# Morphometry elements of hydrographic basins with use in the characterization of relief

Ion ZĂVOIANU[1], Nicolae CRUCERU[1], Gheorghe HERIŞANU[1]

**Abstract.** Since the ground surface has entered under the action of sub-aerial agents, water was the main relief-modelling agent in the temperate zone. Its vectorized action focused on slopes and on the hydrographical network has generated in time the present relief configuration. In this context, it should be normal that for the geomorphologic characterization of any geographical space we also take into account the fluvial morphometry parameters, which can be very useful in quantitative geomorphology studies. We propose, selecting from these parameters, the use of the river segments frequency of successive ascending orders within the Horton-Strahler classification system, as a ratio between their number and the surface of the investigated unit. Another parameter with importance on the dynamics and the intensity of the relief modelling processes is the geodeclivity that ensures the potential energy of any territorial system. This assumes that it is necessary to analyze the slope of the topographic surface, as well as the surface of the river network considered as size orders and the mean value for the entire valley network, divided on relief units under research. The drainage density, expressed as a ratio between the sum of the river segments and the catchment surface or investigated unit surface is similar with the relief fragmentation density already used in classical geomorphology studies. A very important element for the flow processes and flash flood generation is the length of the slope flow calculated with the formula proposed by Horton in 1945 as the inverted value of the drainage density double.

**Keywords:** river segments frequency, catchment slope, network slope, drainage density, slope flow length.

## 1. Introduction

The use of morphometry in the field of geomorphology has systematically been used since the middle of the last century, with the work of Strahler (1952) who, by the quantitative analysis of the hypsometric curves, has fundamented the determination of the youth or maturity degree of the hydrographical catchments relief.

Most part of the early classic geomorphology works conduced at the level of different relief units of Romania give little attention to quantitative assessments, but emphasize the qualitative aspects related to relief description based on the performed field researches or on the analysis of the cartographic fund (Roșu, 1967; Badea, 1967; Hârjoabă, 1968; Morariu & Velcea, 1971). The parameter most frequently used in these geomorphology researches was the density of the hydrographical network. The reference parameter used in these geomorphology researches was the density of the hydrographical network (Morariu et al., 1956).

In time, the international as well as the national researches have been developed and intensified introducing into the circuit new elements in correspondence with the level of development of the discipline (Ichim, 1979; Grecu, 1992; Schreiber, 1994; Grecu & Zăvoianu, 1997; Armaș, 1999; Comănescu, 2004; Filip, 2008; Ionita, 1998; Dimitriu, 2007 ș.a.). For example Hârjoabă (1968), in *Relieful Colinelor Tutovei*, presented the map of the mean density of relief fragmentation and the depth of relief fragmentation. In addition, the information related to the slope analysis are also important, as they are involved in the dynamics of the present relief modelling processes, based on the maps scaled 1:50 000.

In the chapter *Morfosculpture* from the work *Stânişoara Mountains, Geomorphology study* Ichim (1979) briefly presents *The hierarchy and the structure of the valleys system* (after the Horton-Strahler model), considering that this analysis *„offers the logical base of the comparative geomorphologic study of the valleys in report to the different factors that determine their evolution”* and the present morphography of the study unit. In what concerns the study of the *longitudinal profiles* the main purpose was to discover the connection between the slope changes and the lack of terraces and also the reference significance of the confluences in the process of valleys evolution.

Zăvoianu (1985) applies the newest results from the international literature to the conditions specific to Romania and processes a large volume of data related to the analysis of the hydrographical basins morphometry, in the Horton-Strahler classification system. The synthesis of the performed researches allowed the development of a series of new laws and the finding of quantitative relations and indices, included in the work *The morphometry of hydrographical basins*, which can be very well used for geomorphologic characterizations as well.

