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Quantitative morphometric analysis of a river basin using GIS techniques: Case study of Miljacka River, Bosnia and Herzegovina

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Abstract

This paper concerns the analysis of the morphometric characteristics of the Miljacka river basin using the Digital Elevation Model of the terrain in the Geographical Information System. A quantitative geomorphological analysis of general characteristics was performed, whereby the analysis was supplemented with specific parameters of the drainage system, which are of linear, areal and relief characteristics. Standard mathematical formulas and software tools for Surface and Hydrology in the GIS software environment were used to estimate the mentioned parameters, using ArcMap 10.4. By working in the Arc Map program, a database system was created, with the use of a grid system, which offers the possibility of overlaying geospatial data, extracting certain parameters and their analysis and synthesis. The analyzed parameters are indicators of the shape and recent processes in the relief. They represent a supplement in the inventory and typification of relief forms, which, thanks to GIS software, have a geographic reference, which facilitates their correlation. The importance of the conducted analysis is reflected in the fact that the obtained data have a numerical value, are verifiable and can be applied multiple times in practice for the purposes of determining erosive processes, protecting and improving space and the living environment, solving water management problems, planning economic activities and drafting spatial plans.

Keywords: Geomorphology, Digital elevation model, GIS, Hydrology, Miljacka River Basin, Planning.

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Contents

Contribution of this paper to the literature

The use of GIS in this work made it possible to obtain specific data on the various geo morphological and hydrological characteristics of the watershed. In the same way, other watersheds in Bosnia and Herzegovina can be analyzed, which will contribute to better spatial planning, arrangement and use of space.

1. Introduction

In the last few decades, a significant focus in the field of geomorphology was directed to the development of quantitative methods important for the analysis of the genesis, evolution and behavior of drainage systems [1]. The branch of geomorphology, based on an analytical-cartographic approach and quantitative characteristics of the Earth, is geomorphometry. It is an interdisciplinary field whose scientific and methodological basis is in mathematics, natural sciences and informatics [2]. Morphometry as such includes methods that are basically geomorphological, based on the principles of computer analysis of the Geographical Information System (GIS). GIS has proven advantages in the areas of visualization of spatial data and manipulation of a large number of data, which is basically a characteristic of morphometric analyses. In addition to the obvious advantage in the area of collecting and manipulating a significant amount of data, GIS is an effective tool for preparing data for modeling [3]. Considering the above, this tool encompasses a significant number of scientific disciplines, and in addition to being successfully used in scientific research, it is an indispensable part of work processes in the field of resource management, property management, development and spatial planning, cartography and infrastructure planning [1]. An indispensable part of modern geomorphometric analysis, which uses the wide possibilities of the geographic information system, is the digital elevation model of the terrain [2]. A digital elevation model represents a special type of geodata, in the form of a digital statistical terrain model with a series of known three coordinates [4, 5]. It is based on the collection of height data, by sampling points with a certain accuracy and interpolation into software programs, continuous quantitative data on the terrain is obtained in the form of raster data [4, 6, 7]. In the earth sciences, GIS methods are improving more and more rapidly, new machine learning algorithms are being developed, and automation in geospatial analysis is improving the precision and quality of modeling and geo visualization[8]. The last decade has been characterized by a large number of geoportals from which medium-resolution DEM data can be downloaded, which has facilitated and improved research in this area.

Morphometric characteristics of drainage systems show a significant level of dependence on natural factors. The characteristics of the surface conditioned by the geological structure and climatic influences are directly reflected in the creation and parameters of the river network and basin [9]. Although it is primarily a hydrological unit, the river basin also represents a natural entity, and is therefore a subject for physical, economic and social planning and development [10, 11]. Given the aforementioned high level of interdependence between natural factors and the river basin, changes in any component of the watershed can change the entire environment of the watershed [12]. GIS data can also contain data on the risk of torrential floods, which helps to reduce potential risks and their consequences in all spheres of life Kovačević-Majkić, et al. [13]. Ivanova Ivanova, et al. [14] states that morpho-hydrographic analyses, which are based on hydrographic and geomorphological methods and GIS, have their practical application especially in the sustainable use and management of natural resources.

The results obtained from the quantitative geomorphological analysis carried out in this paper concerning the Miljacka river basin are of great importance in determining the intensity of erosive processes in the recent period, protecting and improving space and the environment. Morphometric parameters are presented tabularly, graphically and on thematic geomorphological maps.

2. Study Area

Miljacka represents the right tributary of the Bosna River, one of the most important hydrographic streams of Bosnia and Herzegovina. It mostly flows through Sarajevo, the capital of the state (Figure 1). Miljacka is formed by the confluence of the Paljanska and the Mokranjska Miljacka in the area of the Han Bulozi settlement, and flows into the Bosna River in the Rajlovac settlement. Using hydrological tools for extracting the river network in the GIS software environment, the total length of the Miljacka River was determined to be 20.02 km, or, with its larger component, a length of 40.43 km. The catchment area of 378.51 km^2 drains the mountainous terrain of the northern part of Ravna Planina and Trebević, the southwestern slopes of Romanija, the southern parts of Bukovik and Crepoljski uplands. The lowest point in the watershed includes the area of the river mouth in Bosna and is 478 m, while the highest point is on the slope of Jahorina, at an altitude of 1665 m.a.s.l.

This area is characterized by the heterogeneity of the geological structure. Relations between the hydrological collectors (limestones and dolomites) and isolators (werfen deposits) caused the creation of springs. According to Figure 2, rocks of intergranular porosity are represented by alluvial deposits of Miljacka. Fissure porosity is found in ladinic deposits, while cavernous-fissure porosity is a feature of anisic limestone. Triassic carbonates are the most important aquifer of potable groundwater in the Miljacka river basin. Predominantly impermeable complexes are clastics of the Lower Triassic and deposits of "Orlovački" conglomerates of the Upper Miocene, while practically impermeable rocks are Miocene sediments of the “Koševska” series.

According to the values of the basic climatic parameters, the Miljacka catchment area primarily belongs to the Cfb climate, while hypsometrically, the entire basin is under the influence of the Cfc and Dfb climates [15]. C climate class is determined with regard to the thermal regime recorded at meteorological stations. The mean temperature of the hottest month is higher than 10 °C, and the mean temperature of the coldest month is above -3 °C Drešković and Mirić [16]. Drešković and Mirić [16] state that areas of the Cf climate type in the average annual pluviometric regime do not have a pronounced dry period, which can be noticed based on the annual flow precipitation at all three meteorological stations. The annual amount of precipitation in the basin area is determined by the regional position of the area in relation to the Mediterranean and continental influence, as well as the relief characteristics of the wider area. The amount of precipitation is indirectly related to the annual course of temperatures, air humidity and cloudiness, as the main factors of condensation and sublimation of water vapor and its excretion in the form of precipitation. The sum of annual precipitation ranges from 947.4 on meteorological station Bjelave to 968.8 on meteorological station Pale.

