Morphometric Features Study of the Sous Basin using Geographic Information System
Hicham BERDGUE

Abstract:
The study aims at identifying the importance of the use of modern technologies such as remote sensing and geographic information systems (GIS) in the detection of the Morphometric features of the Sous basin in terms of morphological and terrain characteristics. It also targets to identify the forms and patterns of water drainage system, and this latter’s associated variables and statistical significance as well as its impact on the surface and topography of the Sous Basin. Through this overall study, an accurate geographic database will be provided and sophisticated digital maps of the basin will be afforded, too.
**Introduction:**

GIS has become a fundamental way of dealing with different data in multiple scientific fields, geographical studies are one of them. Thanks to this system, accurate results in the analysis and processing of spatial data are the expected outcome. Thus, it makes it easier for us to study the morphometric characteristics of the Souss basin, using advanced techniques to create a hydrological and morphometric database, with the aid of the Digital Elevation Model (DEM), to achieve fast and accurate results in contrast to traditional methods that are time consuming and frequently leading to inaccurate results.

The study of the morphometric characteristics of river basins by GIS is one of the key elements that assists the understanding of the mechanism of development of river basins. Also, it studies the terrain in quantitative manner. The main objective of it is to compare basins with each other based on the calculation of several indicators to determine the development of the morphology of the valleys, such as (basin area, shape, ocean, gradient, length and width of the watercourse ...). As well as, to clarify the relationships between some watercourses depending on the different forms, and lengths in the water basins.

**Geographic Location**

The basin under study is a wide one extending between the High Atlas in the North to the Anti Atlas in the south. It faces the Atlantic Coast on the west with an area of up to 17,278 km², between latitudes 30 ° and 31 ° north, longitude 8 ° and 9 ° west, and Greenwich East line.

This basin is characterized by its closure inside and its openness to the Atlantic Ocean with a cross-section of 40 kilometers. Within this basin, the Sous plain extends from the east to the north-east towards the west and south-west at a distance of about 150 km, It narrows in the east, and expands as we head towards the west, and occupies an area of up to 4400 km. It is bordered by Massa valley from the south and Tensift valley from the north. In the east, there are a set of lattices which form main the tributaries of Sous river, such as: Imirguen and Arguen.
I. Morphometric Characteristics of Sous Basin hydrographic network:

The study of the characteristics of the hydrographic network of river basins allows us to draw comparisons between them. It is also one of the most important elements of the morphometric study as it is reflecting the structural properties of rocks in terms of fractions and spikes, and the quality of rocks in terms of hardness and permeability, as well as climatic characteristics, especially rain precipitation, and are a direct factor in the formation of river tributaries (Abdel Aziz, 2008).

The characteristics of the hydrographic network include: river level and discharge density, the ratio of the diffraction, river recurrence, the rate of the (zig zag...).

1. River level:

It means the numerical gradation of the tributaries that comprise the valley or the river (Mahsoub, 2003). There are many methods used to study the river level; the most important ones are : Horton, Shreve, Strahler.

(Strahler, 1957) is considered the most commonly used one thanks to its simplicity of application and the ease of making comparisons by river basins.

This method focuses on three basic rules:

**Rule 1:** Any tributary which is not available on other river tributaries is considered Class 1.

**Rule 2:** The confluence of two strands of the same rank \( n \) gives us a second-order tributary \( n + 1 \)

**Rule 3:** The confluence of two tributaries from two different classes, the next strand takes the top rank.

According to the Strahler classification, The Sous Basin is ranked in the sixth level. The high Atlas is the starting point of its main tributaries, from Toubkal summit 3500 m and through Uziwa, which is the origin of Sous valley. It is connected to the plain at Awloz at a height of 700 m, and it reaches the Atlantic ocean in a linear and horizontal way but it narrows as it approaches the downfall to reach the width of 15 m, and what distinguishes it is that water leaks partially. But from the point Ouled Rabia to the sea, Sous river streams well, and like all the desert rivers, it is irregular which usually causes sudden floods.
2. Numbers of river tributaries:

They are the tributaries of the water total flow in the basin regardless of its size or location in the river basin (Salama, 2010).