The work of Mac (1986) *Elements of dynamic geomorphology* has a chapter referring to the *Fluvial morphodynamics* relevant for accomplishing a relief study that wishes to analyze the temporal evolution of the morphography of a geographic space. This is also based on the Horton-Strahler system due to its implementation in the geographical literature and presents "*the order of the river segments, the law of the rivers number, and the law of the rivers length so on.*"

Schreiber (1994) analyzes for the morphometry of Harghita Mountains the maximum relief altitude, the mean altitude, the density of the hydrographical network, the depth of the relief fragmentation, slopes declivity and the relief energy. In the case of the mean altitude, it uses very well, as a quantitative expression, the formula used in hydrology form the determination of the mean altitude of the hydrographical basins, and for the density of the network it uses the ratio between the sum of rivers length and the corresponding surface. For the slopes declivity, the values are calculated based on the maps scaled 1:100 000.

Significant contributions to the fundamentation and development of the fluvial geomorphology based on new quantitative data are gathered in the work of Ichim et al., (1989), *The morphology and dynamics of riverbeds.* The special contribution of the work resides in the approach of theoretical problems of novelty for the Romanian geomorphologic literature, based on the newest researches in the field and it offers a special methodological basis for the practical studies of fluvial geomorphology. Nevertheless, sustaining the idea that for geomorphology development the quantitative analysis is necessary, he determines, in another work, numerous variables, such as: the number of 1st order rivers, the number of 2nd order rivers, basin surface, mean basin altitude, mean basin slope so on. Thus, he has strengthened the necessity of using these parameters in a relief study (Ichim et al., 1998).

In a regional study of environmental geomorphology Filip (2008) presents in the 3rd part the analysis of a classical geomorphology study and the analysis of a geomorphology study that includes the antropic component, giving the practical utility of the relief studies. In the work *Models of functional geomorphology of the valley-slope system in the Transilvanian Depression*, Roşian (2011) highlights the novelty of the interfluves order (the law of the interfluves number), established in a similar way as the hydrographical network order. The author calculates the *knot report (Rn)* or the intersection knot (analogous to the confluence report) and he presents the hierarchy on size orders and the graphical representation of the law of the interfluves number for a significant amount of interfluves.

In correspondence with the increase in number of the followers of these new approaches, we can say that at the national level few research nucleus appeared.

Thus, at the Geography Institute of the Romanian Academy, the classification system of the hydrographical network proposed by Horton was first applied in Romania by Platagea and Popa (1962). Afterwards, the researches continued by moving and applying these methods to the detailed study of the hydrographical basins situated in different geographic conditions (Zăvoianu, 1985; Sandu 1998; Jurchescu, 2007 ş.a.).

Along with the individual investigations, it is necessary to mention the special contributions of the Stejarul Research Centre in Piatra Neamț and of the research team in Suceava, conduced by Maria Rădoane, with contributions to the theoretical and practical fundamentation (Rădoane et al., 1991; Rădoane, et al. 1996; Rădoane et al., 1999; Rădoane, Rădoane, 2002-2003).

At the Faculty of Geography within the Bucharest University there is to be noticed the interest in using morphometrical parameters in studying the relief of the hydrographical basins (Grecu, 1992; Grecu & Comănescu, 1998; Armaș, 1999, Bogdan & Şandric, 2002-2003; Grecu et al., 2005; Grecu & Palmentola 2003; Grecu et al., 2012). In *The study of relief. Workbook for practical studies* (Grecu, Comănescu 1998), a series of morphometrical analyses are presented within the hydrographical basins, with use for the study of relief in both a morphographic and a dynamic way. In 2003 the work *Dynamic Geomorphology* appears (Grecu & Palmentola), where we can also find a chapter entitled *The morphohydrographic basin – elements of dynamic geomorphometry*.

At the Faculty of Geography within Babeş-Bolyai University in Cluj, both regional and local approaches are in view (Mac, 1986; Haidu, 1993; Pandi, 1997; Filip, 2008; Roşian, 2011 s.o.).

At the Faculty of Geography and Geology of A. I. Cuza University a series of theoretical and practical works are notable, of whom we recall Ungureanu, 1978, Bojoi, I. et al., 1998 s.o.

The characterization of the geomorphologic units and subunits with the aid of fluvial morphometry parameters, also accomplished within the PhD thesis from the last decade, is useful for the theoretical studies as well as for the practical activity of organization and improvement of the geographical space, of the hydrology, erosion and environment conservation studies, etc.

## 2. Methodology

The data needed for the determination of the analyzed morphometrical parameters have been obtained starting from the processing of the cartographic fund scaled 1:25 000, using the GIS and DTM methodology. Thus, the level differences between the maximum and minimum altitudes for all the basins, on size orders. The summed individual values and the sums reported to the number of used basins allowed the determination of average values of the relief of successive ascending orders basins. The slope of the hydrographical basins was determined for each basin separately using the length of the main contours, their equidistance, and the surfaces of the basins or the investigated geomorphologic units. In what concerns the segment slope of the rivers of successive ascending orders, we had in view the altitudes of the initial and final points of each river segment, and the corresponding length. From the subtraction of the two values, the level differences for each segment was obtained, which, summed on size orders, have offered a values range with the sums of level differences on size orders. By reporting these values to the number of river segments taken into account for each order, the mean values of the level differences on size orders were obtained. The same procedure was used for the mean lengths resulted from the river segments lengths summed on orders, reported to the number of segments corresponding to each order. This way, two data ranges were obtained for mean differences and average lengths. From the report between the two value ranges a third row is obtained, containing the average slope of the river segments of successive ascending orders.

The declivity, as a tangent of the tilt angle is an adimensional parameter that can be determined both for the basins and the hydrographical network as the ratio between the fall (ΔH) between two points and the length of the horizontal distance between them (L).

$$tg\ \alpha = \Delta H / L$$

On the field, this can be established with the clinometers, the theodolite, or the total station. In the cabinet, for measuring declivity, the work supports are the topographic maps, the plans with contour lines and the methods are the classic ones, the diapason or the slope graphic, respectively.

## 3. Results and discussions

In the temperate zone, regardless the genetic type of relief (fluvial, glacial, periglacial), relief modelling, and the genesis of the present morphography was conduced by the hydric agent this fact motivating us to support the necessity of using some parameters of fluvial morphometry in the characterization of the existent landforms.

### *3.1. Relief*

In the international geomorphologic literature, the term relief is generally used with two senses. On one hand, it stands for the absolute relief, which represents the height of a point above sea level. In the Romanian geographical literature, this type of relief is known as *the altitude.* On the other hand, the second meaning is that of relative relief, defined by the level difference between the local maximum and minimum altitude of a hydrographical basin or a geomorphologic unit (Selvan et al., 2011). In the Romanian geomorphology, the notion of relief has a more complex significance, but with a generalized aspect included in the term morphography.

If we consider a hydrographical basin or a relief unit, the relative relief of the hydrographical basins can be determined, because, being summed on size orders, it tends to form a descending geometric progression. The obtained data row reported to the number of identified basins generates a third geometric progression, which establishes that *the medium relief of the basins of successive ascending orders tends to form an ascending geometric progression in which the first term is the medium relief of the first order basin and the ratio is the report of the successive* values (Fig. 1 a, b). The distribution of the values and the existent relations between the medium relief and the size order of the hydrographical basins prove an exponential growth function of the order, with higher ratios for the basins in the mountain area and lower in the subcarpathian and plain areas.

The relief of the basins or of the relief units is essential for geomorphology, because it gives dimension to the potential energy existent in the respective entities, energy that induces the modelling and the intensity of the actual processes that, in time, modify the general morphography of the topographic surface (ex. Grecu, 1980, 1981; Sandu, 1980; Grecu & Zăvoianu, 1997; Grecu et al., 2012 s.a.).

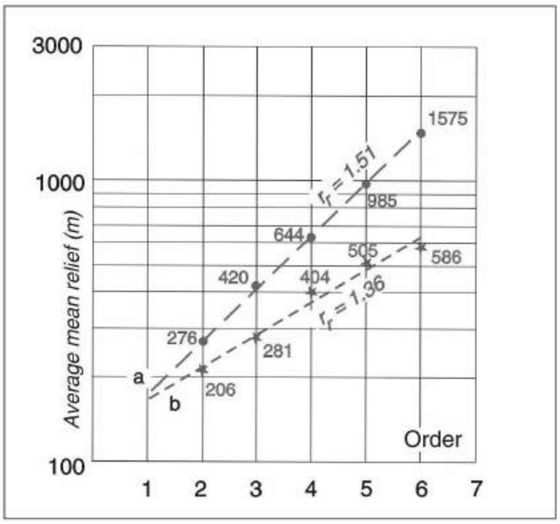


*Fig. 1*. **The medium relief of the basins of successive ascending orders in the hydrographical system**:
a) Doftana upriver of the confluence with Prahova
b) Cricovul Sărat upriver of the confluence with Lopatna

### *3.2. River segments frequency*

As a report between the total number of river segments (in the Horton-Strahler classification system) and the surface of the basin or of the corresponding geomorphologic unit, the frequency of the river segments is an important parameter that offers information upon the basins reaction to the action of precipitation and erosion processes (Selvan et al., 2011). Considering the fragmentation degree of the relief, a high value of the river segments frequency implies an accentuated incisation of the relief with all the consequences that derive for the dynamics of the processes that occur within hydrographical basins. An increased fragmentation degree assumes a shorting of the interval between the flow arteries and, consequently, a reduction of the length of slope flow. As a following, the response of the hydrographical basins to rain action will be shorter, because the accentuated fragmentation enfavors the rapid formation of flash floods with a significantly higher erosion and transport force.

In the Romanian geomorphology, stands the work of Grecu (1980, 1992, 2008) has been analyzing the number of the river segments (N) and the frequency of the elementary thalwegs ($f_1$) for the Hârtibaciu basin, while Comănescu (2004) did the same for the Casimcea morphohydrographic basin.

In 2012 Grecu et. al use a great number of morphometric parameters in a work dedicated to the Romanian Plain and highlights the necessity of these parameters in geomorphological studies. The obtained data are used to highligh the critical values, to define the risk triggering thresholds and, also, to establish the different classes of relief vulnerability to geomorphological processes.

The analysis of a high number of cases of river segments frequency in the Horton-Strahler classification system proves the fact that this frequency is strongly influenced by the resistance degree of the rock types from the hydrographical basins (Zăvoianu et al., 2004). If we take into account large relief units, it is noticeable that the highest frequency of the river segments is encountered in the subcarpathian area, followed by the mountain area and the plain area, the latter showing the smallest values.

### *3.3. The surface declivity of the basins and of the hydrographical network*

The present slope of the relief, defined as tangent of the bent angle of a line or of a plan of the terrain is the result of the complex and continuous interaction between the internal and the external forces that act at the surface of the terrestrial land. The size of the slope depends on the rock, but also on the thickness, texture, and mobility of the deposit of debris, which, on their turn, depend on the climate (Baulig, 1959). Within a drainage the slopes and channel declivity is directly connected with the quantity of potential energy that determines the intensity of the flow, erosion and transport processes that lead to the establishment of an equilibrium state of the declivities in relation to the ensemble of the local geographical conditions. The role of the declivity is also very important for the fluvial processes. The flow, the formation and propagation of floods, the hydro energetic potential of the water courses, the formation and evolution of the river channels, the processes of relief modelling, erosion and accumulation through channels etc. cannot be approached without knowledge about basins and river network declivity.

**The mean declivity of the drainage basins surface** (Sb) or of a relief unit can be determined using the expression:

$$S_b = \Delta h(l_o + l_n)/2 + l_1 + l_2 + \ldots\ldots + l_{n-1} + l_n)/A$$

where Δh (constant) is the equidistance, $l_o$, $l_1$, ………. $l_n$ the length of the utilised contour lines and A the surface of the basin. In a shortened form, the expression is currently used in the speciality literature (Diaconu & Lăzărescu, 1965;

Vladimirescu, 1978). In a shortened form, the expression is:

$$S_b = \Delta h\ \Sigma L/A$$

where $S_b$ is the declivity of the basin, Δh the equidistance of the contour lines utilised, ΣL the length of the contour lines, and A the surface of the basin or of the investigated unit.

*The law of the average basins declivity.* The values of the mean basins declivity can be summed on size orders. The obtained sums reported to the number of basins involved are the mean values of the mean declivity for each order. The obtained values row graphically represented in semi logarithmic coordinates emphasize a very good relation between the averages of the mean declivities and the size orders of the basins. The relation highlights a geometric progression in which *the averages of the mean declivities of the basins of successive ascending orders tend to form a geometric progression in which the first term is given by the average of the mean declivities of the first order basins $s_{b1}$ and the ratio is expressed by the report of the mean declivities of successive ascending orders $r_{sb}$* (Zăvoianu, 1985). The ratio of the new row can be obtained also from the report of the ratios for row of number of successive ascending basins and the one of the sums of mean declivities for the basins taken into account, resulting that $r_{sb} = R_c/R_{sb}$ and the general term of the relation is:

$$sb_u = sb_1\ r_{sb}^{u-1}$$

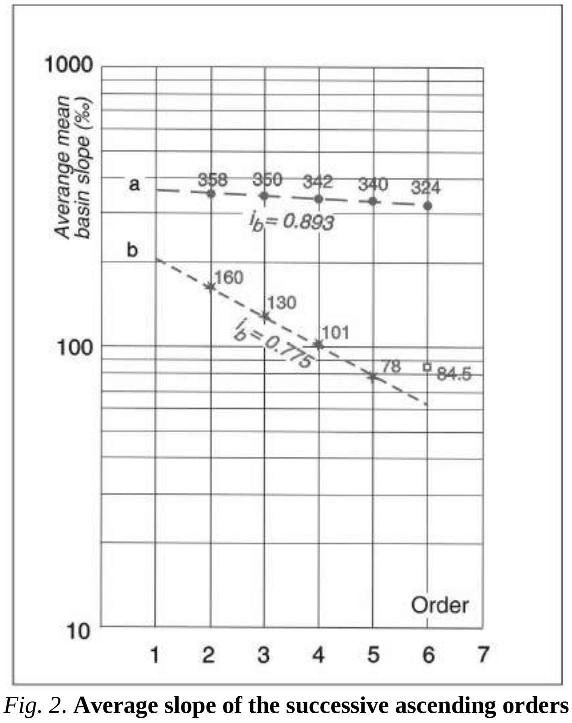


*Fig. 2.* **Average slope of the successive ascending orders basins for the hydrographical system**:
a) Doftana upriver of the confluence with Prahova
b) Bucovel upriver of the confluence with Teleajenul

The values determined for a large number of basins from the Ialomița hhydrographical system, basins situated in different geographic conditions, prove an exponential decrease function of the order and the fact that the highest slope values belong to the basins situated in the mountain area, followed by the ones in the hill and plain areas, respectively. The basins that are completely or partially situated in the mountain and subcarpathian areas present high slope values, with small differences between the orders, as we can see from the value of the ration, close to the unit ($i_b$ = 0.893) which assumes a small slope of the regression line (Fig. 2). Nevertheless, in the case of the subcarpathian area, where the basins are sculpted in poorly or unconsolidated rocks, with small resistance to erosion, the differences between the declivities of the successive orders are higher and, subsequently, the ratio has a smaller value (ib = 0.775) (Fig. 2 b).

**The average slope of the drainage network.** In the lower part of the slopes, the slope flow enters the channel network, as the waters pass by in the same time to a flow regime determined by the hydraulics of the channels, in which the slope has a very important role. The factors that determine the slope of the riverbeds are very numerous. Among these factors we can distinguish the geomorphologic evolution, the structure and the tectonics of the geological formations, the degree of vegetation cover and not last the surface of the basin, which determines the water debits and implicit the grain size of the materials found in the channel. Ever since 1877, Gilbert noticed the fact that the declivity of rivers is inversely with the flown water debit, as it is found in an inverse relation with the determined basin surface and in a direct relation with the size of the material within the riverbed (Hack, 1957). He also highlights the relations between slopes, lithology, and tectonics.

From all the morphometrical elements of a channel network, the slope is a very dynamic element, which rapidly adapts to the physical-geographical local conditions, with control of the base level and the resistance imposed the ground to the action exerted by the water volume of the respective watercourse. The slope regime controls most of the morphohydrographic processes that take place in channels, the intensity of the erosion, transport and accumulation processes, the degree of alluvial loading of the river, continuously imposing the manifestation of a tendency towards a dynamic equilibrium. In a lithologically homogenous space the sizing of the slopes is made considering the water debit, which, in his turn, depends on the basins surface.

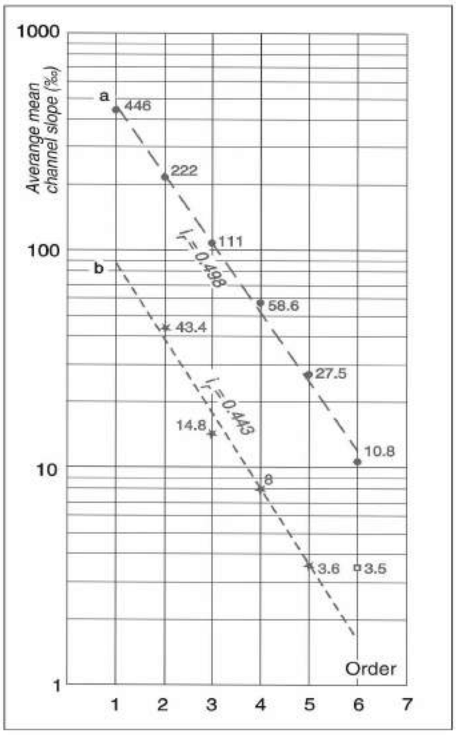


*Fig. 3.* **Mean slopes of river segments of successive ascending orders for the following hydrographical systems**:
a) Doftana upriver of the confluence with Prahova
b) Bucovel upriver of the confluence with Teleajen

**The slope of river channels.** Being a representative element of a watercourse, the slope has been defined and used for a long time in practical purposes. In many cases, the focus is on the slope of the river from its source until the discharge or on a certain sector, but there were no studies to appreciate the average slope for the entire rivers network in a given hydrographical basin. A first step in this sense was made ever since 1945 by R. E. Horton who came with the concept of the law of the average slope for the rivers with successive ascending orders. The problem has been later on re-evaluated by Strahler (1952), Schumm (1956), Hack (1957) who have used this law, verifying it in many cases. Hack, for example, has established an equation by which the slope of the channel is directly proportional with the power 0.6 of the ratio between the size of the particles and the drainage surface of the basin. In 1962, Morisawa formulated the law of the slopes and expressed it both in a exponential form as well as in a geometric progression form.

*The law of the average slopes of riverbeds.* In order to know the average values of the slopes of the courses of successive ascending orders the row of values defining the law of average falls will be reported to the row of values defining the law of average lengths. A new row of values is obtained, which, if represented in semi logarithmic coordinates function of the order of the courses proves that *the average slopes of the courses of successive ascending orders tend to form a descending geometric progression having as the first term the mean slope of the first order courses $s_1$ and as a ratio the report between these slopes $r_s$ or the result of the report between the average heights and the average lengths* (Zăvoianu, 1985). The following relation gives the general term of the progression:

$$s_u = s_1 \, r_s^{u-1}$$

The exponential connection between the average slopes and the size order of the segments show that the highest slopes correspond to the first order segments and the smaller belong to the segments with the highest order. In comparison with other laws previously analyzed, this law is very well verified, fact that proves that the slopes of the drainage network tend faster to a equilibrium state imposed by the mass and energy transfer through the drainage ways in report to the specific conditions of the basin.

Following the connection between the values of the average slopes corresponding to the courses of successive ascending orders from the fifth and sixth order basins from the hydrographical system of Ialomița river, it is visible that the slope of the determinate lines varies from a basin to another function of the physical-geographical conditions specific to each basin. In comparison to the slope of basins surface, the slope of river segments of successive ascending orders create geometric progressions with much higher differences between the slopes of neighbouring orders, this being shown by the low values of the ratios (Fig. 3).

*The average slope of the entire drainage network within a hydrographical basin or a given relief unit.* The determination of the average slope of a river sector or of a rivercourse from the source until a certain point is not difficult when we know the level difference and the length of the route. Nevertheless, most of the works that take into account this element always use the slope of the main river as a resultant of the processes that take place in that basin.

If between the debit and the slope there is an inverse relation that means that the main artery with the highest debits has also the lower slopes in the basin. This implies that the mean slope of the main river does not reflect the situation of the collected affluent, their slopes being constantly higher, as observed from the analyzed laws. Even so, the entire rivers network with its characteristics contributes to the formation and evolution of many hydrological and geomorphologic processes, this fact imposing the necessity to determine a mean slope of the entire rivers network in a given basin. In addition, from the investigated situations results that the average slopes of the thalwegs of a hydrographical basin also imposes a certain slope of the basin surface. Between these two elements, there always is the tendency to create an equilibrium function of the local physical-geographical factors and, first of all, function of the geological resistance coefficient.

In the conditions of the Horton-Strahler classification system, the mean slope of the entire drainage network from a given hydrographical basin can be easily calculated as a report between the sum of the level differences and the summed lengths at the basin level. As these values are already known from the progressions determined by the level differences and the lengths summed on size orders, calculating the mean slope of the entire network is not difficult any longer.

### *3.4. Drainage density*

Defined as the length of the river segments on the surface unit, the drainage density is connected to rock strength to erosion, to the climatic conditions, soil permeability and so on. In geomorphology the term *density of fragmentation* is utilised and it is given by the report between the length of the valleys and the investigated surface, evaluated in the same measurement units (km/kmp) (Filip, 2008).

$$Dd = \Sigma L / A, \text{ where:}$$

Dd is the drainage density, ΣL the summed length of the drainage network and A the surface of the investigated unit or of the hydrographical basin. From the hydrological point of view, high values of this parameter imply a high degree of relief fragmentation, with an important role on the erosion processes and formation and propagation of the flood waves (Abrahams, 1972; Bauer, 1980).

The evaluation of this parameter, although it is very important, it has subjective values regarding the determination methodology and the map scale that is being used. For the determination the grid method or the module squares are utilised, for a reference surface of one $km^2$. Another used method is that of counter lines that uses as a base the previous method, interpolating the results obtained. The results obtained with the method on hydrographical basins, sometimes hierarchal, are similar with the results obtained with the modules method. There is also the profiles method, used more rarely due to the generalisation of the obtained results. In order to obtain values more closely to the reality we propose the use of the information existent on the maps scaled 1:25 000 and the length of the network evaluated in correspondence with the principles enunciated by Horton in 1945.

In order to determine the drainage density it is necessary to calculate the sum of the river segments length from a hydrographical basin or a relief unit with a known surface, on size orders. By cumulating the sums for all the size orders we obtain the sum of the length of the river segments network, which reported to the investigated surface gives the mean value of the drainage density. At the same time, *the drainage density on size orders forms a descending geometric progression in which the first term is the drainage density for the first order* ($D_1$)*,and the ratio is given by the report between densities* ($R_D$) (Armaş, 1999).

### *3.5. The length of slope flow Σ*

The length of the slope flow, defined by Horton ever since 1945 as being the distance of water flow on the slope before it concentrates into channels, is synonymous with the length of the surface flow as it is called in some works in this domain. As a basis element of flow formation, it is used in many formulas of hydrologic prognosis to calculate the maximum flow, the duration of water flow concentration, being one of the most important variables directly involved in the evolution of hydrographical basins. The concentration duration of the maximum flow depends on it, being involved in the formation of flood waves, because as lower the values of this variable get the shorter is the concentration time and the opposite.

In 1945, Horton calculated the length of the flow slope ($L_v$) as being approximately half the mean distance between the river channels, respectively the opposite of the double of the drainage density ($D_d$) using the formula:

$$L_v = 1/(2D_d)$$

Although it is very simple to determine, the formula has not been used in the scientific research that continued to use, even in detailed cases, other formulas to determine this variable. The inconvenient that made the formula proposed by Horton not to be used, although it is logical and easy to apply we consider that are due to the way of determining the drainage density.

First, we have to mention that there is in the literature two terms expressing the network density. It is the *density of the hydrographical network* ($D_r$) as a report between the length of the watercourses (ΣL) and the surface of the corresponding basin ($S_b$).

$$D_r = \Sigma L/S_b.$$

In order to determine the dimensions involved, in most cases we take into account those watercourses that are marked on the map with blue lines, which means that at the time of map construction the rivers had water flow. This is estimated on maps at small scales that do not allow considering the detail morphology (Zăvoianu, 1978, 1985).

Except for this notion, in the last decades *the drainage density* ($D_d$) has been used more often expressing the result of the report between the lengths of all the negative forms that have the capacity to direct and organize the flowing ($\Sigma L_r$) and the surface of the corresponding basin ($S_b$).

$$D_d = \Sigma L_r / S_b$$

Thus, the formula remains the same, but the difference is made by the detail and precision degree of the measuring manner of the flow paths lengths. In conclusion, the method of obtaining the drainage density depends on the analyse purpose, the choice being determined by the precision of the maps and by scale (Zăvoianu, 2006).

Of course that for having data as close to field reality as possible large scale maps are necessary, the best being those scaled 1:25 000, because hey offer the necessary information to correctly estimate the drainage density and it is requisite that all parameters be analyzed at the same scale.

The determination of the drainage density in the Horton-Strahler classification system is easy to determine with the condition to determine the law of the summed lengths of the successive ascending orders rivers network. Clearly that the thoroughgoing study can take into consideration the fact that in the real lenght of the slope flow the cartographic projection is not included, but there is a value determined by the hyponenuse of a rectangular triangle in which one of the chatetus is the horizontal projection of the slope flow lenght and the second is given by the average height of the watershed above the horizontal plan that crosses the flow channel. Thus, knowing the horizontal projection of the slope flow lenght ($L_v$) and the cosinus of the angle given by the mean slope of the first order basins (cos α) we can also calculate the real lenght of the slope flow ($L_p$) within a given hydrographic basin.

$$L_v = L_p / \cos \alpha$$

## 4. Conclusions

The analyzed parameters and not only can be used for the characterisation of the hydrographical basins as well for the geomorphologic units and subunits. Using the Horton-Strahler classification system, these parameters can be studied and evaluated quantitatively on successive ascending size orders or globally, using the properties of the geometric progressions. The fact that between the mean slope of terrain surface and the one of the drainage network there is a direct connection proves that between these variables there are interdependence relations that can be discovered and efficiently used in the purpose of a future sustainable development.

The mean slope of the basins surface does not replace or exclude the slope or geodeclivity maps that evidentiate numerically and cartographically (if GIS program have been used) some areas at the slopes level with higher potential energy that can favourites a more accentuated dynamics of the present morphodynamic processes. The mean slope of the (drainage) network on size orders is useful in the studies of fluvial geomorphology because the slope is the most dynamic element that evidentiate the adaptation of the hydrographical network to the local physical-geographic conditions, function of the base level, rock properties, water volume and so on.

The drainage density, known in the geomorphologic literature under the name of relief fragmentation density or the density of the hydrographical network or the relief horizontal erosion also presents an image of the spatial repartition of this variable that highly depends on the degree of resistance of the rocks from the geomorphologic units and subunits.

The average length of the slope flow is a very important element for the dynamics of the present relief modelling processes, controlling in a very strong way the intensity of the present relief modelling processes.

All these justify the necessity of using the presented parameters in the study of relief morphography and dynamics, for the quantitative evaluation of the present state of the physical environment. Numerous software used within GIS can facilitate fast results and can evidentiate morphography and morphometry aspects that can emphasize the state or the dynamics of the geomorphologic processes and phenomena.

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**University of Spiru Haret, Faculty of Geography**
**Bucharest, Romania,**
ionzavoianu@yahoo.com
crucerunick@yahoo.com