that the automatic delimitation of basins has a lower subjectivity and that even using different softwares, the results are closer when compared to manual methods that depend on human perception.

Figure 4 shows the SBH of the Espinharas river with its drainage network ordered according to [25]. SBH is formed by intermittent and ephemeral channels, which are typical flow regimes in the region in which it is inserted. The basin is classified as 5th order of branching, with dendritic pattern.It is predominantly occur in the studied region. The drainage area is 3,267.16 km² and 552.30 km of perimeter.

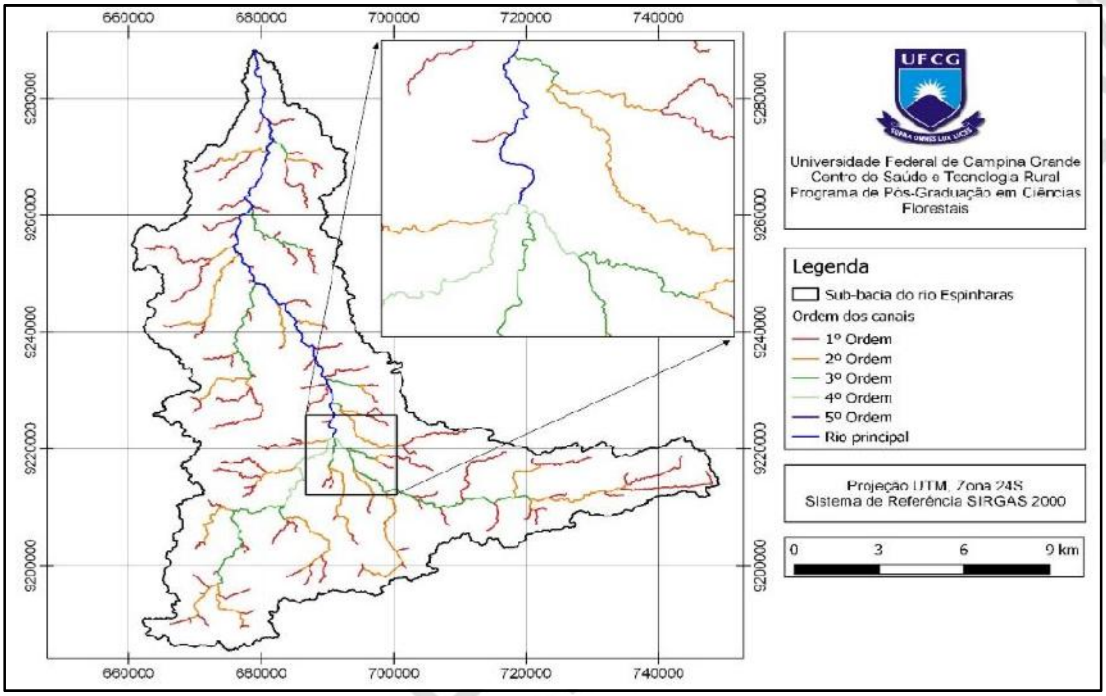


Figura 04. SBH do rio Espinharas, destacando a sua delimitação e ordenamento dos canais de drenagem de acordo com a classificação de Strahler[25].*Mention year*

In summary, the delimitation of BH and the generation of the drainage network through the SRTM are shown to be accurate and compatible with those obtained by manual methods, which expedite the processing time and have less detail in their configuration [24].

It can be seen in Table 04 that the first-order drainage channels appear in greater numbers, corresponding to 45.5% of the total, which are located in areas of higher altitudes, springs or headwaters, where the relief is more dissected .

Table 4 - Number and length of channels, in order of classification, of SBH of the Espinharas river.(Source:???)

Order	Number of Channels	Total length (km)	%
1	94	452,2	45,5
2	26	267,3	26,9
3	10	147,3	14,8
4	2	27,7	2,8
5	1	98,5	9,9
Total	**133**	**993,0**	**100,0** ***Total is not***

UNDER PEER REVIEW

	correct.Please insert 0.1 in one of the %

Table 04 shows the data in number and total length of channels, in order of classification. According to Landau (year??); After analyzing the drainage obtained by three different sources (ASTER, TOPODATA and SRTM), it was observed that the SRTM data presented unsatisfactory data, due to the spatial resolution being of 90 m, not identifying the small tributary rivers, while that the drainage networks obtained from ASTER and TOPODATA data obtained better results, because their resolution is 30 m.

However, SRTM data can be used for SBH delineation and in several other hydrological studies. The limitation of this procedure is that variations can occur in obtaining the drainage network, differentiating it from reality. In this scenario, it is recommended to compare with other remote sensing data or topographical charts to make proper corrections [4].

3.2 Morphometric variables

Table 05 shows the results of the morphometric parameters found for the SBH of the Espinharas river. According to the values of the coefficient of compactness (2.68) and shape factor (0.32), the SBH has an irregular shape that differs from the figure of a circle, approaching an elongated shape, and is thus not very conducive to flooding. Even so, several floodplain and landslides occurred in 2009, resulting in numerous homeless families in the municipality of Patos-PB, where it rained approximately 300 mm in 6 hours [26].

Table 05. Results of the morphometric parameters obtained from SBH of the Espinharas river, Paraíba, Brazil.

Geometric Features		
Parameters	Values	Units
Sub-basin area (A)	3267,16	km²
Perimeter (P)	552,30	km
Coefficient of Compaction (Kc)	2,71	Dimensionless
Form Factor (F)	0,31	Dimensionless
Circularity index (CI)	0,13	Dimensionless
Sinuosity index	0,96	Dimensionless
Drainage pattern	Dendritic	
Characteristics of the Drainage Network		
Total length of channels	993,00	km
Main Channel Length	98,5	km
Order of the basin (Strahler 1957)	5	
Density of drainage (Dd)	0,30	km/km²
Relief Characteristics		
Minimal Declivity	1	%

UNDER PEER REVIEW

Average Declivity	16,7	%
Maximum Declivity	68	%
Minimum Altitude	126	m
Average altitude	477	m
Maximum Altitude	1197	m
Altimetric amplitude	950	m

The Circularity Index (0.14) is considered low, corroborating with the previous information. According to Christofoletti [27], the closer to 1.0 the SBH format, it is closer to a circle. According to Villela; Matos [28]; Cardoso et al. [3]; Andrade et al.[29] in circular-shaped basins, there is greater possibility of flooding when intense rains occur, in all their extension, differently from the behavior of elongated basins.

The elongated shape is less susceptible to flooding in normal precipitation situations, but the possibility of rainfall covering entire extension, including the tributary rivers, is also low, as the flood hits the main river at several points [30].

Silva et al. [31] studying the morphometry of the Soledade-PB and reservoir basin and Marinho and Silva [32] found similar values in the morphometric analysis of the urban basins affected by floods in Manaus-AM. According to the authors, values of circularity index below 0.51 favor the rapid flow of water over the basins.

Feitosa et al. [33] studying the Pueu River Basin, PE and Silva et al.[31], when studying the Açude Soledade-PB basin, noticed similar climatic characteristics. They concluded that due to the elongated shape of the basin, the process of drainage of rainwater to the main channel becomes little vulnerable to flooding.

3.3 Slope map

Table 6 shows the slope values corresponding to the respective relief classes, corresponding area and percentage. The altitude of the SBH varies from 126 m to 1197 m, with an average altitude of 477m. The mean slope was 3.5%, being a peculiar characteristic of the SBH studied, where the soft and undulating relief predominates.

Table 06 Classes of slope and their relative areas and percentage in relation to SBH area of the espinharas river, Paraíba, Brazil.(Source:???)

Declivity (%)	Classes	Area (km²)	Área (%)
0-3	Plan	382,6	11,7
3-8	Soft wavy	1427,0	43,7
8-20	Wavy	875,0	26,8
20-45	Strongly wavy	454,9	13,9
45-75	Mountainous	118,2	3,6
>75	Strongly hilly	9,4	0,3
Total	-	3267,2	100,0

As can be observed in Figure 5, the smooth, and wavy class with 43.7% and 26.9% respectively, are the most representative classes of SBH where, during periods of higher

UNDER REVIEW

rainfall, these areas become least likely to be flooded. In addition to declivity, waterproofing and flow accumulation are characteristics that directly interfere with the risk of flooding. Therefore, the use and occupation of land, as well as the relief features can converge into a scenario that is vulnerable to flooding. The least representative classes were: Mountainous, Mountainous, flat and strong wavy with 0.3%, 3.6%, 11.7% and 13.9% respectively of the SBH area.

The highest slope classes were identified in the areas represented by the Borborema Plateau, where relief predominantly looks wavy to strong mountainous (Figure 05).

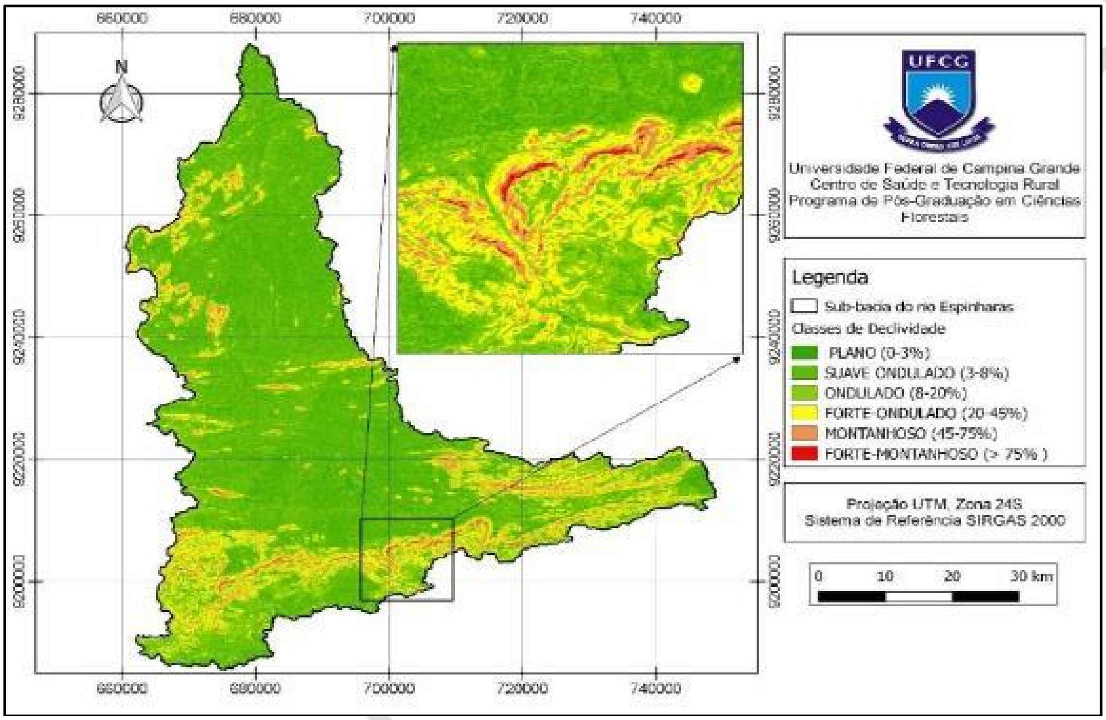


Figure 05. Slope classes of SBH of the Espinharas river, PB / PE / RN.(Source:???)

Felipe et al. [34] reiterate that the relief is of fundamental importance in planning and management actions in the preservation of BH. According to Ribeiro and Perreira [35], the absence of vegetation cover, the soil class, the intensity of rainfall associated to the greater slope, leads to a higher flow velocity, which in turn results in a smaller amount of water stored in the soil. This, in more pronounced floods, exposes the basin to degradation phenomena. The velocity of the water flow influences the peak of floods. The infiltration process and the susceptibility to soil erosion justify the adoption of apt measures that ensure soil protection and slowing down of the flood. In the SBH studied, 44% of the area has its relief ranging from corrugated to hilly, requiring measures of soil conservation.

The identification of the parameters of slope of a BH is fundamental for its environmental planning, either to observe the legislation or to guarantee the balance of the interventions of the man in the studied area with the natural environment. Moreover, this factor plays an important role in the water distribution between the surface and underground runoff [36].

3.4 Intensity of use of SBH soils of the Espinharas river

In relation to the northeastern semi-arid region, this classification is peculiar, since the highest intensities of land use correspond to areas previously used for agriculture. Improper management of agriculture resulted in the cultivated land subjected to varying degrees of degradation.

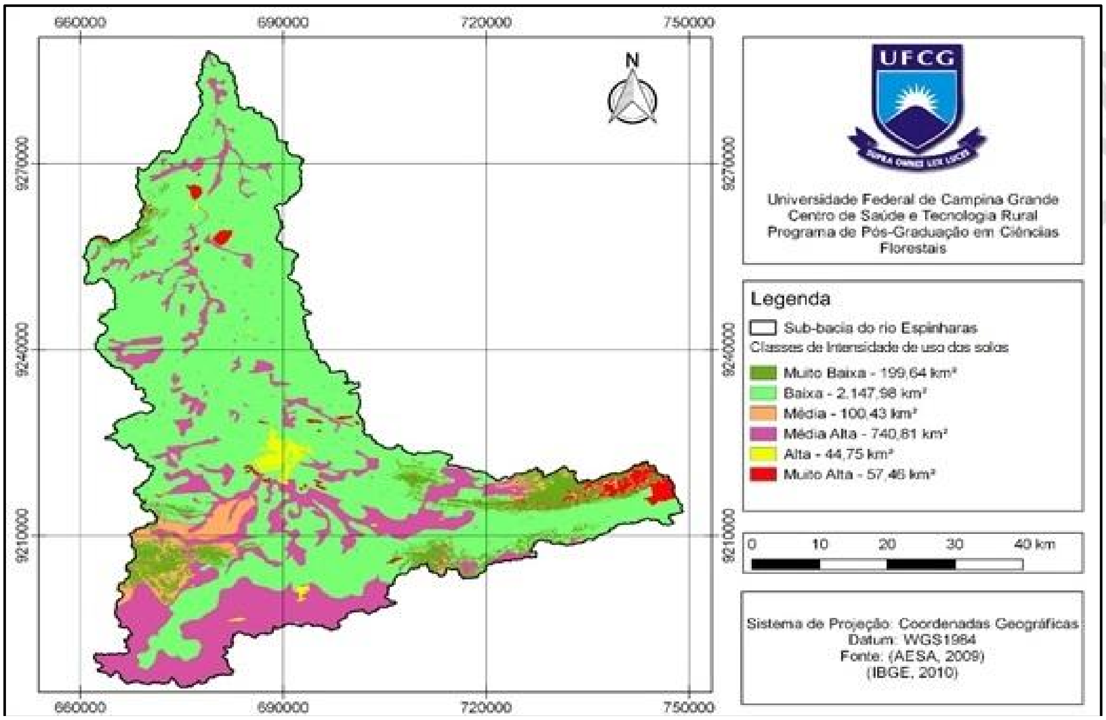


Figure 06. Map of Intensity Classes of Soil Usage of SBH of the Espinharas River (Source ???).

According to (Table 07), (Figure 06), the degree of incidence of different levels of intensity of land use was observed in percentage terms.

Table 7. Intensity classes of soil use of SBH of the Espinharas river(Source:???).

	Intensity of use of the soils	
Classes	Area (km²)	% in relation to the basin area
Very low	199,64	6,07
Low	2.147,98	65,27
Average	100,43	3,05
Average high	740,81	22,51
High	44,75	1,36
Very high	57,46	1,75
Total	3.291,08	100 ***(Insert 0.1 in %???)***

Areas with very high Intensity of soil usel are characterized by a high degree of deforestation, exposed soils, stony, eroded and unsuitable for agriculture and generally with ore exploitation. These areas correspond to 57.46 km² (1.75%) and are located southeast SBH of the river Espinharas, characterized by strong anthropism with highly degraded stretches.

The areas of high intensity of soil use with 44.75 km² (1.36%) are characterized by high population density, presence of minifundios, semi-open vegetation and predominantly Mimosa tenuiflora (Willd) (Jurema), Herissantia crispa (L.) Briz . (Malva) and Senna obtusifolia (Mata-pasto), as well as invasive plants from abandoned areas, represented by the presence of Prosopis juliflora (Algaroba) mainly in alluvial shoals. These areas are closer to the municipalities' headquarters and, according to Lima [20], are areas that show intensity of land use, due to the greater pressure on natural resources by the population.
The high average intensity class corresponds to an area of 740.81 km² (22.51%). They are areas where agriculture is developed and they are located around the reservoirs and along the banks of river courses, where the humidity is greater.

The areas with medium intensity have an area of 100.43 km² (3.05%) and are characterized by patches of arboreal vegetation interspersed with rocks in an undulating relief area.It is located southwest of SBH of the Espinharas river.

The areas with low intensity class of use have the highest representation in this basin, covering an area of 2,147.98 km² (65.27%). This class presents medium homogeneity in the spacing of shrub / arboreal vegetation and are areas at rest due to the low productivity they present.

The very low intensity class is formed by areas of dense vegetation, with soil covered with organic and herbaceous debris. This class represents an area of 199.64 (6.07%). The intensity of land use is very low, located on the banks of the Capoeira Dam, rural area of the municipality of Santa Terezinha-PB. This area is considered to be preserved due to difficult access, being located in an area sloping and distant from the urban area of the nearest municipality.

3.5 Mitigating measures for identified environmental problems

3.5.1 Farming

SBH of the Espinharas river presents several nonconformities of environmental impacts generated mainly by the bad planning in use of the area and disrespect to the legislation; among them, we can mention agriculture and livestock, with bovinocultura, swinocultura and caprinocultura and the vegetal production through the agriculture of subsistence and pasture.

These activities are generally developed in the Areas of Permanent Preservation (APP) or Areas of Restricted Use (AUR), contrary to the current environmental legislation, Law No. 12,651 of May 25, 2012 (Forest Code) and Law No. 12,727 of December 17, October 2012 [37, 38].

The adoption of measures and practices for soil conservation in these areas is fundamental to maintaining the ecological quality of these resources in the long term. Failure to observe this balance in the formulation of agricultural systems has been responsible for the breakdown of the balance and continuous degradation of this resource, mainly due to soil loss due to erosion in the cultivated areas.

Federal Law No. 8,171, dated January 17, 1991, provides for the Agricultural Policy and for disciplining and supervising the rational use of soil and water, as well as of fauna and flora [39]. The objective of Soil Conservation is to combat erosion and avoid its impoverishment through the use of techniques such as proper management, crop rotation, replacement fertilization, maintenance of desirable levels of organic matter for influencing its fertility.

The implementation of conservation practices is considered a great resource within the reach of the farmer to mitigate the problems of soil fertility, which together with the choice of the ideal crop in relation to the local environmental characteristics are basic methods for a sustainable agriculture practice [40].
Among the mitigating measures to be taken to avoid soil degradation, according to [40], we can mention:

- Keep the soil with cover, being able to be vegetation cover alive or dead (crop residues, litter) seeking the increase of soil organic matter levels;
- Implement the process of crop rotation with the use of different cultures and rest periods;
- Division of the agricultural area in small plots and integration of trees and shrubs in agriculture and livestock (agrosilvipastoril);
- Formation of protection strips against erosion, using level curves and terraces;
- Reforestation of poorer lands, with native species adopting measures of erosion control;
- Maintenance of the areas of riparian forests and native vegetation, within the legal limits;
- Restrict the access of animals in the native forest lands (Legal Reserve, APP and AUR) in rural properties;
- Avoid deforestation and fires, when necessary, seek licensing from the competent environmental agency;

The occupation of riparian vegetation by agricultural activities is one of the main causes of the loss of environmental services provided by this ecosystem. The extreme proximity of the growing areas to the bodies of water increases the negative effects of erosion on the availability of water in the stream, while reducing its flow capacity, quality and quantity of water available for consumption. In the semi-arid Northeast, the relatively inferior quality lands/ areas are used by small farmers to grow temporary crops, due to the presence of moisture for a longer time [41].

In this case, it is necessary for research to support effective public policies that favor less impacting agricultural practices, allowing the farmers or family members who can, at the same time, provide for their subsistence, remain in the activity and act as a friend of the environment, allowing that future generations may also survive in the semi-arid areas.

3.6.2 Solid and Liquid Waste

According to Medeiros [42], the pollution of rivers is increasingly visible due to the presence of solid waste and polluted liquids.The pollution leads to production of successive processes of deterioration and high loss of water quantity.

According to Mucellini and Bellini [43], the age old culture and habits of people characterize the way of using the environment, the production of waste and the way in which these products are treated.The ill planned day to day activities result in heaps of garbage.These heaps develop inappropriate environments.One can see littered and stinking garbage in vacant plots, river banks and lakes, weir and even sidewalks in public places.

The problem of irregular disposal of solid and liquid wastes is cultural and educational. Regarding solid waste, what is lacking in fact is a work of environmental awareness and education.

For the verified problems regarding the provision of irregular solid and liquid wastes in watercourses, the following developmental and preventive measures are suggested based on the document of Banco do Nordeste [40]:

- Map and characterize the environmental situation of the region, particularly at the HBS level, diagnosing levels of contamination of ground and surface water, soil and air;
- Establish an efficient collection service, minimizing clandestine discharges by considering the sociocultural habits of the population to define the collection plan;
- Use community collection systems, with the use of appropriate land to receive the recyclable material and construction residue;
- Elaborate solid waste management projects, considering landfill projects and specific areas for the implementation of recycling and composting stages;
- Effective execution of the basic sanitation policy of all the cities inserted in the SBH of the river Espinharas avoiding the discharge of "in natura" sewage in the rivers, eliminating the serious pollution of these springs;
- The implantation of the Landfill system, including solid waste pickers, as a professional category, reverse logistics and shared responsibility in the cities that are part of the SBH of the Espinharas river;
- Require industries to carry out the Solid Waste Management Plan (PGRS) prior to disposal of the waste;
- Clear the river gutters, especially in urban areas, in order to protect the banks of these springs to minimize silting and, consequently, the risk of flooding and flooding. In addition, to create projects of recovery of the riparian forests through the implantation of Projects of Recovery of the Degraded Areas - PRAD.

There is a need for joint actions involving public authorities and organized civil society aimed at achieving the goals of sustainable development, with special attention to reducing the impacts that affect the Espinharas River and any area of contribution, which will revert to its recovery and / or restoration.

4. CONCLUSION

The QGIS and GRASS software were tools capable of performing the main operations on the MDE, to extract the physical information of the SBH of the river Espinharas. The use of these tools with the remote orbital sensing, associated to the IDRISI SIG, allowed identifying the intensities of land use.

The analysis allowed the knowledge of the relief characteristics, such as slope, slope orientation and hypsometry, as well as the main morphometric indexes of SBH of the Espinharas river.

The low intensity of land use preponderated in this sub-basin and results from areas previously used generally in the cotton crop and abandoned for recovery, the high intensity area of use, is located in the urban area of the municipality of Patos-PB.

The main environmental problems identified in the field trips were the use of preservation areas for temporary agricultural crops, irregular deposition of solid and liquid waste and deforested areas.

UNDER PEER REVIEW

REFERENCES

1. Simões AO, Silva HÁ, Metelo KCC, Santos AS, Birth VEN. Morphometric analysis of the cuiabá river basin as a subsidy to the management of hydrographic basins. Monograph (Environmental Engineering) -Centro University of Várzea Grande, Várzea Grande, 2017. (In Portuguese).

2. Rocha RM, Lucas AAT, Almeida CAP, Meneses Neto EL, Aguiar neto AO. Morphometric Characterization of the Poxim-Açu River Sub-basin, Brazil. Ambiente e Água. 2014; 9(2): 276-287. Available: < http://www.scielo.br/pdf/ambiagua/v9n2/v9n2a09.pdf > Access: 17 january de 2019. (In portuguese).
3. Cardoso CA, Dias HCT, Soares CPB, Martins SV. Morphometric characterization of the Debossan River Basin, Nova Friburgo, RJ. Revista Árvore. 2006;30(2):241 – 248. (In Portuguese).

4. Oliveira PTS, Alves ST, Steffen JL, Rodrigues DBB. Morphometric characterization of watersheds using SRTM data. Revista Brasileira de Engenharia Agrícola e Ambiental. 2010;14(8):819-825. (In portuguese).

5. Ribeiro HJ, Ferreira NC. Comparative analysis of hydrological networks generated from hydrologically consistent surfaces. Geodetic Sciences Bulletin. 2014;20(4):784-805. (In portuguese)

6. USGS - UNITED STATES GEOLOGICAL SURVEY. Shuttle Radar Topography Mission (SRTM) 1 Arc-Segund Global. 2016.

7. JPL – JET PROPULSION LABORATORY. Shuttle Radar Topography Mission. 2019 Available: < http://www2.jpl.nasa.gov/srtm/> Access: 20 january 2019.

8. Araújo neto JR, Andrade EM, Palácio HAQ, Santos JCN, Oliveira FAL. Comparative analysis of surface runoff of experimental microcatchments in tropical semiarid climate.2013:2:111-120. Available < em https://www2.ufrb.edu.br/wrim/images/wrim-2-3-2013/v02a03a01.pdf> Access: 21 January 2019. (In portuguese).

9. Arnáez J, Lana RN, Lasanta T, RUIZ FP, Castroviejo J. Effects of farming terraces on hydrological and geomorphological processes. A review Catena. 2015;128:122-134.

10. Silva RMP, lima JR, Mendonça IFC. Alteration of the vegetation cover in the sub-basin of the Espinharas River in the period 2000-2010. Brazilian Journal of Agricultural and Environmental Engineering. Campina Grande. 2014;18(2):202 – 209. (In portuguese)

11. Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek G. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift. 2014;22:711–728.

12. AESA – Executive Agency for Water Management of the State of Paraíba. Annual report on the state of water resources in the State of Paraíba: hydrological year 2008-2009. AESA, 2010b. (In portuguese).

UNDER PEER REVIEW

13. Paraíba. Secretary of State for Science and Technology and Environment - SECTMA. PERH-PB: state water resources plan: executive summary & atlas / State Government of Paraíba; State Secretariat for Science and Technology and the Environment, SECTMA; Executive Agency for Water Management of the State of Paraíba, AESA. - Brasília, DF: Consortium TC / BR - Concremat, 112p .: il. 2006. (In Portuguese).

14. EMBRAPA, Brazilian Agricultural Research Corporation. Embrapa UEP Soils. Recife, 2006. Available: <www.uep.cnps.embrapa.br/solos/index.html>. Access: January 20, 2019.

15. SUDEMA – Superintendence of Administration of the Environment. Update of the forest diagnosis of the State of Paraíba. Southampton: SUDEMA, 268p. 2004.

16. AESA – Executive Agency for Water Management of the State of Paraíba. Interactive map. AESA, 2010a. (In portuguese).

17. Mitasova H, Mitas L. Interpolation by regularized Spline with tension: I. Theory and implementation. In: Mathematical Geology. 1993;25:641–655.

18. Neteler M. Introduction to GRASS GIS software, 2 ed., Hannover - Germany. (A GRASS beginners tutorial in English language), 1998.

19. EMBRAPA, BRAZILIAN AGRICULTURAL RESEARCH COMPANY. National Soil Survey and Conservation Service (Rio de Janeiro, RJ). Summary of the 10th Technical Meeting of Soil Survey. Rio de Janeiro, 83p. 1979. (In Portuguese).

20. Lima JR. Society, energy and the semi-arid environment: a study of the Sumé Watershed. Thesis (doctorate) - State University of Campinas, Faculty of Mechanical Engineering. Campinas, sp; [s. n.], 205p. 2004. (In Portuguese).

21. Germany. Federal Ministry for Economic Cooperation and Development (BMZ). Guía de protecciona ambiental: material auxiliar para la identificación y evaluación de impactos ambientales. Eschborn: (GTZ) GmbH, 1996. Tomo I, 613p.

22. World bank. Libro de consulta para evaluación ambiental: lineamientos sectoriales. Washington, v.2. 276p. 1991.

23. World bank. Libro de consulta para evaluación ambiental: lineamientos para evaluación ambiental de los proyectos energéticos e industriales. Washington, v.3. 233p. 1992.

24. Sobrinho TA, Oliveira PTS, Rodrigues DBB, Ayres FM. Automatic delimitation of watersheds using SRTM data. Agricultural engineering. 2010;30(1):46-57. (In portuguese).

25. Strahler AN. Quantitative analysis of watershed geomorphology. Transactions of American Geophysical Union. 1957;38:913-20.

26. Nascimento PJA, Lira RTM. An approach on the urban development of the city of Patos, State of Paraíba. RBDGP, Pombal – Paraíba. 2013;1(2):10-16. (In Portuguese).

UNDER PEER REVIEW

27. Christofoletti A. Geomorphology, 2.ed. São Paulo, Edgard Blucher, 188 p. 1980.

28. Villela SM, Mattos A. Applied Hydrology. McGraw-Hill, São Paulo. 245 p. 1975.

29. Andrade NLR, Xavier FV, Alves ECRF, Silveira A, Oliveira CUR. Morphometric and pluviometric characterization of the Manso river basin, MT. Geociências. 2008; 27(2): 237-248. (In poruguese).

30. Fraga MS, Ferreira RG, Silva FB, Vieira NPA, Silva DP, Barros FM, Martins ISB. Morphometric characterization of the catchment area of the Catolé Grande river, Bahia, Brazil. Nativa. 2014;2(4)214-218. (In portuguese).

31. Silva L, Lima VER, Almeida HÁ, Costa filho JF. Geomorphometric characterization and mapping of conflicts of use in the drainage basin of Aude Soledade. Revista brasileira de geografia e física. 2010;3(2):112-122. (In portuguese).

32. Marinho RR, Silva ECM. Morphometric analysis of areas affected by urban flooding in Manaus (AM). Paths of Geography. Uberlândia. 2016; 17 (59): 162-176. (In Portuguese).

33. Feitosa A, Santos B, Araújo MSB, Morphometric Characterization and Identification of Areas Susceptible to Erosion in the Pajeú River Basin, PE: the Case Study of the Pajeú River Basin / PE.Revista Brasileira de Geografia Física. 2011;4(4): 820-836. (In portuguese).

34. Felipe AC, Campos S, Parizoto NMSF, Nardini RC, Traficante DP. Geoprocessing applied in morphometric of the Ribeirão do Veado watershed – Piratininga (SP), seeking the conservation of the water resources. Brazilian Journal of Applied Technology for Agricultural Science. 2013;6(2):89- 95.

35. Ribeiro G.F, Pereira SY. Morphometric analysis of the Vargemas de Caldas basin, Plançto de Poços de Caldas, MG. Terræ. 2013;15-20. (In portuguese).

36. Soares LS, Lopes WGR, Castro ACL, Araujo GMC. Morphometric analysis and prioritization of river basins as an integrated environmental planning instrument. Journal of the Department of Geography. 2016;31:82-100. (In portuguese).

37. BRAZIL. Código Florestal Atual. Lei n° 12.651 de 25 de maio de 2012a. Available:< http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm>. Access: 28 january 2019.

38. BRAZIL. Alteração da Lei N° 12.651 de 25 de maio de 2012. Lei n° 12.727 de 17 de outubro de 2012b. Available: < http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12727.htm>. Access: 28 january 2019.

39. BRASIL. Política Agrícola. Lei n° 8.171 de 17 de janeiro de 1991. Available:< http://www.planalto.gov.br/ccivil_03/Leis/L8171.htm>. Access: 15 january 2019.

40. BANCO DO NORDESTE. Manual of Environmental Impacts: basic orientations of environmental aspects of productive activities. Fortaleza: Banco do Nordeste, 297p. 1999. (In portuguese)

UNDER PEER REVIEW

41. Sarcinelli O, Marques JF, Romeiro AR. Cost of environmental suitability of riparian vegetation areas: a case study in the Córrego Oriçanguinha watershed, SP. Revista Informações Econômicas. 2008;38(10):70-79. (In portuguese).

42. Medeiros FS. Environmental impacts and delimitation of the permanent preservation area in the Espinharas River in the urban stretch of Patos-PB. (Monograph) Federal University of Campina Grande, UFCG / CSTR - Patos, 88f .: il. color. 2015. (In Portuguese).

43. Mucelin CA, Bellini LM. Garbage and perceived environmental impacts on the urban ecosystem. Society & Nature, Uberlândia, 2008; 20 (1): 111-124. (In Portuguese).

UNDER PEER REVIEW