Table 1: Number of river tributaries in each rank.

<table>
<thead>
<tr>
<th>River Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Tributaries</td>
<td>1907</td>
<td>919</td>
<td>494</td>
<td>249</td>
<td>145</td>
<td>87</td>
<td>3801</td>
</tr>
</tbody>
</table>

From the above table, we notice that the tributaries in the Souss Basin are 3801. Most of them fall within the first and second rank by a percentage of 74. This is mainly due to the lack of vegetation which leads to the erosion and the formation of plenty tributaries when it is raining heavily.

3. Length of river tributaries:

Table 2: Length of the tributaries at each level in Souss Basin

<table>
<thead>
<tr>
<th>River Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lengths of tributaries</td>
<td>5116</td>
<td>2805</td>
<td>1360</td>
<td>627</td>
<td>190</td>
<td>195</td>
<td>10293</td>
</tr>
</tbody>
</table>

The total length of the tributaries in Souss Basin is of 10,293 km, in that the tributaries of the first and second rank constitute 50% and 27% respectively. So they occupy about 77% of the total length because of the increase in the number of streams in the first and second levels. The greater the number of streams get the longer the tributaries get.
4. Flow density:

It refers to the density of the numerical drainage of the total number of valleys and river tributaries in the basin area unit. Flow density is a fundamental measure of Geomorphologic study because it is an indicator of the extent to which the surface of the earth is exposed to the processes of erosion and cutting, the quality of the rocks and the amount of their permeability through watercourses (Adam, 2003). It is demonstrated through the following mathematical formula:

\[ Dd = \frac{\sum L}{A} \] (Horton, 1932)

\[ Dd \] Drainage density km / Km². \[ L \]: Total length / \[ A \]: Area of basin per km.

Sous basin density has reached 0.57 km / km², and it means that for each 0.57 km of the length of the flow occupies an area of 1.02 km². This low ratio is mainly due to lack of rain, high evaporation rate, and rock nature.

Figure 2: Map of the distribution of the flow density in Souss basin.

5. Divergence/Ramification Ratio:

It is one of the most important factors that control the rate of drainage, and thanks to it the possibility of flooding can be determined. That is to say, the less the proportion of the divergence gets, the less the drainage density gets, so the rainwater collects in few streams and it could cause flooding. In contrast, if the more the percentage of the ramification gets, the drainage density increases and therefore the water is distributed over a larger number of streams, reaching the main stream while are dispersed and thus
reducing the risk of flooding. The divergence is a reflection of the geological structure and rock quality of the basin and also of climatic conditions (Horton, 1945). To determine the divergence rate we apply this equation:

\[ R_b = \frac{N_u}{N_u+1} \] (Horton, 1945)

Souss Basin divergence ratio is: \( R_b = 2.07 \).
We can say that this ratio is very low, it is even below the average which is 3 to 5 set by (Strahler, 1964). This indicates that the basin is not cut by its minor streams. Therefore, the rainwater will accumulate in a few runways to give a quick surface runoff and increase the risk of flooding.

6. **River recurrence/frequency**

It refers to the number of river tributaries in the basin surface unit (Km 2). This indicator represents another way to measure the flow density (Abu Raya, 2007), and it reflects the relative relationship between the number of streams and basin area regardless of the length of these streams or waterways (Mahsoub, 2003). (Schumm, 1977) points out that dry land valleys/basins are characterized by a low recurrence of tributaries, ranging from 0.1-1 tributary/km². This indicator is measured as follows:

\[ DF = \frac{N}{A} \] (Horton, 1945)

\( DF \): River Frequency / \( N \): Number of tributaries. / \( A \): Basin Area.

Souss river Frequency rate has reached 0.22 tributary/km². It is considered low and it matches the low value of the flow density too. The reason for the decrease in the value of the river frequency is due to the large area of the basin. As there is a lack of significant amounts of rock content with a high degree of water erosion, thereby reducing the water drainage directions of the basin (Salama, 1980).

