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Morphometric analysis of the Wegnia lake watershed in Mali: implications for hydrological and geomorphological processes

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Abstract:

Understanding the morphometric characteristics of watersheds is crucial for hydrological behavior, sediment transport, and landscape evolution. Despite the fact that watershed morphometry has been widely researched, little research has been done on the Wegnia Lake watershed, particularly regarding its structural controls and sediment deposition dynamics. By using ASTER GDEM (30 m) and GIS-based methods to analyze the Wegnia Lake watershed's morphometric features, this work seeks to close this gap. Four main morphometric features are taken into account in the study: relief, texture, linear characteristics, and basin geometry.

According to the findings, the Wegnia Lake watershed is of the 8th order with 9,020 stream segments and drainage area of 1,143.59 km². Dendritic drainage pattern means that slope and local relief are the parameters that primarily control stream development. The mean bifurcation ratio of 3.69 with fluctuations in the various stream orders suggests structural control on drainage development. The watershed's elongated shape (form factor = 0.38) controls its hydrologic response and runoff characteristics. In addition, concave slopes (39.11%) dominate the landscape, which indicates high sediment deposition areas.

These findings are essential to watershed management, particularly in predicting runoff response, control of soil erosion, and water resource sustainability planning in the future. Follow-up research should include hydrological modeling to provide quantification of climate fluctuation impact of the watershed dynamics.

Keywords: Morphometric analysis, GIS, ASTER GDEM, Lake, Watershed, Hydrological processes

INTRODUCTION

The mathematical study of the proportions and shapes of landforms and other features on the Earth's surface is known as morphometry (Obi Reddy et al., 2002). In the past several decades, geomorphology has placed more emphasis on applying quantitative techniques to get a deeper comprehension of the behavior of surface water networks and the physical features of drainage basins (Horton, 1945). Digital Elevation Models (DEM) and satellite data may now be used to manage watershed settings because to developments in morphometric analysis (Pareta, 2004).

Morphometric features at the watershed scale can offer important information on the basin's origin and evolution, as well as the hydrological, climatic, and geomorphological processes occurring there (Singh, 1992). Understanding and describing watersheds requires a quantitative description of the drainage system, which morphometric analysis provides (Strahler, 1964). Geographic Information System (GIS) technologies provide a versatile and potent platform for spatial data analysis and visualization, and are now frequently utilized to evaluate topography and morphometric aspects.

The objective of this study is to analyse the morphometric parameters of the Wegnia Lake basin in the Kolokani district of Mali.

I Description of study area

The Lake Wegnia catchment area is located in the cercle of Kolokani and Kati (Koulikoro region, Mali). A tributary of the Baoule on the Senegal River, it lies between **13°17'52"** and **13°18'70‘' N** and **-8'7'31‘'** and **-8°7'45‘' W**. Lake Wegnia was classified as a RAMSAR site in 2013. It lies to the north in the Tioribougou hills, to the south in the Mandingo mountains, to the east in the Nossombougou plain and to the west in the Baule reserve. It is the only lake in the Koulikoro region in terms of surface area. The catchment area of Wegnia lake covering **1,143.59 km²** and a perimeter of **245 km**. The lake itself is located to the west of the basin, in the rural commune of Guihoyo, cercle de Kolokani (Koulikoro region). It covers **1.22 km²** area and **10.76 km** perimeter. The Lake Wegnia catchment area flows in a south-westerly direction.

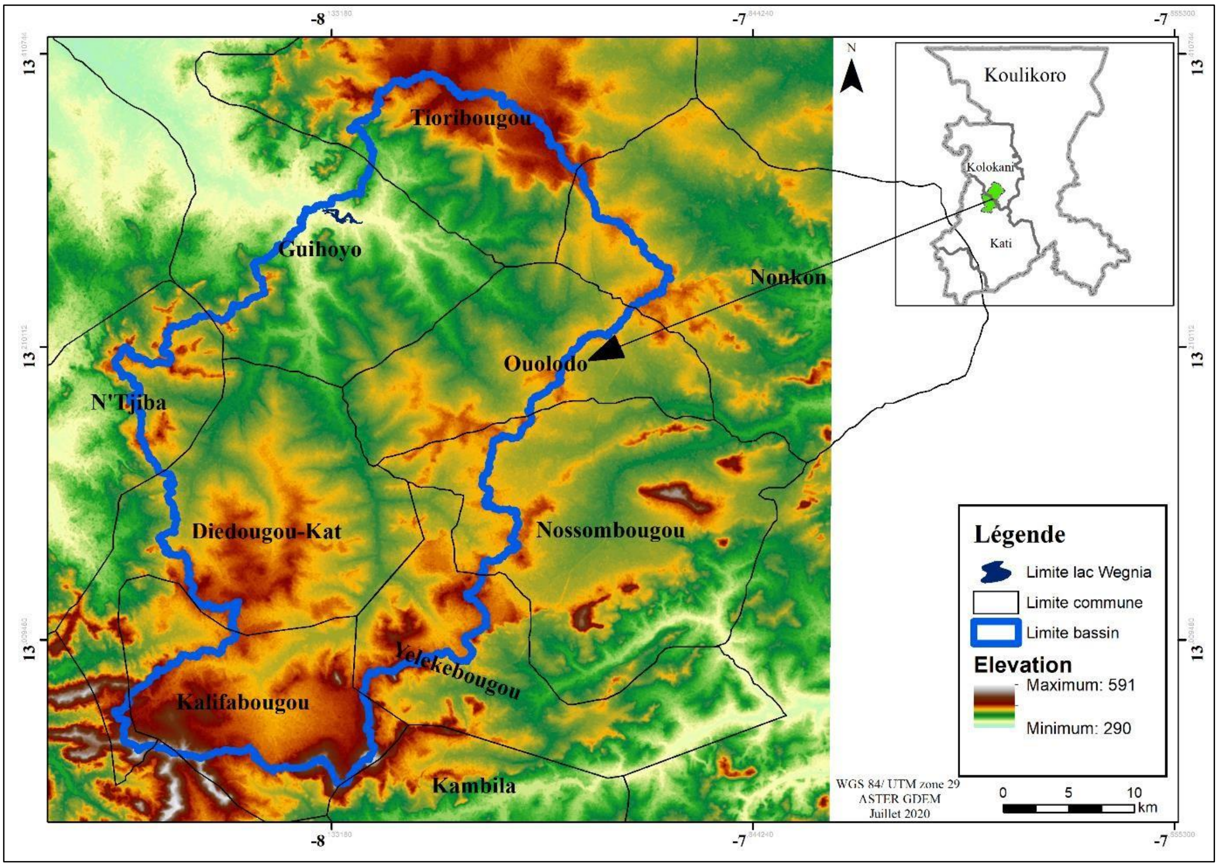

Figure 1: presentation of study area

II METHODOLOGY

In the context of the research, a number of data were required for the preparation of this study, in particular the ASTER GDEM 30 metre Digital Terrain Model (DTM) for the delimitation of the basin, satellite images, climatic data and data on the administrative boundaries of the study area.

The tools used in this work for processing, analysing and interpreting the various data are :

- GRASS GIS 7.9 software: for processing and correcting DTM satellite images downloaded from the “Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Map” database (delimitation catchment area, extraction hydrographic network, slope, slope profile and relief). Extraction of morphometric parameters)
- ArcGIS 10.3 software for spatial analysis and map production;
- Global Mapper software for downloading the DTM of the study area;
- QGIS 3.10 software for geometric processing and ;
- Excel software for analysing and processing statistical data and rainfall graphs, and INKSCAPE software for drawing graphs.

III RESULTS AND DISCUSSION

3.1 Geology and geomorphology

The geological formations in the Lake Wegnia catchment area form bands of sub-Cambrian sedimentation, the site of groundwater circulation in two types of aquifers: discontinuous aquifers and superficial aquifers (Service Hydraulique, 2008). The relief consists of an immense sandstone plateau to the north of Bamako, at the junction of the Sudanian and Sahelian zones (Michel Rasse, 2001). The Mandingo plateaux to the south are rugged, but there are wide plains and depressions surrounded by hills formed of sandstone and dolerite resting on a granitic and schistose base from the Lower and Middle Precambrian. The maximum and minimum altitudes range from 328 to 575 m. Soil types include silt, sand, clay and sandstone. The sandstone soils and the silty and clayey soils are located on the plains surrounded by the hills of the area.

3.2 Slope

Slope is the fundamental element in the shape parameters and geomorphological processes of a landscape. It is of paramount importance in the classification of relief and also affects the direction of flow and the rate of sediment deposition. It indicates the change in surface features or the inclination of a given surface on a horizontal plane. It is the outcome of intricate and ongoing interactions between external and internal forces operating on the surface of the Earth. Slope is expressed in degrees or as a percentage. The slope map was extracted and produced in Grass GIS, using the command r.slope.aspect and extracting the statistics for our study (Figure 5).

Several authors have given different classifications, but the Meybeck classification was used for the slope of the Lake Wegnia basin. It was classified into four (4) types (from 0-2) corresponding to the plain, from (2-5) corresponding to the gentle slope, from (5-15) corresponding to the steep slope and from (15-25) which corresponds to the steep slope). The lowland and gentle slope classes occupy 92% of a surface area of 1,048.52 km² (Table 5). The Lake Wegnia basin is mainly made up of plains and gentle slopes. The low degree of erosion in the studied region is the cause of this.

Slope classes			
Classes		**Area km^2**	**Percentage %**
0-2°	Plain	403.36	35.23
2°-5°	Gentle slope	574.53	50.18
5°-15°	Steep slope	165.22	14.43
15°-25°	Very steep slope	1.69	0.15
25°-35°	Escarpment	0.04	0.004
Total		**1139.65**	**100**

Table 1: Slope classes

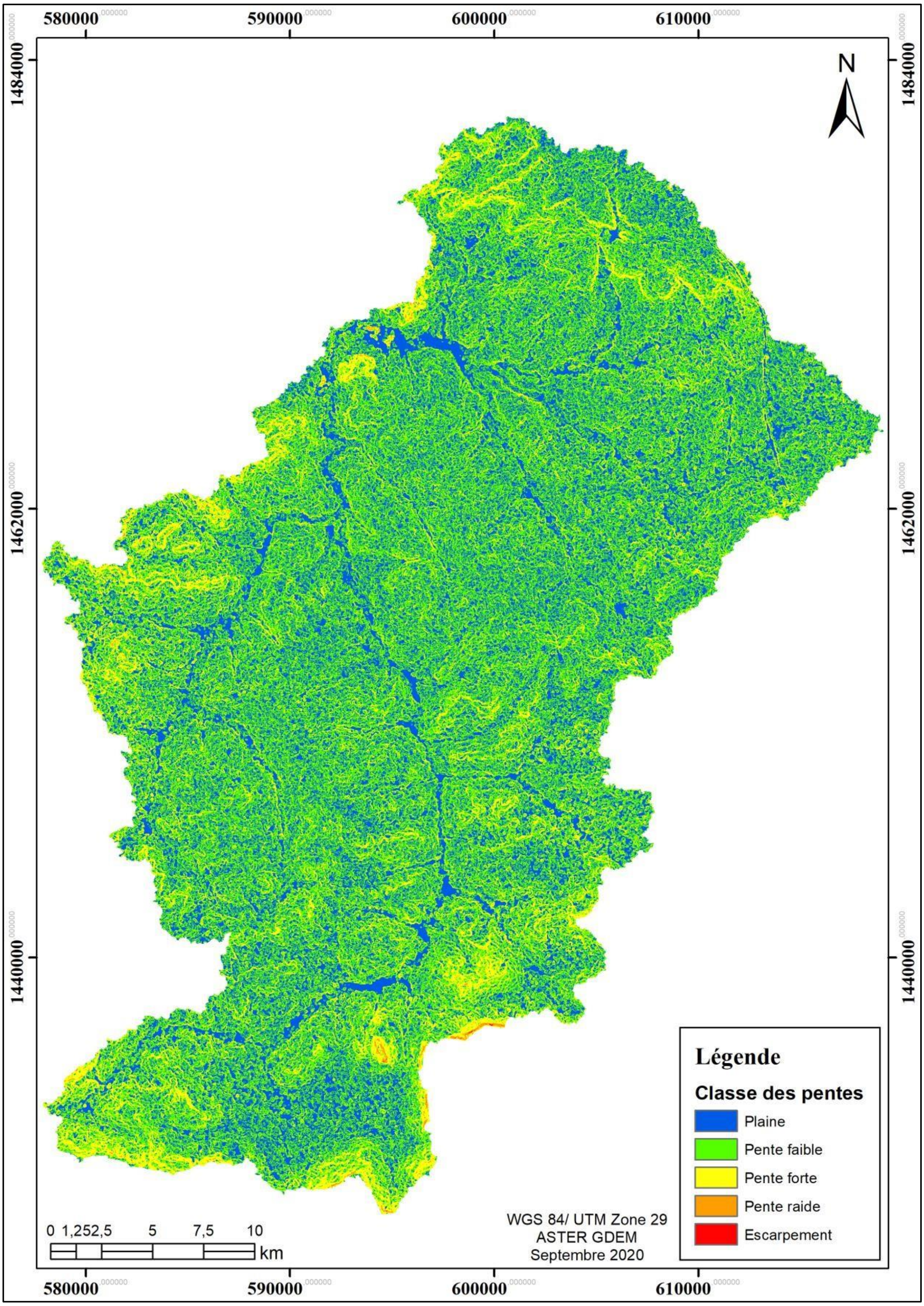

Figure 2: slope classes

3.3 Slope profile

The slope profile is important in the analysis of geomorphological and hydrological processes. It is determined by two characteristics: the curvature profile and the tangential profile.

The curvature profile shows the direction of the steepest slope, the rate of accumulation and deposition, and the direction of flow, while the tangential profile provides measures of flow direction at convergence and divergence.

Curvatures are between -1 and 1, negative and positive, negative for concavity and positive for convexity. Curvature and tangential profiles are classified into 3 forms: flat slopes 0.001 and -0.001; convex slopes between 0.001 and 1 and concave slopes -0.001.

Courbure	**Convexe**	**Concave**	**Plan**
Profile	33,86	39,11	27,03
Tangentiel	33,79	27,31	38,9

Table 2: Curvature class

The convex slope for the curvature profile occupies 33.86%, the concave 39.11% and the flat 27.03% in the Lake Wegnia basin. In other words, deposition rates are higher than erosion rates in the study area. Sediment accumulation is very high in the basin. In terms of tangential curvature, the convex part occupies 33.79%, the concave part 27.31% and the flat part 38.90%. The flat part is superior to the convex and concave slope of the basin, showing a divergence of the flows inside the basin, at 33.79%. The convex tangential curvature gives us information on the convergence of water draining inside the basin, while the concave part corresponds to the divergence of runoff.

3.4 Altitudes

In this study, the approach used was the classification of (Meybeck et als, 2001) for the relief of the Lake Wegnia basin, but the values of this classification are too high for our study area, given the low altitudes in the study area, which range from 328 to 575. For better identification of the relief. All the altitude classes were classified locally according to the terrain, The altitude classes 328-393, 393-458, 458-523 and 523-575. The classes between 328-393 and 393-458 make up 94.88% of the terrain, which is to say that the terrain consists mainly of plains and hills. They cover 1,089.84 km² of the total surface area of the basin. Meybeck's classification did not allow the different classes to be clearly visualised, as the area is essentially made up of plains with little relief. It ranges from 0-200, 200-500, 500-1000, 1000-2000, 2000-3000, 3000-4000, 4000-5000, 5000-6000, 6000-.

<. The 200-500 and 500-1000 class corresponds to our study area. In Meybeck's classification, the 200-500 class corresponds to medium-altitude plains and 500-1000 corresponds to high-altitude plains (hills, plateaux). We used our own classification to identify the different elevations in the area.

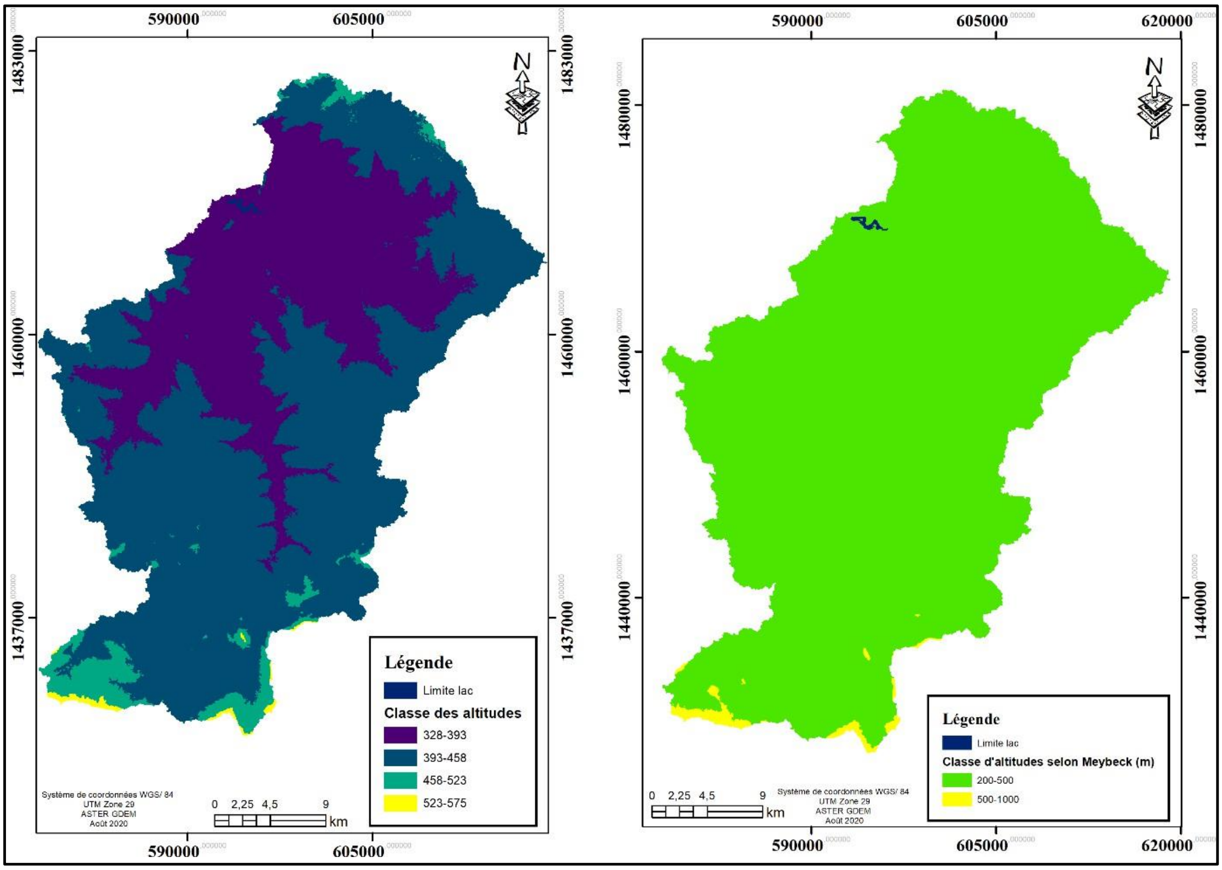

Figure 3: Altitudes classification

3.5 Morphometric analysis

Basin geometry

The surface area of the basin: is the watershed up to the mouth and is expressed in km² (Schumm, 1956). The surface area of the basin is 1143.59 km².

Watershed length: runs along to the main drainage line and is the basin's longest dimension (Schumm, 1956). The Wegnia Lake Basin is 54.21 kilometers long.

Watershed perimeter: is a total length of outer boundary of the basin. The basin perimeter is measured along the watershed lines and is one of the important factors determining the shape and size of the catchment area. The perimeter of the catchment is 245 km.

Basin width: is the total of the basin's surface area throughout its entire length. This indicates the catchment's breadth. The distance is 21.02 kilometers.

Shape factor: is the catchment area divided by the catchment length squared. The form factor offers a measure of the relationship between catchment area and basin length and the effects on hydrology (Fryirs and Brierley 2013). The value of the form factor for a perfectly circular catchment is 0.754. Elongated catchments have a low form factor value, while higher values indicate for circular catchments. Our research area's shape factor value is 0.38. This indicates that Lake Wegnia's catchment area is longer.

The elongation index: is the proportion between the basin's diameter and length. According to Strahler (1964), the catchment is classified as round (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (< 0.5) based on the elongation ratio index. The research area's aspect ratio is 0.7. As a result, the Lake Wegnia catchment area is longer.

Circularity ratio: The ratio of the basin's surface area to the area of a circle with the same diameter as the basin's perimeter is known as the circularity ratio. The degree of circularity of the basin as a function of the watercourse flow in the catchment is expressed by the dimensionless circularity ratio (Miller, 1959). It is affected by geological formations, vegetation cover, temperature, slope, and the length and frequency of watercourses. The landform's youth, maturity, and aging stages are shown by the circularity ratio values. For the studied region, the circularity ratio is 0.23.

The lemniscate ratio: The basin's form is described by the word lemniscate, which is more consistent with empirical reality than the ideal circular shape for a basin (Chorley, 1957). According to the author, the pond is circular when the K value is smaller than 0.6., if it is between 0.6 and 0.9 then the pond is oval and if it is greater than 0.9 the pond is elongated. The highest value obtained for the Wegnia lake basin is 2.58, which means that the basin is elongated. The surface parameters are presented in Table 4.

Surface parameters	Formula	Results	References
Area of the basin	A	1143,59 km^2	Schumm, 1956
Basin perimeter	P	245 km	Schumm, 1956
Length of basin	Lb	54,21 km	Schumm, 1956
Basin width	A/Lb	21,09 km	Schumm, 1956
Elongation index	Re= $\frac{1{,}129\sqrt{A}}{Lb}$	0,70	Strahler, 1964
Circularity index	Rc= $\frac{4\pi A}{P^2}$	0,23	Miller, 1959
Form factor	Rf= $\frac{A}{Lb^2}$	0,38	Fryirs et Brierley 2013
Lemniscate	K= $\frac{Lb^2}{A}$	2,56	Chorley, 1957

Table 3: Geometrical characteristics

3.6 Linear characteristics

River order: this is the most important step in carrying out morphometric analysis of the river system in a catchment. Horton (1945) was the first to recommend the river ranking system, and Strahler subsequently modified it and made it more complete. In our study, the Lake Wegnia catchment was classified using the Strahler 1952 classification system. It is of order 8, with a total of 9020 identified watercourses, of which 6820 flows are of order 1, 1727 flows of order 2, 363 flows of order 3, 85 flows of order 4, 17 flows of order 5, 5 flows of order 6, 2 flows of order 7 and 1 flow of order 8. In the Lake Wegnia basin, the number of streams declines as the flow order rises.

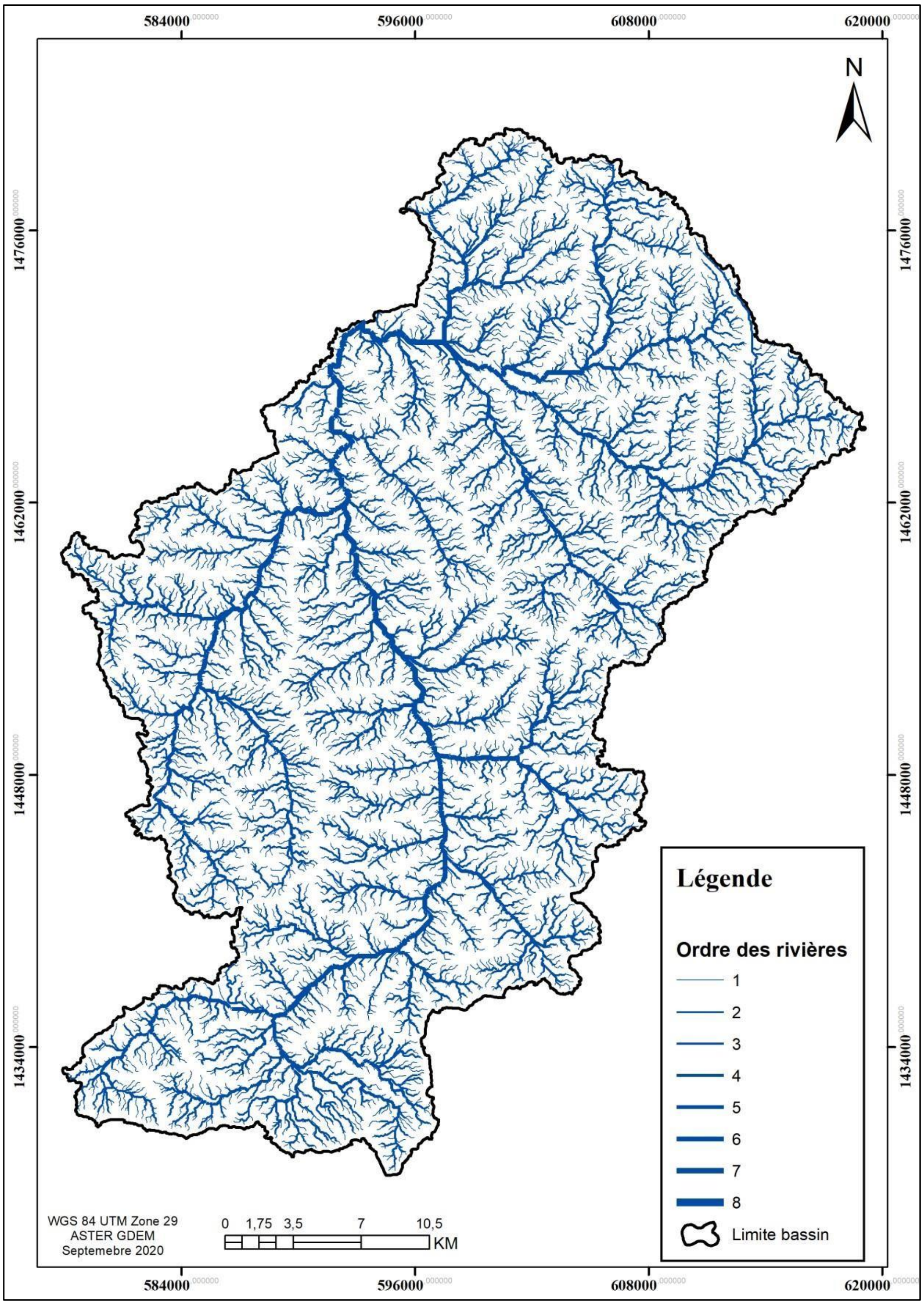

Figure 4: Order classification

Length of watercourses: is the total length of the watercourses in the order defined in the basin. It is one of the most important hydrological factors characterising runoff variations in the basin. The results show that the total length of the first-order flow is higher in the basin, at 2226.60 km. The second order is 1104.95 km, the third order is 461.30 km, the fourth order is 223.14 km, and the fifth order is 117.71 km, 53.13 km for the sixth order, 33.74 km for the seventh order and 0.14 km for the eighth order. The first-order rivers have the largest river segments along their entire length, and also the length of the flows decreases as the order of the flows increases.

The bifurcation rate: represents the proportion of streams of a certain order to streams of the next higher order (Horton, 1945). The anomalies of the watershed's geological evolution determine the bifurcation rate. Within a watershed, it shows the level of integration that exists between streams of various orders (Strahler, 1957). A natural drainage system inside a homogenous rock structure, which is what our research region is, is suggested by a bifurcation ratio between 3 and 5. Flat or undulating catchments are characterized by lower bifurcation ratio values, but dissected catchment network systems may be represented by greater values, which show structural control over the drainage pattern (Horton, 1945).

When the bifurcation rate is high, it may result in an increased risk of flooding; conversely, a low bifurcation rate may result in a reduced risk of flooding (Horton, 1945). This bifurcation rate is used to delimit rivers. that are susceptible to flooding. The average bifurcation rate for our study area 4.4 which means that the risk of flooding is very low. The average bifurcation rate for our study area 4.4 which means that the risk of flooding is high in the Lake Wegnia basin.

3.7 Relief features

Watershed elevation: The elevation difference between the watershed's highest and lowest points is known as basin relief. Understanding the basin's denudation phenomena requires an understanding of relief, which is also crucial for drainage, surface and subsurface water flow, erosion characteristics, permeability, and landform evolution. High runoff, limited permeability, and high water gravity are all indicated by high relief values. The watershed has a maximum elevation of 575 meters and a minimum elevation of 328 meters.

Ratio of relief: is the proportion of basin length to relief. It serves as an indication of the severity of erosion processes acting on river basin slopes and is used to quantify the total slope of a basin. The research area's relief ratio is 8.32.

Terrain roughness: It is an important geomorphological variable used in understanding landforms, material properties, current and past processes and time since formation (Grohmann, Henrique, & Mike, 2011).

Classes	**Area**	**Percentage**
Subhorizontal	444,36	38,69
Very flat	165,54	14,41
Flat	142,22	12,38
Slightly dissected	187,75	16,35
Moderately dissected	179,18	15,6
Very dissected	29,44	2,56
Total	**1148**	**100**

Table 4: Basin roughness class

The slope map and the stream direction map were merged to produce the roughness of our study area. The roughness values correspond to 6 classes for our study area, each class corresponding to types of terrain dissection (subhorizontal, very flat, flat, little dissected, moderately dissected and very dissected). The subhorizontal and very flat class represents 609.90 km² or 53.10%, the flat and slightly dissected class 329.97 km² or 28.73%, and the moderately dissected and highly dissected class 208.62 km² or 18.16%. The roughness of the relief surface of the Lake Wegnia watershed is dominated by subhorizontal and very flat terrain with 53.10% of the total area. The study area is dominated by sediment deposits.

Hypsometric integral: is the relationship between horizontal cross-section and drainage basin area at elongation. It measures the degree of erosion of the river landscape (Strahler, 1952). The hypsometric integral gives the terrain type and relief evolution. The hypsometric integral varies between 0 and 0.30 for old landforms composed essentially of plains and hills. Deposits are visible in this type of relief

0.30 to 0.60 for mature landforms, composed mainly of plateaus and low mountains.
From 0.60 to 1.0, the relief is young and made up of mountains. Erosion dominates over transport and deposition. The basin's hypsometric integral is 0.1, which means that its relief is old and made up of hills and predominantly deposits.

Roughness index: The robustness index of (Schumm, 1956) was calculated for our study area. This index is the product of two basin factors: drainage density and relief. The Lake Wegnia catchment has a roughness index of 0.91. This value indicates that the watershed is less subject to erosion.

Cross profile : The study of the transverse profile is the best representation of the geometry of valley forms. It is an erosion curve, allowing interpretation of historical erosion processes and their stage of development. It was produced in GRASS GIS software and its analysis shows the importance of the profile. The results gave a total of five (5) V-shaped valleys

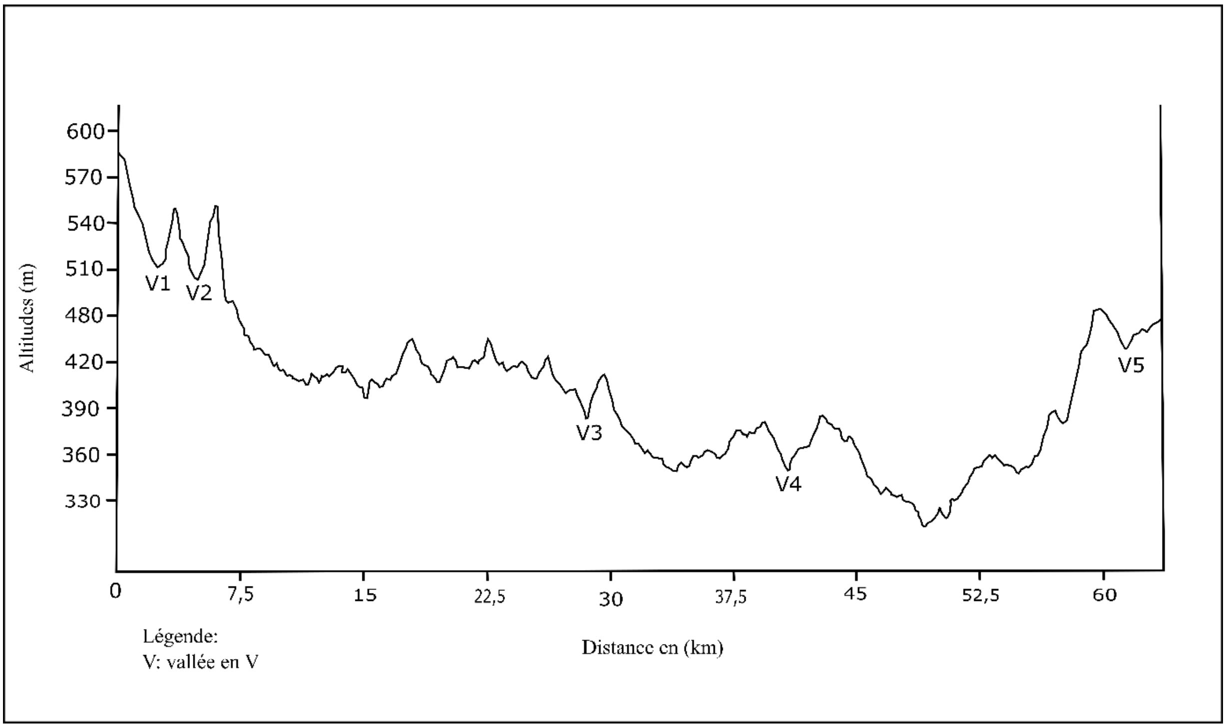

Figure 5: Cross profile

The hypsometric curve: obtained from the r. hypso algorithm in GRASS GIS. It provides information on the topography and erosion of flow channels. The hypsometric curve's form and the integral's values have a significant role in determining the study area's relief. They exhibit significant regional variances as well as changes in geological structure and developmental stage. As the terrain deteriorates toward a stage of maturity and old age, the hypsometric curve, which shows relief in the youth stage, has a big integral but declines (Strahler 1952). In essence, the relief is made up of hills and plains.

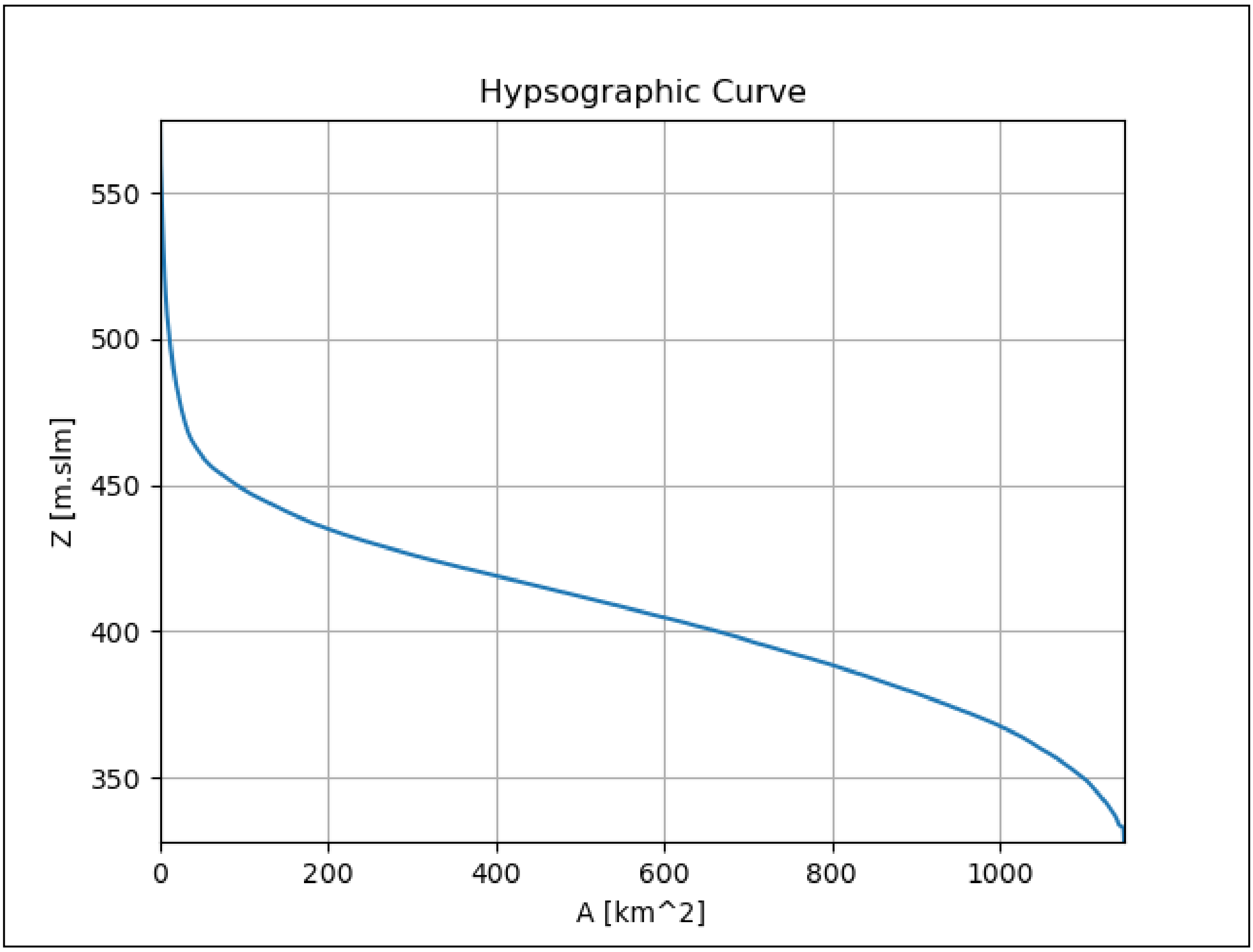

Figure 6: Hypsometric curve

Table 5: Characteristic of relief parameter

Relief parameter		Formula	Results
Relief of the basin		$H = Hmax - Hmin$	247 m
Average height of the basin		$h = \frac{Hmax + Hmin}{2}$	451,5 m
Average relative altitude of the basin		$Hm = 1.08h - 137$	350,62 m
Relief ratio		$Rh = \frac{H}{lB}$	8,32
Hypsometric integral		$E = \frac{Hmean - Hmin}{Hmax - Hmin}$	0,1

3.8 Textural characteristics

Stream frequency: The total number of stream segments of any sequence per unit area is known as the stream frequency (Horton, 1945). Frequency of streams also expresses a spatial distribution of streams within the basin and shows the degree of stream fragmentation. Stream frequency reflects drainage texture and density. The number of stream frequency value for the study area is 7.88 streams per km². When stream frequency is high in a basin, this indicates an increase in streams and drainage density.

Drainage density: The total length of all types of watercourses relative to the total drainage area is known as the drainage density. The effectiveness of river water drainage is at least partially indicated by drainage density, which is a quantitative measure of the average length of overland flow and is represented in km/km². It is a component of drainage analysis that makes it possible to better understand quantitative expression in the dissection and study of landforms, even though they are influenced by the local climate, lithology, structures, and relief history. In the end, it can serve as an indirect indication to explain the morphogenesis of landforms and a variety of geomorphological processes (Horton, 1945; Strahler, 1952). Drainage area density is low relief, and strong, resistant, or permeable subsurface are the typical locations for drainage area density. (Horton, 1932) observed that very permeable basins had relatively low drainage densities, while regions with greater precipitation had larger densities. Whereas a low drainage density indicates a sluggish hydrological reaction to rainfall events, a high drainage density indicates a highly dissected watershed and a quick hydrological response. The low value of drainage density is one of the characteristics of the wet region (Dingman, 2009). The study area has a moderate drainage density with a value of 3.66 km/km^2.

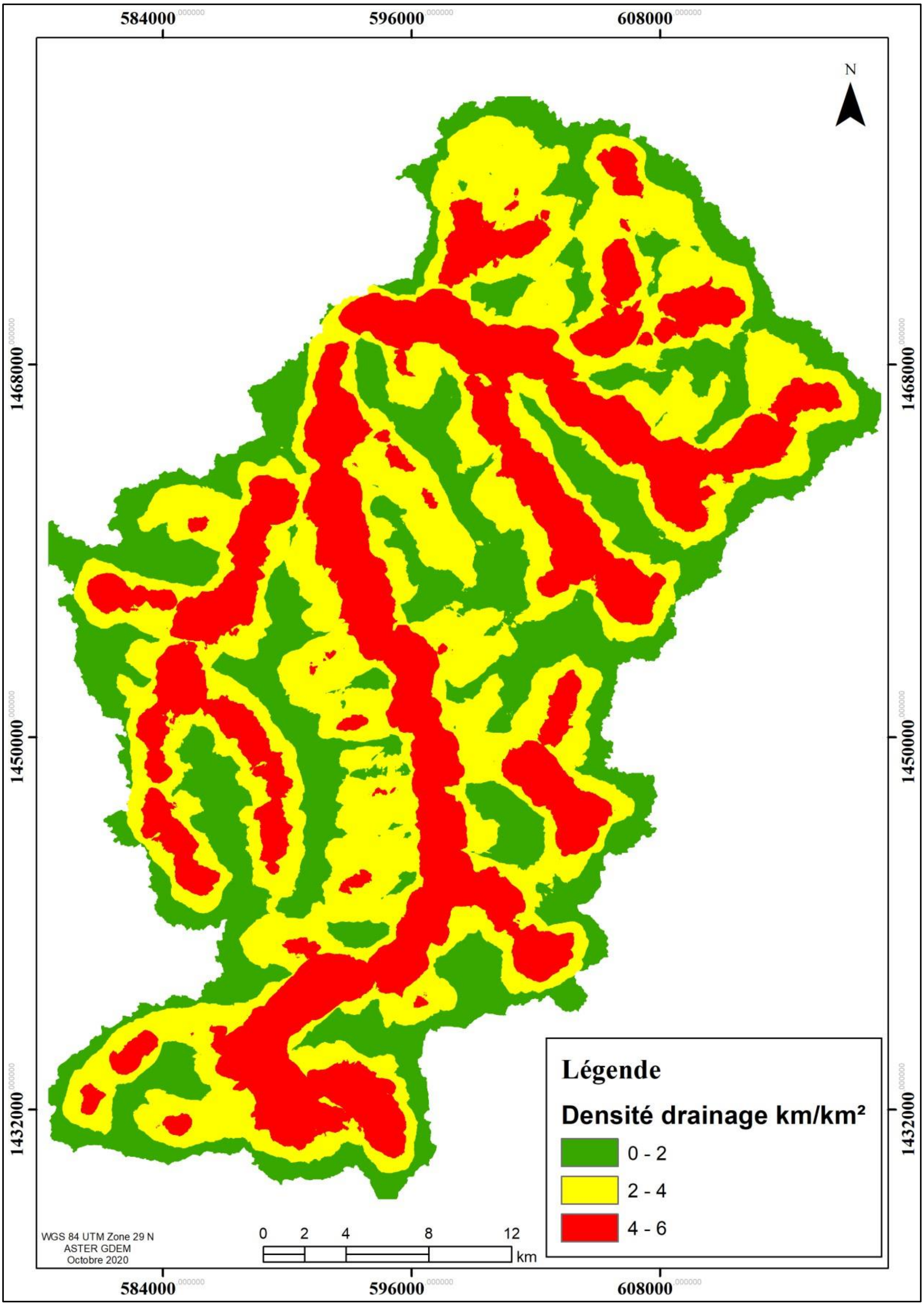

Figure 7: Drainage density

Consistency of channel maintenance: is drainage density's opposite, the unit of measurement is km^2/km. It is influenced by vegetation, climate, lithology, and the permeability and infiltration capability of surface materials (Schumm, 1956). Thus, it is a gauge of basin erodibility. A high drainage network density and a reduced surface area needed to maintain one kilometer of drainage are indicated by a low channel constancy value, and vice versa. The constant also shows how many km^2 of basin area are needed to create and sustain a channel that is one kilometer long. It has a particular meaning and conveys the relative sizes of the landform units within the watershed (Strahler, 1957). The channel maintenance constancy value for the Lake Wegnia watershed is 0.27, meaning that 0.27 km^2 of basin area are needed to maintain 1 km of channel.

Diffuse flow length: alludes to the length of time rainwater travels over the ground surface before it is transmitted to adjacent watercourses, and is half the distance travelled between channels (Horton, 1945). It is a crucial element in the concentration time required for rainwater to move within the basin. Horton claims that diffuse runoff is half as long as the distance between the drainage density and the stream.

In our study, the overland flow length of the Lake Wegnia watershed is 1.84 km.

Texture ratio: is the number of stream segments of all sorts in the perimeter divided by the distance between the stream lines. Landform, infiltration capacity, and lithology all have a role (Horton, 1945). Smith distinguished five types of drainage texture: fine (6 to 8), intermediate (4 to 6), very fine (>8), coarse (2 to 4), and very coarse (<2). The Lake Wegnia watershed's texture ratio in this study is. It shows that 9.67 is the drainage texture category.

Drainage intensity: is the proportion of drainage density to stream frequency. The watershed is extremely vulnerable to floods, gully erosion, mass movement, and landslides when drainage density, stream frequency, and drainage intensity are low because surface runoff is not quickly removed (Faniran, 1968). The Lake Wegnia catchment's drainage intensity score is 2.13, indicating that floods is not a concern for the studied region.

Infiltration intensity: is the product of river frequency and drainage density. It is an important characteristic of the hydrographic network, as it gives an idea of the infiltrability rate in the basin. The infiltration capability decreases as the infiltration value increases.

According to Smith (1950), runoff increases with decreasing infiltration capacity and decreases with increasing infiltration capacity. The intensity of infiltration is 29.07.

Network textures	Formula	Results	References
Stream frequency	$Fs = \frac{N}{A}$	7,88 num/km²	Horton, 1945
Drainage density	$Dd = \frac{L}{A}$	3,69 km/km²	Strahler, 1964
Channel maintenance constancy	$Lo = \frac{1}{2} \cdot Dd$	1,84 km	Horton, 1945
Diffuse flow length	$C = \frac{1}{Dd}$	0,27 km²/km	Schumm, 1956
Texture ratio	$Dt = \frac{Nu}{P}$	**36,81**	Strahler 1964 et Horton, 1945
Drainage intensity	$Di = \frac{Fs}{Dd}$	2,13	Faniran, 1968
Infiltration intensity	$If = Fs * Dd$	29,07	Smith, 1950

Table 6: Drainage texture

4.9 Morphometric Characteristics and Dynamics of Lake Wegnia

Geometric Characteristics of Lake Wegnia

Surface Area of Lake Wegnia

This is the total surface area covered by water within the lake. It is expressed in km². The lake's shapefile is delineated on Google Earth Pro and exported to GIS software to calculate the actual surface area of the lake, taking into account the period of flooding and receding water levels. The surface area of Lake Wegnia is 1.22 km².

- **Perimeter of Lake Wegnia**

This is the total length of the lake's outer boundary. The perimeter is expressed in kilometers. 10.76 km is the perimeter of Lake Wegnia. 3.3.6.4 Length of Lake Wegnia

- **Maximum Length of Lake Wegnia**

This is the line joining the two furthest points from the shore. This maximum length was determined using Grass GIS software. It was measured along the length of the lake. Therefore, it is difficult to give a precise value for the maximum length, as it is used in limnology as a descriptive measure and has limitations (Häkanson, 1981). It is 3.15 km.

- **Effective Length of Lake Wegnia**

This is the straight line joining the two furthest points from the shore, where wind and waves can cause disruptions to the surfaces and islands around the lake (Häkanson, 1981). This is an important parameter in many limnological and hydrological studies. The effective length of Lake Weignan is 1.14 km.

- **Direction of the major axis of Lake Wegnia**

This defines the maximum length by the general compass direction and is expressed as a compass rose.

Width of Lake Wegnia

- **Maximum width of Lake Wegnia**

This is defined by the straight line forming a right angle to the maximum length (Lmax), which connects the two most distant ends of the shoreline without crossing the land surface but can cross the islands it encounters. This value is also describable in limnological studies (Häkanson, 1981). It is 0.98 km.

- **Effective width**

This is a straight line on the lake surface and perpendicular to the maximum effective length (Le) while connecting the two points furthest from the shore (Hakanson, 1981).

Formula: Be=A/Lmax

The effective width is 0.38 km

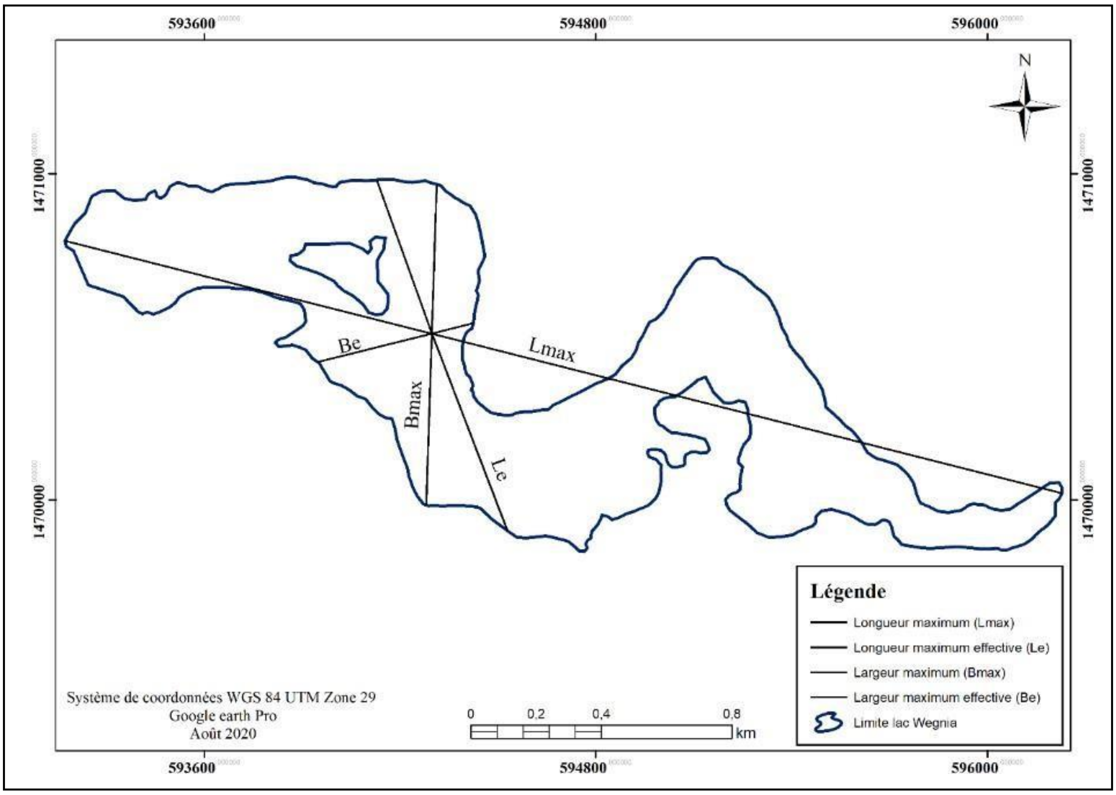

Figure 8: Lake Wegnia morphometric

This map below lists the morphometric characteristics of Lake Wegnia using GIS and remote sensing tools. It was created thanks to the work of Hänkson and Wetzel to understand the morphometric evolution of Lake Wegnia.

Depth of Lake Wegnia

- **Maximum Depth of lake Wegnia**

This is the deepest area located at the lake level. The maximum depth of the lake is 10 m. The lake reaches its maximum depth during the month of August. 3.3.6.7.2 Minimum Depth of Lake Wegnia

This is the period when the lake's water level is lowest. This period occurs mainly in April. The minimum depth of Lake Wegnia is 2 m.

- **Average Depth of Lake Wegnia**

This is the volume divided by the surface area of Lake Wegnia.

Formula: $Zm = Dmax + Dmin2$

The average depth is 6 m.

- **Water Volume of Lake Wegnia**

This is the ratio between the total surface area of the basin and the maximum depth. It is enclosed by the contours of the surface area, which corresponds to the total quantity of water available in the lake (Wetzel

& Likens, 2000). The volume of Lake Wegnia was obtained in ArcGIS using the spatial analysis tool. It was calculated using the Topo to Raster 3D tool from the lake boundary and the elevation values of the same lake boundary, and then the volume was extracted using the 3D Volume tool.

The volume of Lake Wegnia is 6,302,864 m3.

- **Shoreline Development Index**

The shoreline development is the ratio of the length of the shoreline to the circumference of a circle with an area equal to that of the lake (Wetzel & Likens, 2000). Formula: $Dl = L2\sqrt{\pi A}$

A more elongated morphometry markedly increases the value of Dl. Lakes occupying flooded river valleys have dendritic contours, while lakes occupying circular shapes are of crater origin. Coastal development is of considerable interest because it reflects the potential for greater coastal development in proportion to the lake volume. The result is greater than 1 for circular lakes and less than 1 for non-circular lakes. This indicates an elongated character for Lake Wegnia with an index value less than 1 (0.81).

Photo 1: lake Wegnia, water body

Table 7: Morphometric parameter

Morphometric analysis of Wegnia lake				
Morphometric parameter	**Formula**	**Symbol**	**Results**	**References**
Area		A	**1.22 km²**	Hakanson,1981
Perimeter		P	**10.76 km**	
Maximum length		Lmax	**3,15 km**	Hakanson,1981
Effective length		Le	**1.14 km**	Hakanson,1981
Maximum width		Bmax	**0.98 km**	Hakanson,1981
Effective width	$Be = \frac{A}{Lmax}$	Be	**0,38 km**	Hakanson,1981
Maximum depth		Dmax	**10 m**	Hakanson,1981
Minimum depth		Dmin	**2 m**	Hakanson,1981
Mean depth	$Dm = \frac{Dmax + Dmin}{2}$	Dm	**6 m**	Hakanson,1981
Volume		V	**6 302 864 m³**	Arc GIS
Shoreline development index		Dl	**0.81**	Wetzel, 1983
Orientation of lake's main axis			**S-W**	

DISCUSSION

The morphometry of Wegnia Lake watershed provides critical data concerning its hydrologic response, sediment processes, and geomorphic development. The watershed's elongation, as evident from a 0.38 form factor, and dendritic drainage pattern indicate a comparatively sluggish hydrologic response to rain showers. This characteristic reduces the vulnerability to flooding but also possibly limits water supply during prolonged dry spells, a common problem in semi-arid environments. The low bifurcation ratio (3.69) and moderate drainage density (3.66 km/km²) are also indicators of a well-developed drainage system, which is typical of semi-arid watershed regions with soft slopes and broad plains dominating the landscape. These geomorphologic features enhance infiltration and groundwater recharge, which are critical for sustaining water resources in the Sahelian region, where water scarcity is a major issue.

The hypsometric integral value (0.1) and concave slope frequency suggest that the watershed is in the mature phase of geomorphologic development, characterized by widespread sediment deposition and quite low erosion rates. However, the relief ratio (8.32) suggests localized erosion risk, particularly along the steeper slopes. The low drainage density and high infiltration intensity (29.07) also show the watershed's resistance to erosion but limit the sediment transport capacity. This could ultimately lead to the slow filling of Lake Wegnia, which might in turn influence its storage capacity and environmental function.

The morphometric characteristics of the Wegnia Lake watershed are consistent with those in other semi-arid regions, that is, elongated basin shapes in the direction, low drainage densities, and mature geomorphological maturity (Pareta, 2004; Obi Reddy et al., 2020). However, the unique association of high sediment deposition areas and concave slopes highlights the significance of local climatic and geological factors in the dynamics of a watershed. For instance, studies of the Indian Dhasan River basin (Pareta, 2003) and China's Three Gorges area (Dembélé, 2012) have documented parallel trends of erosion and deposition of sediment. Yet watershed management implications are quite different due to differences in climate, lithology, and land use regimes, and that highlights the importance of having region-specific approaches for sustainable watershed management.

CONCLUSION

Studying the hydrological, geomorphological, and climatic features of watersheds has been made much easier with the use of satellite imagery, especially data from the ASTER Global Digital Elevation Model (GDEM). According to Horton's 1945 description, the Lake Wegnia watershed had a high degree of branching in the river network and a well-structured hierarchy among the streams when a river classification system was applied. Dendritic drainage, in which the river system branches out in a tree-like pattern, is the predominant drainage pattern seen in this region. The local topography, the land's slope, and the geological makeup of the terrain all have a significant impact on the formation of this kind of network—a conclusion bolstered by Strahler's 1964 research.

The physical structure of the watershed, the arrangement of its hydrographic network, and the general features of the terrain can all be understood by examining a variety of morphometric parameters, including elevation, slope, drainage density, and basin shape. These realizations are essential because they offer a scientific basis for well-informed choices. This data can be used by national and international organizations, scientists, and policymakers to inform sustainable watershed planning and management. In the end, these analyses aid in the creation of responsible and cogent river basin development strategies that uphold long-term resource sustainability and environmental integrity.

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