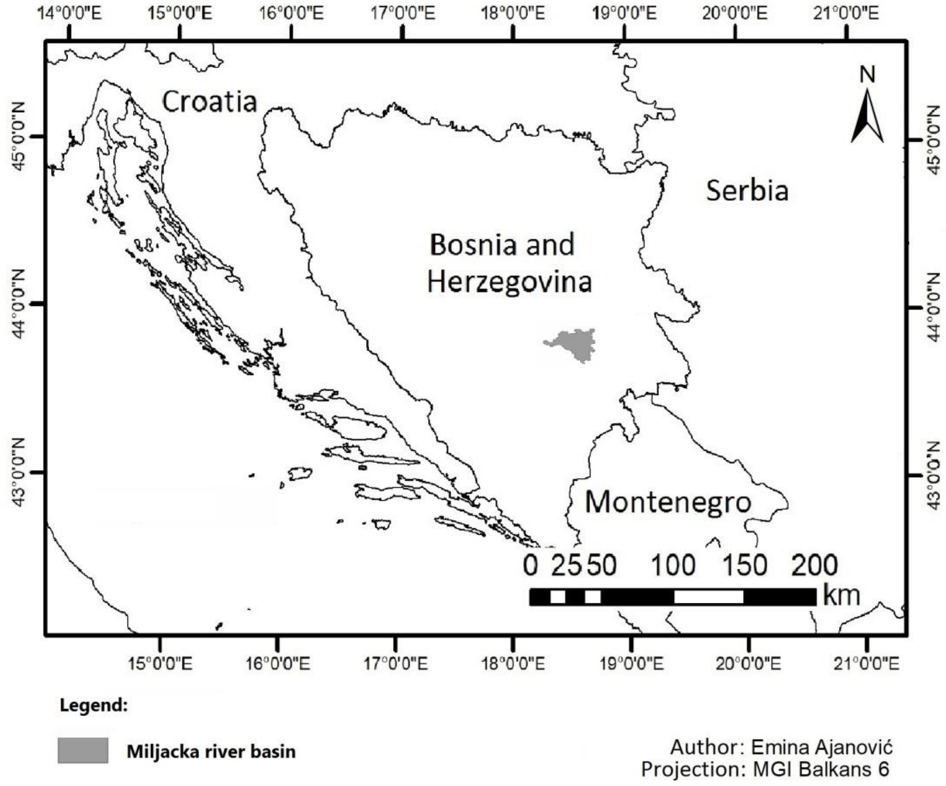

Figure 1. The location of the Miljacka watershed on the map of Bosnia and Herzegovina.

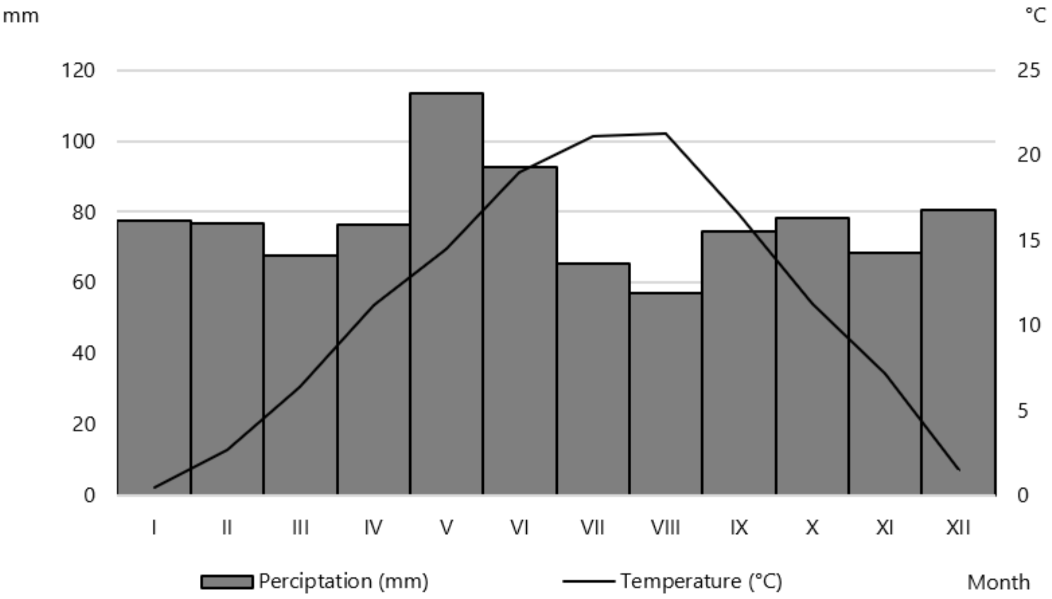

Figure 2. Hydrogeological map of the Miljacka catchment area.

By comparing the analyzed meteorological indicators with those in the recent period, recorded at the Bjelave meteorological station, certain changes can be observed. Average annual temperature for the period 2010-2020 was 11.1°C, which is an increase of 1.7°C compared to the previously analyzed time period. Average monthly temperatures are increasing, and the maximum temperature was recorded in August. Annual amounts of precipitation have been decreasing in the recent period, which indicates a slight increase in the influence of the Mediterranean pluviometric regime. Figure 3. shows that the largest amount of precipitation was recorded in the period of climatological spring, with a maximum during the month of May.

The hydrographic characteristics of the upper part of the basin are conditioned by the local geological-tectonic situation and relief energy, and in the hydrological sense, contacts of water-permeable carbonate deposits with water-bearing verfen deposits are significant. Consequently, the upper part of the basin is abundant with water. The dominance of hydrological collectors in the central part of the basin caused the rare appearance of weaker sources and surface flows (Figure 2), which are also characterized by large drops in the river beds, due to the topographical situation. The hydrographic characteristics of the lower part of the basin are determined by the presence of oligo-miocene sediments, alluvial sediments and anthropogenic factors. In this segment, a significant part of the river Miljacka and its larger tributaries in the Sarajevo region, for the purposes of expanding the urban system, was subjected to hydromelioration and construction works of the underground sewerage network of the city of Sarajevo.

At the water measuring station the maximum water level values during the year were registered in the spring period, due to snow retention. The highest flows are positioned in the spring season (March - June), winter (December - February) and autumn (October - November), while the lowest flows are a characteristic of the summer season (July - September).

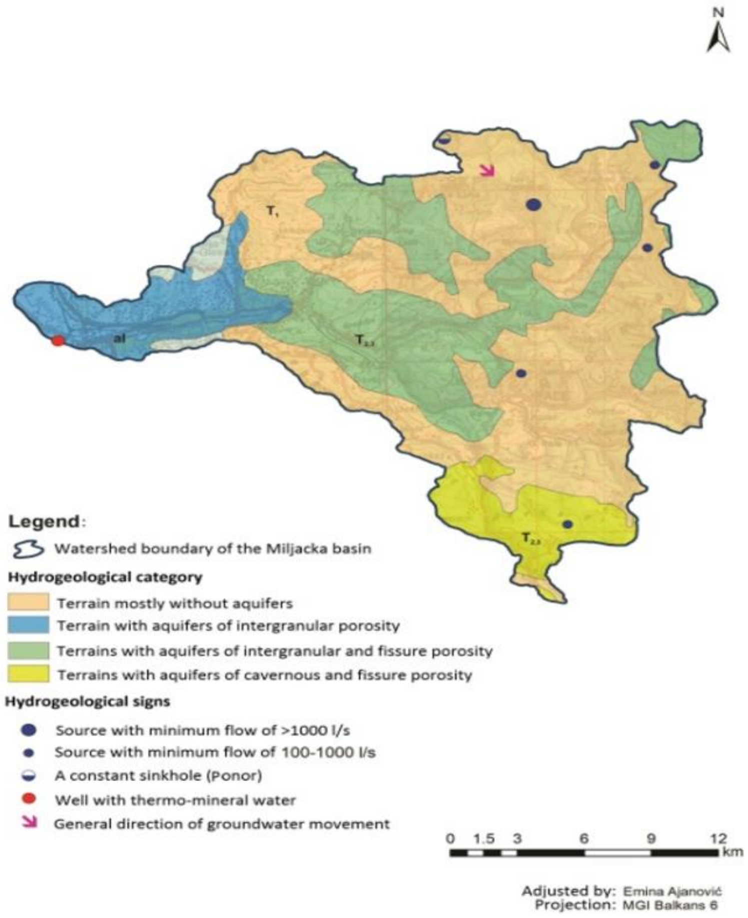

Figure 3. Climate diagram for meteorological station Sarajevo in the period 2010-2020.
Source: Federal Hydrometeorological institute [17].

On the Miljacka River, there are longer regulated sections and embankments in order to protect against floods. It mainly refers to the narrower city area, and in some segments, facilities were built with the aim of protecting industrial zones and agricultural areas.

3. Methods

One of the most important tasks of geomorphology is the study of geomorphological processes and forms with many different aspects, which are also the object of study of auxiliary geomorphological disciplines. One of them is the morphometric analysis, which determines the metric values of the relief shape and measures the dimensions of the relief [18]. This paper includes a morphometric analysis of the basin's drainage system and relief characteristics of the researched area. The paper shows the possibility of automatic extraction and analysis, using the European Digital Elevation Model EU-DEM for the assessment of areal, linear and relief features of the researched area, with the help of the GIS software ArcMap 10.4. in order to overcome the procedure of physically extracting the morphometric characteristics of the drainage system from topographic maps. EU-DEM model encompasses the area of 38 countries, 32 member of the European Union and 6 cooperating countries [4, 19]. For the purposes of this paper, EU-DEM v1.1 was used, which is the resulting data set, created by improving geo-positioning, vertical accuracy and compliance of hydrological parameters. It is a continuous data set, divided into square areas of the size 1000x1000 km, with a resolution of 25 m, with a vertical accuracy of about 7 m (EU-DEM-Copernicus Land Monitoring Service[1]). The GIS software environment offers the possibility of raster and vector analyses, available in the program package of tools for Spatial analysis, within which the tools for Hydrology were used. Strapazan and Petruţ [21] concluded that „computerized hydrologic models have become an essential tool not only for a better understanding of the hydrologic cycle but also for a faster problem solving in hydrology, such as the ungauged catchments" (p.95). Hydrology tools were used for the purpose of separating the drainage network within the previously defined boundary of the catchment area (Figure 4).

After completing the preparatory steps of filling the empty cells and defining the runoff directions of each cell the watercourse network was extracted from the digital terrain model, using the output parameters of the Flow Accumulation function. This function is based on the number of cells, which, considering the slope of the terrain, are "poured" into each cell. The limit value for this raster data was defined by comparing the data with a topographic map, scale 1:25 000.

The ranking of the river network was based on assigning a numerical order to the flows in the drainage network, and the procedure was performed with the help of the Stream Order function, according to Straler's method.

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[1] url: https://land.copernicus.eu/imagery-in-situ/eu-dem [20].

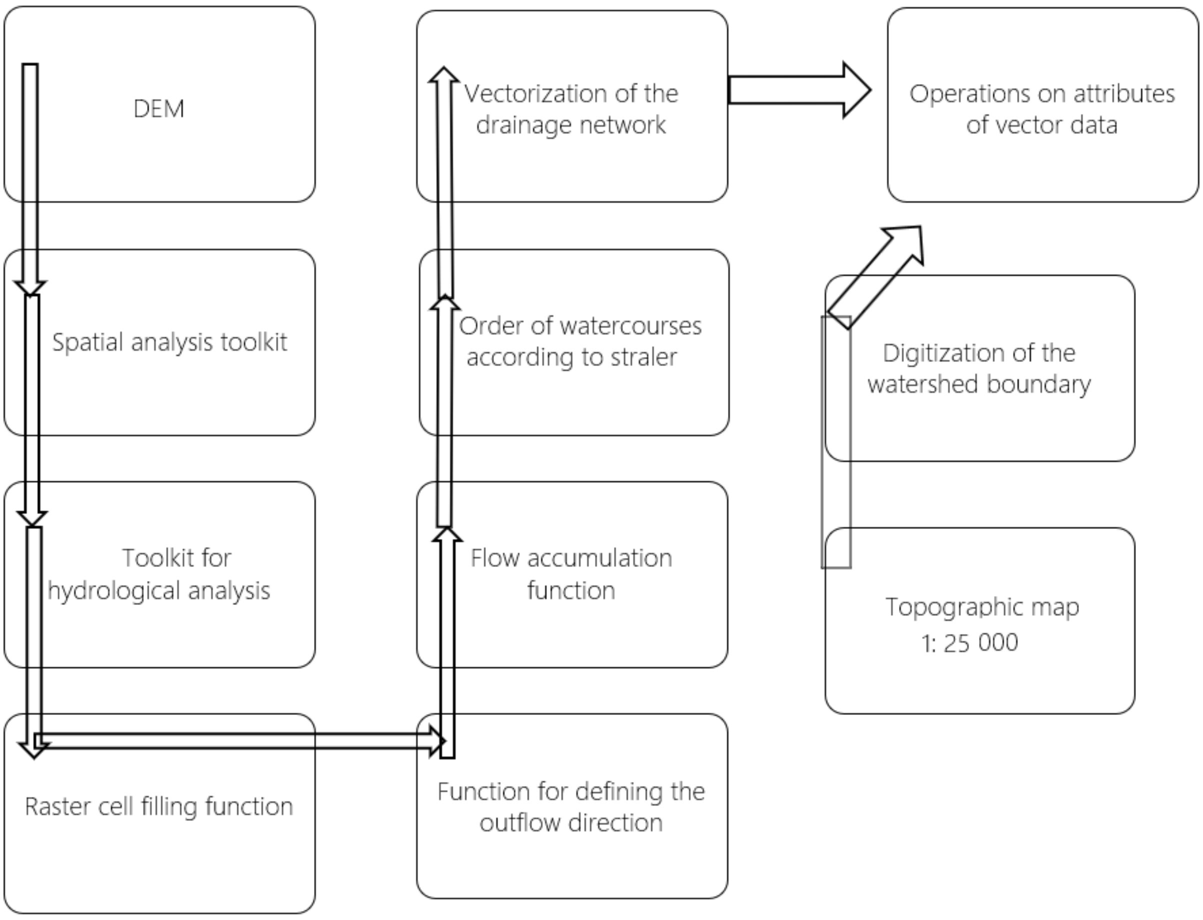

Figure 4. The procedure of applying GIS software tools in the morphometric analysis of the drainage basin.

The aforementioned procedures included input indicators for the conducted morphometric analyzes of the drainage basin, of linear and surface characteristics. The analyzes were carried out with the help of operations on the attributes of geographic entities, which are presented further in this paper. Relief features are an important factor and have a key meaning in the spatial planning process, where they are analyzed from four aspects: morphogenetic, morphological, morphometric and morphographic features of the terrain. For the evaluation of the validity, limitations and/or convenience of the terrain, for the settlement of the population, the construction of residential buildings, roads, lifestyle and tourist activities, morphometric and morphological characteristics are significant [22]. The morphometric analysis of the relief features was carried out using tools for Surface and Zonal statistics of the digital terrain model (Figure 5). Statistical analyzes are supplemented with the Microsoft Excel program, basic scientific methods and mathematical formulas. This paper includes the analysis of hypsometry, terrain slope, exposure, and special attention is paid to the methodology ofderiving parameters for vertical relief dissection. The analysis of hypsometric values is based on a digital terrain model that represents the raster structure of the data. The location of the entity is defined by a direct relationship with the grid network, where each pixel is associated with a square plot on the earth's surface, in other words each pixel has a geographic reference, and new attributes of such a data set are created based on existing attributes, for example by classification [23]. Methods and algorithms integrated into the ArcInfo program were used to calculate the slope of the terrain. The software program determines the values for each pixel (square area), in a way that it calculates the maximum rate of value change from that pixel to the neighboring ones that surround it Radoš, et al. [2]. Slopes were determined by calculating the first-order derivatives of the values within a 3x3 square [24]. The geomorphological classification of slope gradients was performed according to the dominant processes on the slopes and the corresponding relief form. Consequently, the terrain slope is widely used in the analysis of slope processes (e.g. landslides), denudation, erosion and land use [22]. Exposure is a function of determining the orientation of an individual cell towards the cardinal points, and in GIS it is calculated using the function from the Surface tool. The algorithm is based on the calculation of the exposure value of the central pixel in relation to the eight neighboring ones. The final results are subtracted from the value of 90 or 360, and the orientation of each individual cell is obtained according to the azimuths [25]. The analysis of vertical dissection implies the determination of height differences between the lowest and highest points on a unit area (m/km^2). It is an important geomorphological factor for understanding the structural and functional characteristics of the environment, in order to properly manage it. Knowledge and understanding of vertical dissectionare a prerequisite for the prevention of threats of natural disasters and the rehabilitation of destructive processes [22]. According to Lozić [26], the calculation of vertical dissection is based on a formula that originates from the definition of this morphometric parameter:

$$\text{Vertical dissection} = \text{Hmax} - \text{Hmin}/P \ \ (m/km^2) \qquad (1)$$

Where:
Hmax - maximum height in a square cell.
Hmin - minimum height in a square cell.
P- area of a square cell (1 km^2).

The GIS software environment enables the formation of square surfaces, dimensions 1x1 km, together with interpolation points where the values of hisometric parameters are defined. The calculation of the vertical relief dissection was carried out using the Zonal statistics tool program, which opens the dialog box for the analysis of necessary parameters on the digital terrain model. "Range" is the most important parameter during the calculation of vertical dissection, by means of which the software calculates the differences between the maximum and minimum values within each square cell separately. It is important to associate the obtained values with the accompanying attributive tables of vector data, represented by a square grid and interpolation points. This step is enabled through a unique identification code (ID) code. The next step involves the point interpolations.Taking into account the simplicity, input data for this procedure or the fact that in GIS inverse distance interpolation is used to create a raster from point data Burrough, et al. [23], for the purposes of this paper, a map of vertical relief dissection was created using the IDW interpolation method. IDW (Inverse Distance Weighted) type of interpolation is a simple method in which value at the unknown point is calculated by taking the contribution of all points located in a certain radius around it with a statistical weight which is inversely proportional to the square of the distance of the point.

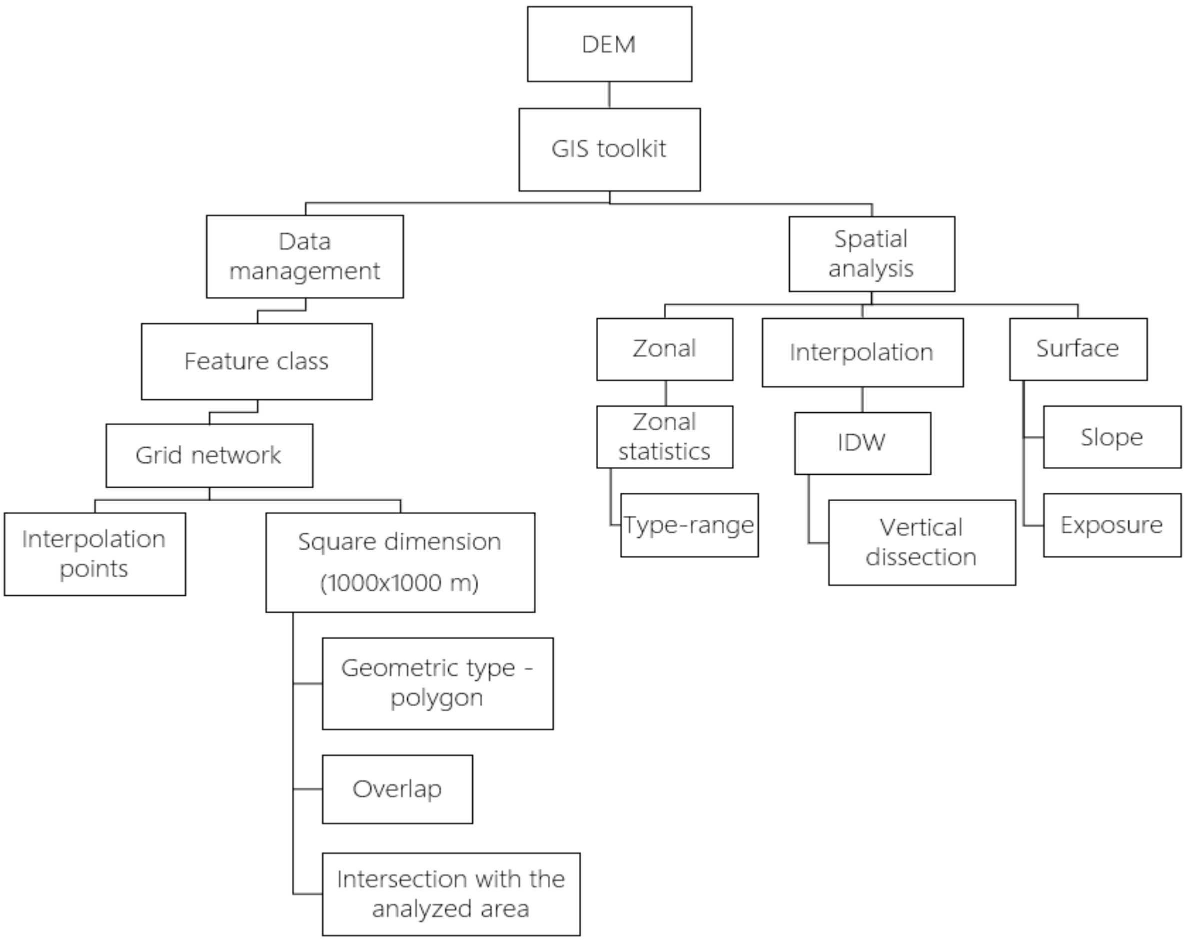

Figure 5. Procedure of morphometric analysis of relief features using the tool package in GIS.

4. Results and Discussions

4.1. General Morphometric Characteristics of the Catchment Area

The general morphometric analysis included the hypsometric characteristics of the terrain of the Miljacka River catchment area. During the analysis, using a digital elevation model, 13 hypsometric levels were distinguished, each with 100 m of relative height (Figure 6). Cartographic representation of hypsometric levels indicates a significant increase in altitude from west to east of the catchment area (Figure 7).

The average height of the basin is 1043 m.a.s.l. which is a consequence of the dominant representation of hypsometric levels in the categories of medium-high mountains 1000-1500 m.a.s.l., low mountains 700-1000 m.a.s.l. and high >1500 m.a.s.l. [18].

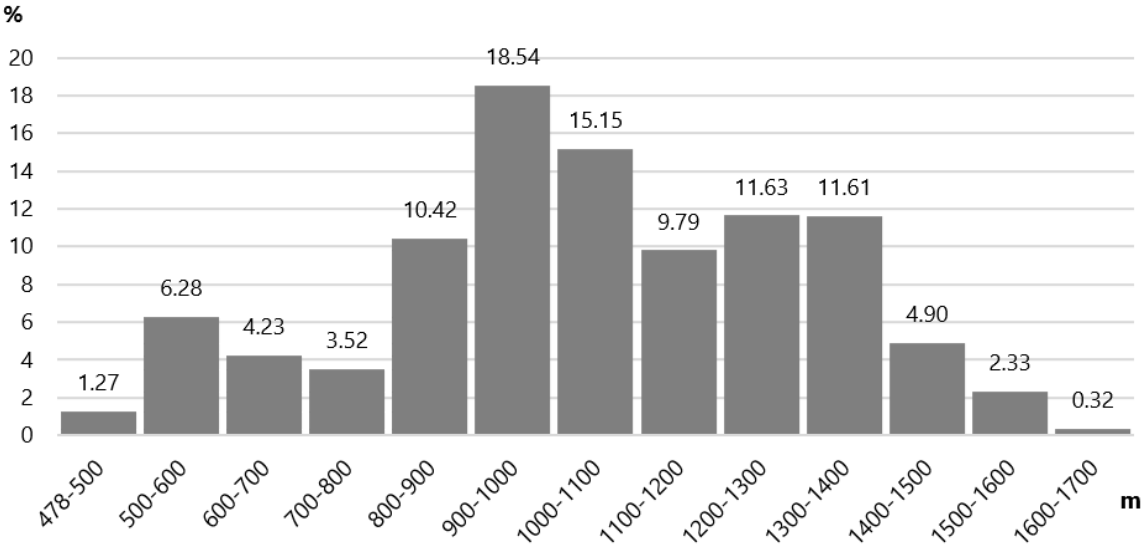

Figure 6. Distribution of hypsometric levels of the Miljackariver basin.

According to this classification, terrains that include medium-high mountain areas make up 53% of the catchment area, 32% of the catchment area is represented by the category of low mountains, 2.7% by high mountains, while the lowest parts of the terrain, up to 700 m.a.s.l., comprise 11.8% of the total area basin. The presentation of the hypsometric characteristics of the terrain allowed an insight into the clear distinction of three significant geomorphological units, with dominant processes: the Mokranjska Miljacka valley, the Paljanska Miljacka valley and the valley of Miljacka from the confluence of the Mokranjska and Paljanska Miljacka to the mouth of the Bosna River.

Deviations in the continuous decline in the longitudinal section are the result of significant direction changes on shorter sectors in a separate watercourse network, reflected in the altitude change during the 3D analysis of the terrain.

The analysis of the spatial distribution and coverage of certain categories of slope grade is important, considering their significance as indicators for the extent and intensity of morphostructural and exo-geomorphological (denudation and accumulation) processes that influenced the genesis of slopes during the paleo-geomorphological period, and are also an indicator of future impacts of the afore mentioned processes on their mutual relations [2].

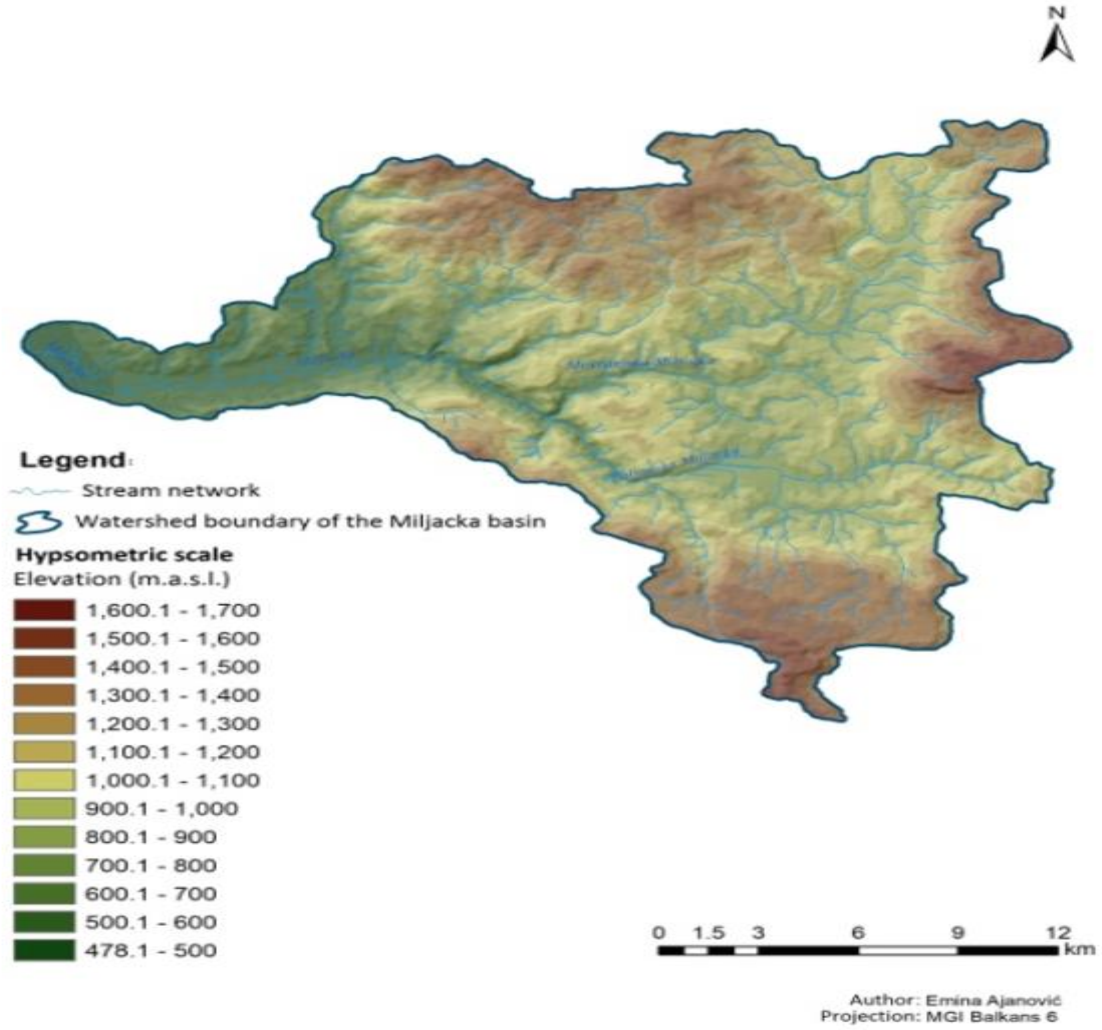

Figure 7. Hypsometric map of the Miljacka river basin.

The represented categories of slopes are presented with regard to the dominant morphological processes, and correspond to the classification accepted by the International Geographical Union. Table 1 summarizes selected slope categories that were used in this study.

Table 1. Representation of terrain slope categories in the catchment area.

Slope (°)	Name of inclined surface	Area (km^2)	Participation (%)
0-2°	Subhorizontal plains	21.24	5.61
2-5°	Slightly sloping grounds	45.39	11.99
5-12°	Inclined terrains	145.87	38.54
12-32°	Very inclined terrains	157.31	41.56
32-55°	Steep terrain	8.66	2.29
>55°	Very steep	0	0

Slope category up to 2° of subhorizontal plains, is characteristic for the largest part of the valley extensions of Mokranjska, Paljanska Miljacka, Miljacka valley in Sarajevo region, especially in the alluvial plain part (see Figure 8). The second slope category in the form of slightly sloping terrain in the amount of 2-5°, represent kind of a contact zone, a gentle transition of valley extensions to steeper mountain ranges. The mentioned valleys were created on the edges, and in the eastern part of the analyzed watershed, they also include smaller valley areas of streams that denuded the slope sides in the advanced stages to the recent slope values. Areas like this on the edge of the Miljacka valley have been significantly anthropogenically conquered. The largest part has very inclined terrains (12-32°), with very strong slope processes, and they are represented in the eastern and central part of the basin, as a result of neotectonic movements, higher hypsometric levels of mountain areas, which are under the strong influence of fluvio-denudation processes.

The exposure of slopes in geomorphological processes is very significant, given that differently exposed slopes receive different amounts of short-wave radiation, in accordance with the apparent movement of the Sun, which affects the characteristics of climatic elements, and thus exo-geomorphological processes. Very warm exposures are south-facing slopes [2]. Figure 9 shows the distribution of exposures in the area of the Miljacka basin.

The highest representation is recorded by the southwest-exposed slopes (14.27%), which is in accordance with the Dinaric direction of providing dominantly represented relief morphostructures. Northern exposures cover considerable areas, i.e. 13.89% of the terrain. Two values of northern exposures were registered, considering the fact that the GIS software records the northern exposure to the west and the east from the zero azimuth, more precisely from 337.5° to 22.5° [1]. In the context of suitability, slopes with very warm and warm exposures occupy 39% of the terrain, neutral exposures account for 23%, and slopes with moderately cool and cold exposures occupy 37% of the terrain. The vertical relief dissection is a component of the overall relief dissection. From the geomorphological aspect, it is aintensity parameter of the development of geomorphological processes [27]. The analysis of the spatial representation of this parameter allows insight into endogenous processes, more precisely the tectonic activity of the area [28]. During the morphometric analysis of the vertical relief dissection, the methodology of forming a unit square grid in the amount of 1000x1000 meters was used, i.e. 1 km^2 of surface (Figure 10).

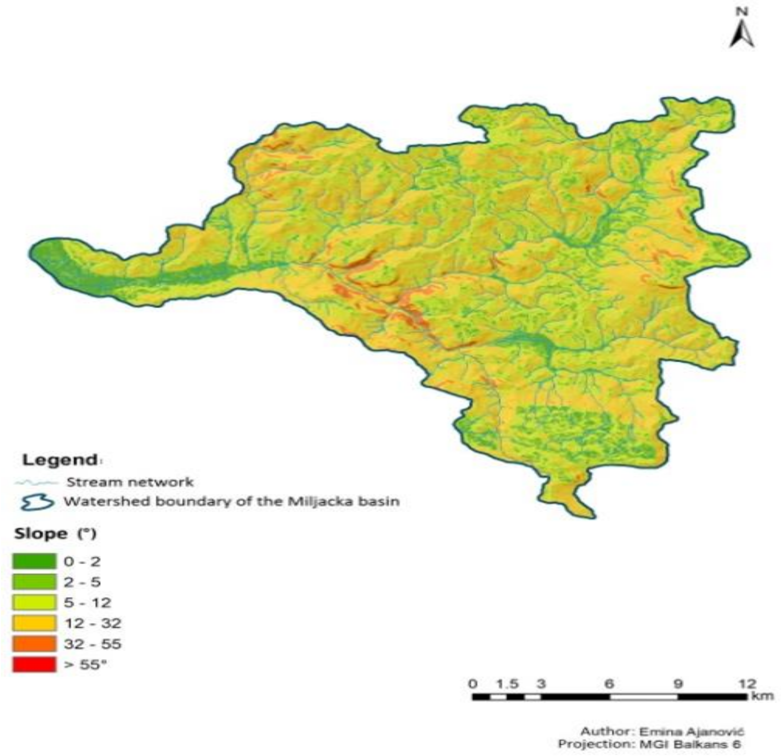

Figure 8. Slope distribution of Miljacka Basin.

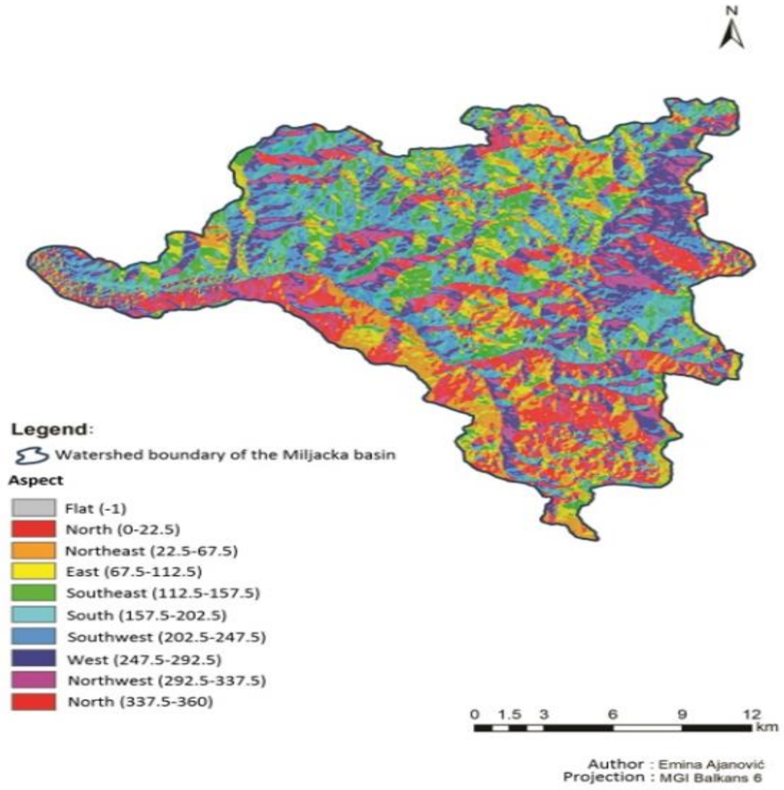

Figure 9. Aspect map of Miljacka Basin.

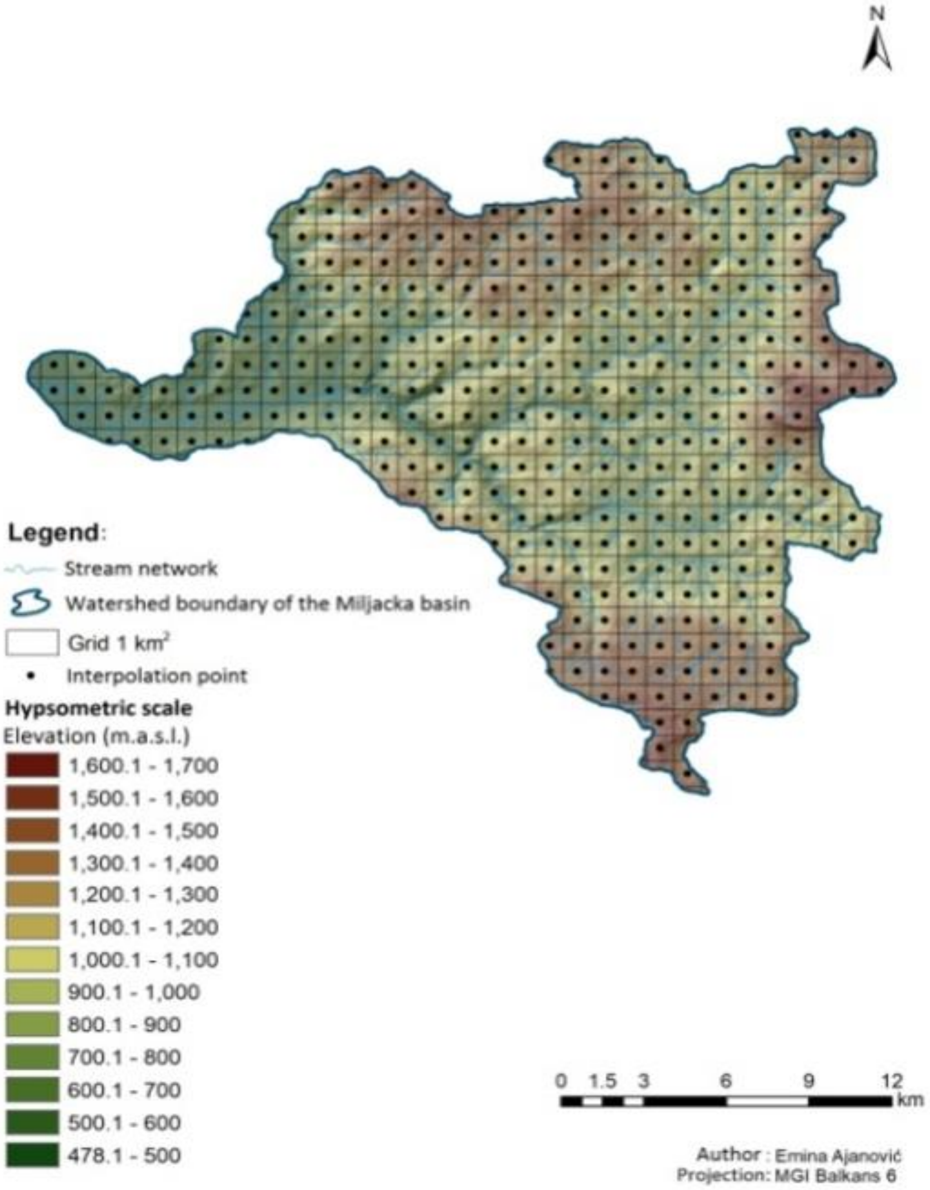

Figure 10. Unit square grid for calculating the Miljacka drainage basin.

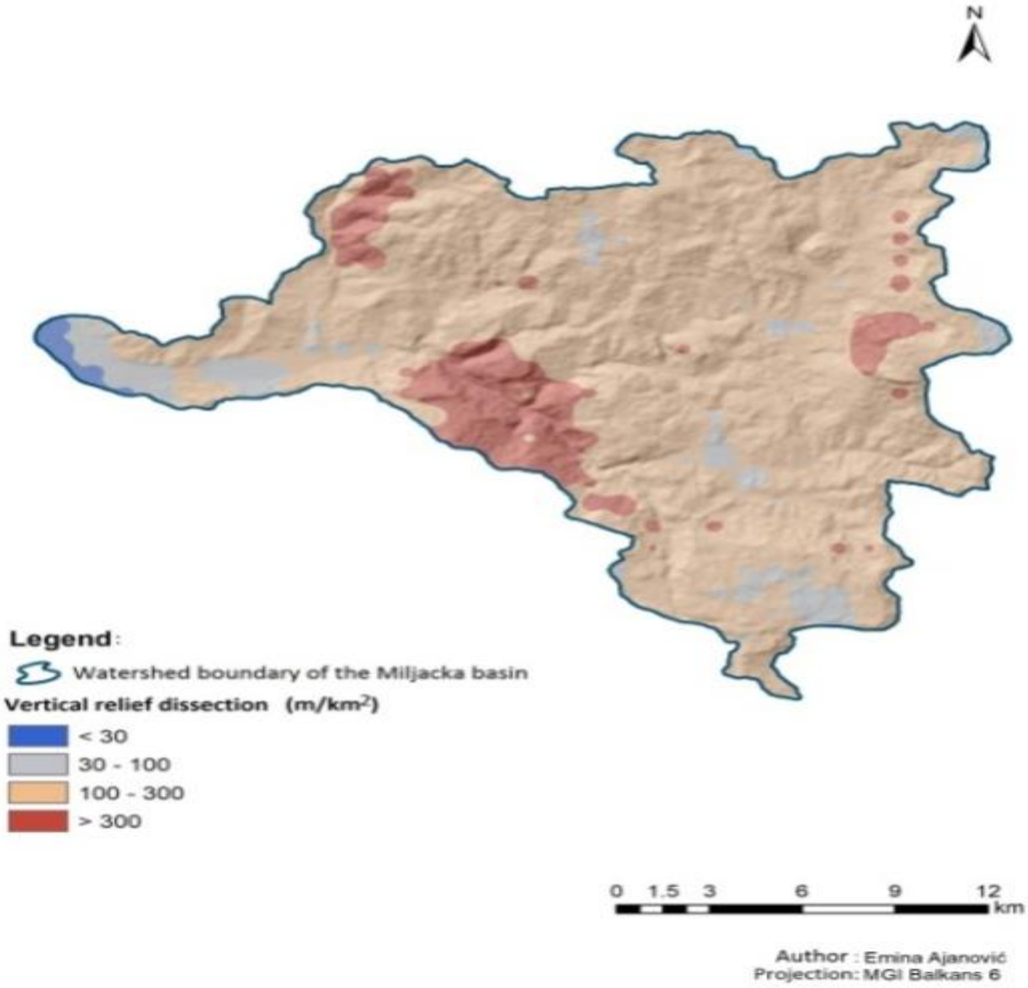

Figure 11. Vertical relief dissection map of vertical dissection in the Miljacka basin.

Within each unit area, the lowest and highest point (height difference) is determined, the values are associated with interpolation points in the center of each square. Using the method of interpolation with inverse distances, a continuous area of categories of vertical dissection was obtained, for which statistical and zonal analyzes determined total areas and participation in the spatial coverage. The least determined values (11.9 m/km^2) and the largest (555.6 m/km^2) of vertical dissection of the terrain indicate that there is no flattened, nor very distinct relief in the researched area. By correlating the value of the slope gradient and categories of vertical dissection, it was determined that accumulation processes prevail in the second category of vertical dissection, while the others are characterized by denudation processes. The distribution of vertical relief dissection categories indicates clearly expressed tectonic relationships in the basin area. Figure 11. shows that the western and southwestern parts are less vertically fragmented and are lowered by neotectonic movements, while the eastern, northeastern and significantly southern parts of the basin are characterized by greater vertical fragmentation due to neotectonic uplift processes.

4.2. Specific Morphometric Characteristics of the River System

Quantitative morphometric analysis resulted in important parameters for the assessment and understanding of hydrological processes in the catchment area.

The parameters are divided into a group of lined, areal and relief aspects of the researched area (see Table 2). The linear parameters include the morphometric characteristics of watercourses, and the areal, a group of watershed characteristics, based on which the derived sizes of watercourse and watershed characteristics can be calculated. The group of relief parameters completes the previous presentation of general morphometric parameters, conditioned by the hydrological processes of the analyzed basin. According to the methodology of determining the order of watercourses according to Straler, the total length of watercourses of order I-VI was calculated [29].

Table 2. Morphometric parameters in the Miljacka basin.

Morphometric parameters	**Formula**	**Result**	**Unit**
Drainage network			
Hierarchical rank (Strahler system) Order stream (Suf)*			
1st		214.58	km
2nd		120.03	km
3rd		66.09	km
4th		20	km
5th		15.33	km
6th		20.02	km
Stream length (Lu)	$Lu = L_1+L_2+\ldots+L_n$	456.1	km
Stream number (Nu)	$Nu = N_1+N_2+\ldots+N_n$	775	
Mean stream length (Lt)*		20.02	km
Main channel length (Cl)*		16	km
River flow development coefficient (C)	C=Lt/Lmin	1.3	
Basin geometry			
Basin area (A)*		378.51	km^2
Basin perimeter (P)*	The length of the outer boundary as projected onto the horizontal plane of the map.	128.02	km
Basin length (L_b)*		35.51	km
Basin width (W_b)	$W_b = A/L_b$	10.66	km
Drainage density (Dd)	$D_d = Lu/A$	1.20	km/km^2
Relief characterizes			
Minimum elevation of the basin (z)*	Elevation of basin mouth.	478.1	m
Maximum elevation of the basin (Z)*		1665.6	m
Total basin relief (H)	H = Z - z	1187.5	m
The average elevation of the basin (Ha)*		1043.4	m
Hypsometric integral (Hi)	Area under the hypsometric curve	0.48	%

Note: *Measured directly using GIS software analysis using DEM.
Source: GIS analysis; according to Korjenić and Temimović [30].

The valleys of the lowest order are connected to the areas of the headwaters of the larger watercourses of the basin, and are mostly represented at higher hypsometric levels. Smaller deviations are observed comparing the watercourses of the V and VI order, considering the specific gorge valley and the elbow bend of the Mokranjska and Paljanjska Miljacka, on the way to their junction and the place of origin of Miljacka, which flows from this area, in the tectonically predisposed and significantly aligned sector of the Sarajevo area. The watercourse length in the system is first of all a reflection of the hydrogeological characteristics, i.e. the stability of the river network of the analyzed area. The obtained density value of the river network for the Miljacka river basin is a consequence of the climatic and hydrogeological conditions of the terrain, and especially the hypsometric scale in the analyzed coverage, which, along with the topographic base, served as an input parameter of the limit values of the watercourse accumulation function or for defining the river network with the help of GIS software tools.

A very pronounced amplitude of heights in the watershed is a condition for high water flow capacity and high runoff, and thus a high potential for erosion in the watershed.

The hypsographic curve is primarily important in the interpretation of the way rainwater flows towards watercourses in the hydrographic system [31]. The curve shape indicates the relief age, that is, the balance of the processes of denudation and accumulation, where the area under the curve shows the relief that should be denuded by these processes. To describe the shape of the hypsometric curve, use the hypsometric integral that quantifies the area under the curve, indicating the mature phase of the relief of the analyzed watershed (Figure 12).

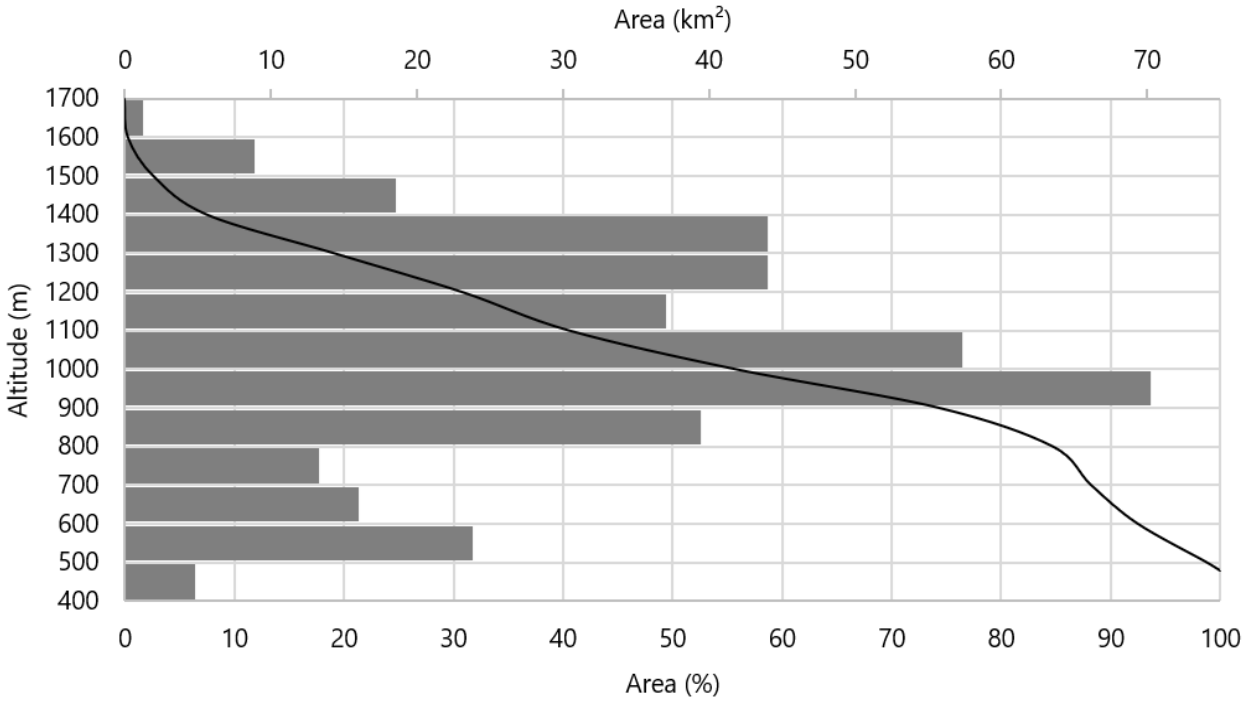

Figure 12. Hypsometric curve of the Miljacka river basin.

5. Conclusions

Lately, Digital Elevation Models have been the subject of increased usage and interest. Resulting in the convenience that this type of data offers in the calculation of various morphometric parameters. The aim of this paper was to show the possibilities of calculating general and specific morphometric parameters in the Miljacka river basin using software tools offered by the Geographical Information System, based on the analysis of raster data, such as the Digital Elevation Model of the terrain, and vector data obtained as output parameters of previous operations. The accuracy of data obtained with such analyzes depends on the availability of raster data, their accuracy, the experience and skill of the experts who work on their preparation and application, as well as the scale of spatial coverage for which they are applied. In order to understand the correlation of hydrological processes and the evolution of the relief, input parameters in the analyzes are important. The accuracy of the application of GIS for these needs can be seen in the obtained results of measuring specific morphometric characteristics. Significant result precision is possible by the automated extraction of individual surfaces of hypsometric levels, which in combination with Excel analyzes enable the creation of graphical representations of the balance of the basic geomorphological processes of the area. The GIS application enabled operations upondigital elevation model data of the terrain, which presented the main morphometric parameters that have a spatial reference. Further application of this type of spatial data is unlimited considering the possibilities of manipulation of huge databases in geographic information systems. This fact is also recognized by the institutions responsible for spatial planning, which in the recent period use morphometric data in the assessment of terrain stability and the prevention of natural disasters.

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