7. **Rate of the fixed flow of the stream**

It is one of the parameters used to indicate the flow density in the basin; it signifies the percentage of the area unit needed for strengthening the water flow unit (Schumm, 1977). That's to say, the higher the value of this indicator gets, the greater the area of the basin is getting at the expense of minor water streams. This indicator is calculated this way:

\[ C = \frac{1}{D_d} \] (Schumm, 1956)

Souss is: 1.69 km/km². It is obvious that there is a large area in front of the basin to extend its water network at a rate of 1.69 km² per a 1 km/tributary. This result obtained goes in parallel with those results of the flow density and ramification rate.

8. **Sinuosity Index**

It refers to the ratio between the length of the riverbed and the length of the straight line connecting the upstream and downstream points (Chorlay, 1977). This coefficient reflects the extent of the diversion of the stream and the impact on the amount of water in the stream in that the greater the degree of diversion gets, the more the possibility of...
evaporation gets and vice versa. It is also a geological indicator to study the quality of the rock structure in the basin; it is referred to by the following mathematical formula:

$$Si = \frac{Cl}{Xy} \quad (\text{Miller, 1968})$$

$Si$ : Sloping / $Cl$ : Stream length / $Xy$ : Surface area.

(Schumm, 1963) has categorized the tributaries depending on their sloping as follows:

<table>
<thead>
<tr>
<th>Stream</th>
<th>Straight</th>
<th>Transitional</th>
<th>Regular</th>
<th>Irregular</th>
<th>Winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value $Si$</td>
<td>1</td>
<td>1.2</td>
<td>1.5</td>
<td>1.7</td>
<td>2.5</td>
</tr>
</tbody>
</table>

By applying the foresaid equation and according to Schumm's categorization, we notice that Souss Sloping value is equal to 1.36 so, the river tributaries are transitional heading to to scale of regular tributaries whose sloping is 1.5. It is thus a little twisted and it is closer to moderation and this is due to the fact that the basin passes through the beginning of its cycle and lateral expansion stage, which reduces the possibility of leakage and evaporation, So the waters flow quickly to reach the downstream in a short period of time, and thus increase the probability of flooding, especially if the rains are heavy.

II. Geometric and Terrain Characteristics of Souss Basin:

1. Geometric characteristics:

1.1 Area and Perimeter / circumference:

It is the area bounded by the water line, it is measured in several ways, including the use of the PLANIEMTRE on the topographic map, or aerial and satellite images (Mohamed Ashour, 1986). It is of great importance because it directly affects the volume of water flow.

Souss basin area equals 17278 km$^2$, this area measurement is obtained by implementing GIS software. The basin's circumference / perimeter are 1,065 km. It is all obvious that there is a strong inevitable relationship between the area and its circumference/perimeter; i.e.: the bigger the area gets, the greater the perimeter gets and vice versa.

1.2 Equal rectangle:

The basin length and width are also two important Morphometric variables that have their own characteristics.

- Length of the basin: refers to the straight line between the highest point within the division of water on top and the estuary point. (Horton, 1945)
- The width of the basin: it is measured as follows: basin area / basin length.

So, Souss basin length is 227.37 km / its width is 103.53 km.

From the given results, we deduce that the length is approximately twice the width.

1.3 Basin Cohesion Index:
Also referred to as “rotation rate”, it reflects the proximity of the basin to the circular shape and to the regularity of the water splitting line. When the cohesion rate is close to (1), the basin is close to the circular shape, and the higher the ratio gets, the longer the basin gets. Thus, the tributaries are getting short and extending on rectangular distances. (Muhamed Abdullah, 2011)

This index is calculated based on the equation (Gravelius, 1914) as follows:

\[ K_G = \frac{P}{2.\sqrt{\pi} \times \sqrt{A}} \approx 0.28 \frac{P}{\sqrt{A}} \]

kG: Cohesion Index / P: Peripheral Basin Area / A: Basin Area.

So :

So : \[ k_G = 0.28 \frac{1065K_m}{\sqrt{17278}} = 1.33 \]

Souss basin cohesion index is 1.33, this means that its shape is far from circular and it is not homogenized.

### 1.4 Form Factor:

It refers to the consistency of the general shape of the basin. It revolves between 0 and 1. If the index is low it says that the shape of the basin is triangular, and if it is high it means that it is moving away from the triangle shape. The form is calculated as follows:

\[ F = \frac{A}{L^2} \]

F : Form / A: area /km² / L²: length

\[ F = \frac{17278}{227.37^2} : 0.33 \]

The index obtained above stresses the fact that the basin form is different from its edges and that its length is greater than its width which can affect the water drainage especially at its peak (heavy rains) which leads to slowing down the pace at which water streams flow towards the estuary.

### 2. Terrain characteristics of Souss basin:

Studying the terrain characteristics is crucial to deal with the morphology and geomorphology of river basins. It is owing to theirs outcomes that we can better understand the topography, structural characteristics, and the geomorphologic stages of the basin, as well as, analyze the evolution of the hydro system.

#### 2.1 Height distributions of Souss basin:
Sous basin is characterized by absolute heights up to 4165 meters at the highest peak at the top of Mount Toubkal (the highest summit in North Africa); With an average height of 1075 meters. It is to be noted that the higher areas are east side while the lower ones stretch to the west of the basin. These miscellaneous heights justify the topographical complexity of this basin.

![Figure 3: Map of height categories in Souss basin.](image)

### 2.2 Incubation coefficient:

This coefficient is highly important to measure the incubation of the surface of the basin according to its length. It is mainly related to the climate, geology and rock nature in the basin itself. It is calculated as follows:

\[
Rc = \frac{H_{max} - H_{min}}{L_b} 
\]

(Shumm,1956)

By applying this equation, we deduce that the value of the target coefficient is 18.31 m / km, this can be considered as being very high and it is justified by the noticeable difference between the highest point and the lowest point in the basin, without overlooking the basin geomorphologic vitality, too.

### 2.3 Relative terrain index:

It refers to the value given from the relationship between the incubation level and the basin area. It is an important morphometric variable through which the basin's structural characteristics can be studied. The low value of the relative terrain indicates rock weak resistance and erosion activity in the basin (Abu Raya, 2007). This indicator is measured as follows:

\[
R_{hp} = \frac{h}{p} \times 100
\]

(Melton,1957)

*Rhp*: Relative terrain index / *h* Top point - lowest point in the basin / *p* basin perimeter.
Souss Basin’s Rhp is 3.91. It is somehow a high value that stresses the Terrain intensity of the basin and this is due to the striking differences among the basin’s heights. This high index also indicates the variations at the level of rock formation and geological structure.

2.4 Ruggedness indicator:
This morphometric measurement deals with the relationship between the basin’s terrain intensity and flow density. This indicator gets higher when the terrain intensity increases along with the increasing in the lengths of the water tributaries at the expense of the area and vice versa. Strahler (1964) states that if the flow density intensifies, the ruggedness/roughness value does the same too. This indicator is to be determined as follows:

\[ R_n = \frac{(D_d\times H)}{p} \] (Strahler, 1964)


Souss basin’s Rn is really high, it is estimated as: 2.30. It obviously signifies the intensity of the basin and the lack of homogeneity in rock formation.

2.5 The Hypsometric curve:
It is considered as one of the best quantitative variables which allows us to study the relationship between the basin’s topography and the erosion taking place on its surface in order to obtain the set of different heights per the total area of the basin (Strahler, 1957).

![Hypsometric curve of Souss basin](image)

As mentioned before, the highest point in the basin is 4165 meters at Mount Toubakal heading to 0 m as the lowest point at the estuary. Through the Hypsometric Survey, we notice that the average height of the basin area is 1000 and 2000 meters and this allows huge waters flow to the basin and so enrich its groundwater.

3. The Slopping:
It is one crucial factor and geometric feature which should be studied carefully while dealing with any river basin because it is inter related with the speed and nature of the flow. The sloping contributes to accelerating the water flow where it is strong, and vice versa if it is weak. To better understand its role, we are going to shed light on some definite indicators.

3.1 The sloping average:

This index is indispensable to study any basin’s characteristics. It gives us a topographic overview of the basin hydrological features. To get this index we have to determine the maximum height (AT. Max) and the minimum height (AT Min) of the basin plus, the The Hypsometric curve (Courbe Hypsométrique), and then we calculate it as follows:

\[ P_{moy} = \frac{\Delta H}{L} = \frac{H_{\text{max}} - H_{\text{min}}}{L} \]

So:

\[ L \approx 227.37 \quad : \quad H_{\text{max}} - H_{\text{min}} / = 4167 - 0 = 4167 \]

\[ P_{moy} \quad 4167/227.37 = 18.333 \text{m/km} \]

The average sloping in Souss basin is 18.33 km / m. It is obviously average. This average sloping reinforces the pace at which surface water flows to meet the main stream.

3.2 The sloping coefficient:

It is determined by exploiting the Hypsometric curve by extracting height units which represent respectively 5% and 95% out of the total area of the hydrological basin. This coefficient gives us a clear view of the overall sloping in any basin. It is determined through the following formula:

\[ I_g = \frac{Du}{L_{eq}} = \frac{H_{5\%} - H_{95\%}}{L_{eq}} \]

Souss Basin’s coefficient:

\[ 8.88 = 0.09\% = \frac{2620 - 600}{d\cdot272.3x} = I_g \]

<table>
<thead>
<tr>
<th>Relief Feature</th>
<th>sloping coefficient (I_g) (m/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Relief Very weak</td>
<td>(I_g &lt; 0.002)</td>
</tr>
<tr>
<td>2 Relief Somewhat weak</td>
<td>(0.002 \leq I_g &lt; 0.005)</td>
</tr>
<tr>
<td>3 Relief feeble</td>
<td>(0.005 \leq I_g &lt; 0.01)</td>
</tr>
<tr>
<td>4 Relief Medium Sloping</td>
<td>(0.01 \leq I_g &lt; 0.02)</td>
</tr>
<tr>
<td>5 Relief fairly strong</td>
<td>(0.02 \leq I_g &lt; 0.05)</td>
</tr>
<tr>
<td>6 Relief Strong</td>
<td>(0.05 \leq I_g &lt; 0.5)</td>
</tr>
<tr>
<td>7 Relief very strong</td>
<td>(I_g &gt; 0.5)</td>
</tr>
</tbody>
</table>
From the table above, it is all clear that the sloping in Souss basin is defined by the nature of its terrain characteristics which are over ally hard and sophisticated.

Figure 5: Map of Sloping levels in Souss basin

3.3 Qualitative supervision:

Its importance lies in the fact that it allows to draw a neat comparison among all different basin types. It is determined as follows:

\[ Ds = Ig \times \sqrt{A} \]

**Ds**: Supersion / m. / **A**: Sloping coefficient / km2. **Ig**: basin Area / km2.

The results are included in the following table:

**Ds**: **1167.23**

From the result got above, we deduce that the specific terrain features are highly sophisticated and it’s the leading reason to erosion.
Conclusion:

The metromorphic study of Souss basin has been a good example in applying different geographic information systems in order to set a prominent geographic database of morphometric variables based on the digital elevation models (DEM). The outcomes take many forms, such as: the basin's morphometric and hydrological measurements and the patterns of water drainage networks. The study is also appreciated thanks to its contribution to implement various promising developing projects in the future.

Throughout this study, many deductions have been underlined:

- Souss river Basin is ranked in the sixth category according to Strahler’s. It is one of the large basins. Its area is 17278 km², and its basin is 1065 km long. It is getting far longer.
- The basin is characterized by its rugged and sophisticated terrain features.
- The dominant sloping category in the southern part of the basin is the lowest one as opposed to the northern section where the slopes are strong which causes speedy water flow and strong erosion.
- The basin is penetrated by a superficial hydrographic network in the south, dense and deep in the north.
- Both the permeability of the rock prevailing in the basin and the diversity of the terrain lead to a decrease in both the flow density and the frequency of the water stream.
- The morphological and metromorphic characteristics of Souss basin are a natural reflection of its geological structure; in that the torsions and cracks are the most dominant factors in determining the overall shape of the basin.
Arabic References:


Foreign References:


