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INTERDEPENDENCE RELATIONSHIP BETWEEN MORPHOMETRIC INDICATORS IN THE "BÂRSA COUNTRY"[1] (ROMANIA)

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[1] *Bârsa Country* – pilot area which overlaps the territory of the internal curvature of the Carpathians, that most historians have defined "Bârsa Country" for medieval period.

Interdependence relationships between morphometric indicators in the Bârsa Country (Romania)

Georgian Ionuț Purcăreață

Relaţii de interdependenţă între indicatorii morfometrici în Ţara Bârsei (România În cadrul unei analize geomorfologice asupra unui spaţiu geografic studiul interdependenţei dintre indicatorii morfometrici ne poate oferi noi detalii referitoare la caracteristicile şi relaţiile cauzale aferente parametrilor urmăriţi.
Metodologia preluată din literatura de specialitate a fost adaptată spaţiului geografic al Ţării Bârsei. Perimetrul de cercetare cuprinde un areal pilot ale cărei limite sunt definite de interfluviile care mărginesc zona de largă confluenţă a râului Olt din depresiunea Braşovului. Modul de dispunere al reliefului conferă perimetrului de cercetare trăsături asimetrice evidente, care sunt completate prin analiza matematică şi grafică din cadrul acestui studiu.
Concluzia care derivă în urma analizei matematice corelate între energia de relief şi densitatea fragmentării reliefului este aceea că energia de relief se află într-o relaţie de strânsă dependenţă faţă de densitatea fragmentării reliefului, corelaţia fiind liniar pozitivă şi direct proporţională, acest fapt reieşind şi din interpretarea modelelor grafice rezultate.

Cuvinte cheie: Ţara Bârsei, corelaţie, energia de relief, densitatea fragmentării reliefului

Interdependence relationships between morphometric indicators in the "Bârsa Country" (Romania). In a geomorphological analysis on a geographical space, the study of the interdependence between the morphometric indicators can offer us new details concerning the characteristics and causal relationships between the considered parameters.
The methodology taken from the literature was adapted to the geographical space of Bârsa. The research area includes a pilot area for which the boundaries are defined by interfluves bordering the large confluence area of the Olt river in the Braşov Depression. The arrangement of the relief gives the research area obvious asymmetric features, which are completed in this study by the mathematical analysis and graphics.
The conclusion derived from the correlated mathematical analysis between the relief energy and the drainage density is that the relief energy is in a closely dependent relationship with the drainage density, the correlation being positively linear and directly proportional, fact prooved by the resulted graphical models.

Keywords: Bârsa Country, correlation, relief energy, drainage density

1. INTRODUCTION

The geographical areas of "Bârsa Country" (Figure 1) represented the study object for both historians, ethnographers, anthropologists, geographers and geologists. Thus, a series of information was recorded in papers that were particularly dedicated to the sub-units of the Curvature Carpathians, or in works that referred to more extended regions.

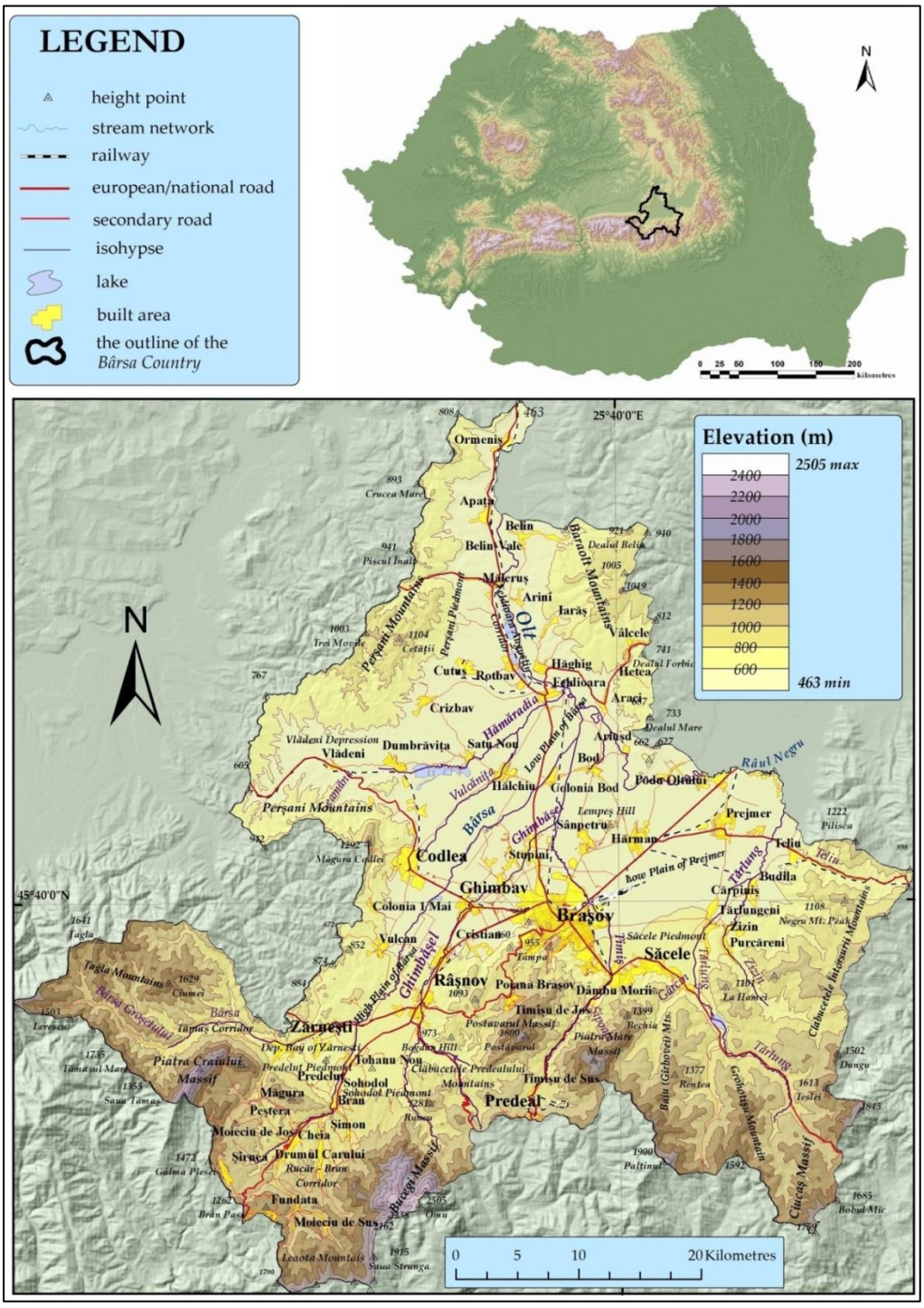


Figure 1. General map of "Bârsa Country"

Among these authors, we mention: Patrulius D. [1], Iancu M. et al. [2], Dunăre N. et al. [3], Ujvári, I. [4], Posea Gr. et al. [5], Băcăinţan N. [6], Cioacă A. [7], Mihai B. [8], Bănică S [9], Munteanu A. [10], Pătru - Stupariu I. [11], Pop A. M. [12], Şandor C. G. [13], or the work conducted in 1987 [14].

The aim of this study is to interpret, for the "Bârsa Country", quantitatively, spatially and correlated, two important morphometric indicators, that are defining the current morphodynamics of relief:relief energy (Figure 2) and drainage density (Figure 3). Thus, we can represent the interdependence relationship between the indicators, two analysis being conducted for the rectangular grid with values per square kilometre. (Figure 4). The mathematical bimodal analysis that underlies the methodology of this study was described in the works of authors such as: Mihoc G., Micu N. [15], Ichim I. et al [16], Rădoane M. et al. [17], Boengiu S. [18], Boengiu S., Török – Oance [19], Zăvoianu I. et al. [20]; or in international literature: Penny A. et al. [21], or Sanders L. [22].

This analysis is extremely useful in a geomorphological study, correlations and connections between the analyzed geographical variables being established. However, in the systems of the natural environment there is not always a causal relationship of direct dependence of geographical variables, good knowledge of these being required [17].

Study area. The present study aims to be an applied geography one for an area with historical meanings. Professor Cocean identified in Romania 18 medieval countries inhabited by Romanians [23]. The boundaries of "Bârsa Country" are not clear. The limits I set will be the historical ones, following geographical rules. They are defined by interfluves bordering the western half of Braşov Depression. Thus, the study area of the "Bârsa Country" (Figure 1) is located in the central-eastern part of Romania, in the internal part of the Carpathian arch, at the contact between the Meridional Carpathians and the Eastern Carpathians, being placed between the geographical coordinates of 25° 58' 26" and 25 ° 02 '03 " E longitude and 46° 2' 4" and 45 ° 22' 52" N latitude and occupying an area of 2280.69 km^2. The limit of 363.7 km spreads mainly on the watershed (92.5% - 336.4 km) and partially in the low floodplain (7.5% - 27.3 km).

The drainage density (Figure 2) is a reference geomorphological indicator in the relationship between the hydrographic network and the current relief configuration, truly highlighting the interdependence degree and dominance of the morphodynamic factors [17].

The hydrographical network is tributary to the Olt river, with the main tributaries on the left: Tărlung (Râul Negru), Bârsa with Ghimbăşel and Timiş, Hămăradia, Măieruş. Due to the relief configuration and lithology, the hydrographical network in the south of the study area is more active. These rivers show a high antecedent regressive erosion which is detrimental to the basin of the Prahova [24].

In the "Bârsa Country" the variation of the drainage density shows a sharp contrast between the southern Mesozoic area with density values above 7 km/km^2 and the interior depressionary area with low values not exceeding 1 km/km^2. Slope, slope processes and lithology lead to the rise of the density drainage values, often involving pluviodenudation and torrentiality. There are 5 classes for the drainage density.

Drainage density values over 7 km/km^2 are characteristic especially of the southern area, in Bucegi Mts, Piatra Mare Massif, Postăvaru Massif, Măgura Codlei, or Piatra Craiului Massif, where values go up to 14.7 km/km^2. The orientation of the rock strata in the suspended hogbacks in Piatra Craiului and Bucegi Massifs shaped a complex network of consequent valleys.

Drainage density values between 5 and 7 km/km^2 characterise mainly the southern mountainous alignment. These areas usually surround the zones with high drainage density values such as in Timiș Depression or Rucăr – Bran Corridor. The latter is an intense tectonic area, with longitudinal and especially cross faults [1].

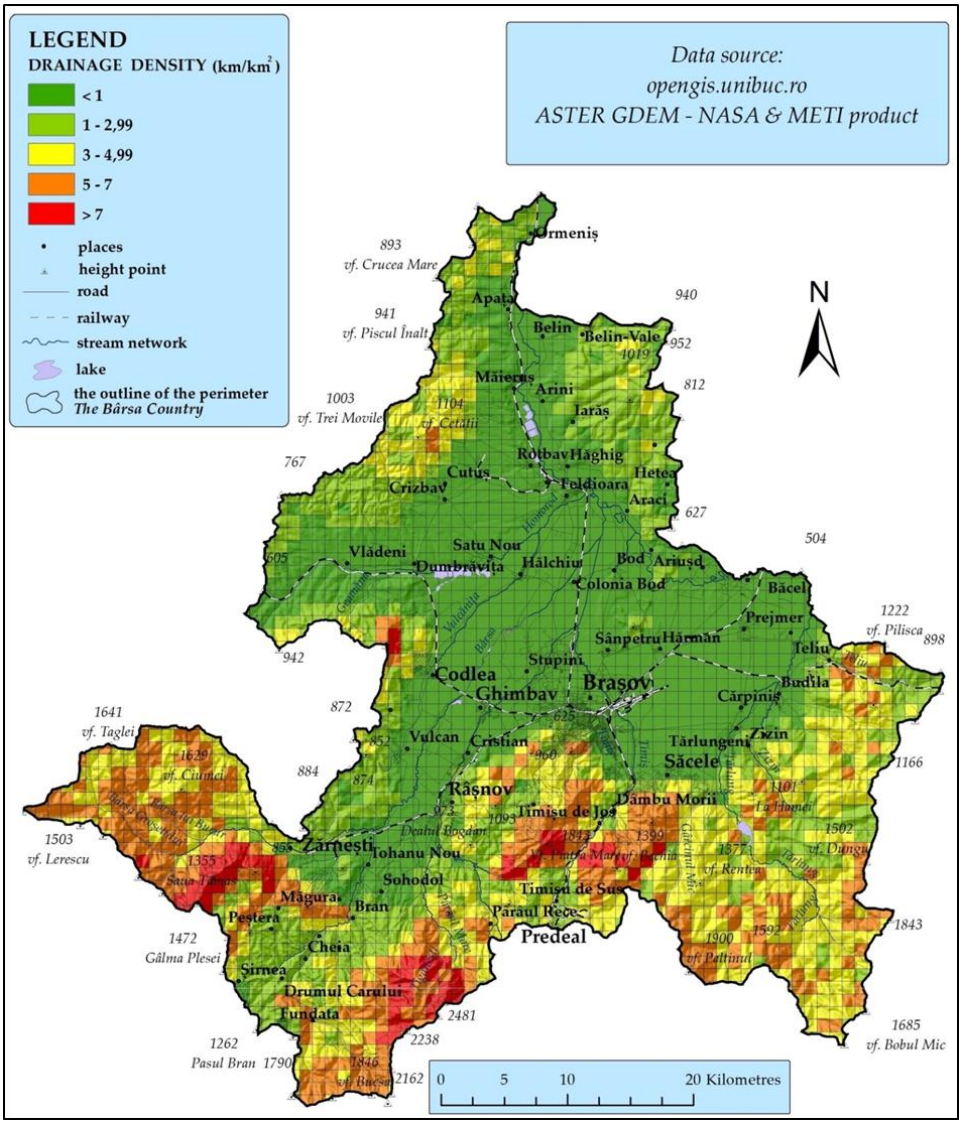


Figure 2. "Bârsa Country" – Drainage density map

Drainage density values between 3 and 5 km/km^2 are present in larger areas, with more developed hydrographical network, namely in the Rucăr – Bran Corridor, in Clăbucetele Predealului and Clăbucetele Întorsurii Mts., in the Central and Southern Perşani Mts. and Baraolt Mts.

Drainage density values between 1 and 3 km/km^2 are specific to the Rucăr – Bran Corridor, glacis areas in the depressionary bay of Zărneşti), piedmont areas (Săcele, Sohodol, Predeluţ or Perşani), and the leveling surfaces of Perşani or Postăvaru Mts. These drainage densities characterise almost a third of the study area.

Drainage density values below 1 km/km^2 characterise approximately one third of the "Bârsa Country", namely: the Bârsa Depression, Prejmer Depression, Feldioara – Augustin Corridor, the glacis areas or large areas of the piedmont areas. Numerous human settlements and over half the length of the road network (70%) and rail (90%) lie on this flat land. This smooth relief caused the unstable and meandering character of minor beds and led to increased gleying soil processes and the development of areas with eutrophic wetlands. All these aspects required complex improvements for an artificial drainage density, without which any infrastructure project would have met hydrological risks.

The relief energy is a geomorphological indicator that reflects the altimetry contrast of landscape, as difference between the extreme altitude values, or the quantification of the relationship between the deepening of the denudation processes and the lifting tendency of the Earth's crust [25]. The analysis may be carried out using the classical method of the rectangular grid, with 1 km^2 grid (Figure 3). There are 5 classes for the relief energy.

Very high values of relief energy, of over 500 m/km^2, are found in alpine areas in the south of the study area (Piatra Craiului Massif, Bucegi Mts., Postăvaru Massif, Piatra Mare Massif, and isolatedly in Culmea Tămaş Mts.). In Piatra Craiului Massif the values are up to 857 m/km^2.

Areas with relief energies between 300-500 m / km^2 are disposed adjacently and usually around areas with higher relief energies, in the same massifs which are added to isolated areas in Clăbucetele Întorsurii Mts., Clăbucetele Predealului Mts., Baiu Mts., Grohotişu Mts., Ciucaş Mts., Southern and Central Perşani Mts.

Relief energy values of 150-300 m/km^2 are characteristic of low mountains (Perşani, Baraolt, Clăbucetele Predealului, Clăbucetele Întorsurii, Baiului, Grohotişu) or areas at the bottom of the high mountains and areas of high corridor (Rucăr – Bran). These relief energy values characterise almost a third of the study area.

Relief energy values of 50 to 150 m/km^2 are specific to piedmont areas (Predeluţ, Sohodol, Săcele and Piedmont of Perşani Mts.), the wide Feldioara – Augustin Corridor or Vlădeni Depression. There are numerous human settlements on these lands.

Relief energy values below 50 m/km^2 are specific to glacis areas in the depressionary bay of Zărnești or Feldioara - Augustin Corridor and the vast depressionary areas (Bârsa and Prejmer Plains). About 52% of the length of the road network and over 70% of the length of the rail network spread on these lands.

The variations of this indicator influence the use of land, the areas with high relief energy being inaccessible to agriculture, infrastructure or residence. In our study area the relief asymmetry between south and north is obvious.

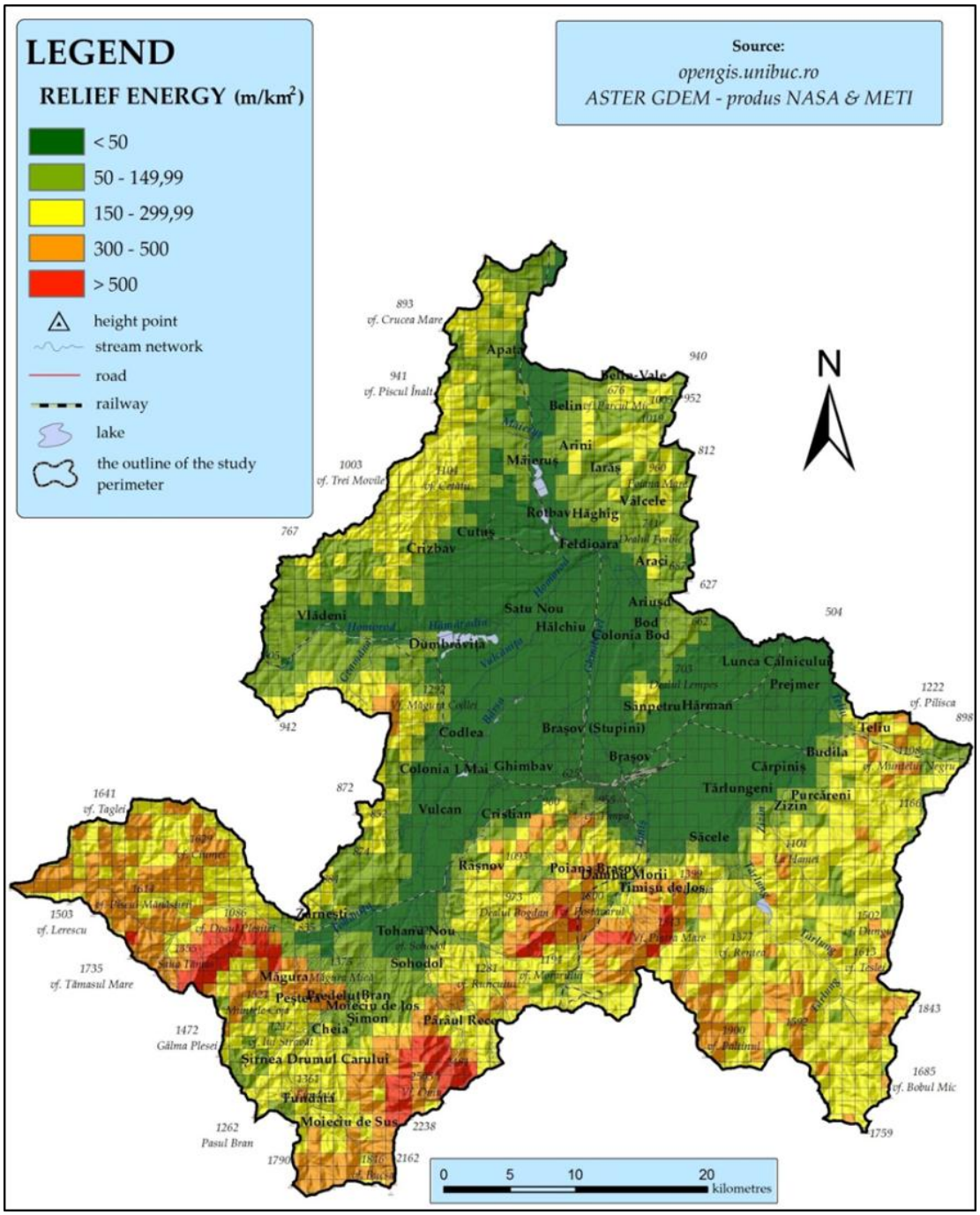


Figure 3. "Bârsa Country" – Relief energy map

2. DATA AND METHODOLOGY

To illustrate the relationship between the relief energy and drainage density I used as Digital Elevation Model the ASTER GDEM (product of METI and NASA) with the spatial resolution of 30 meters (http://earthexplorer.usgs.gov/). Orthophotographs (1: 5.000 scale) free quoted with Global Mapper ecwp://195.138.192.5/mosaics_5000/BRASOV.ecw and topographic maps from http://opengis.unibuc.ro:8080/geoserver/ows?service=WMS (1:25.000 scale). CORINE Land Cover 2006 database from http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-3, was also used for performing the analysis.

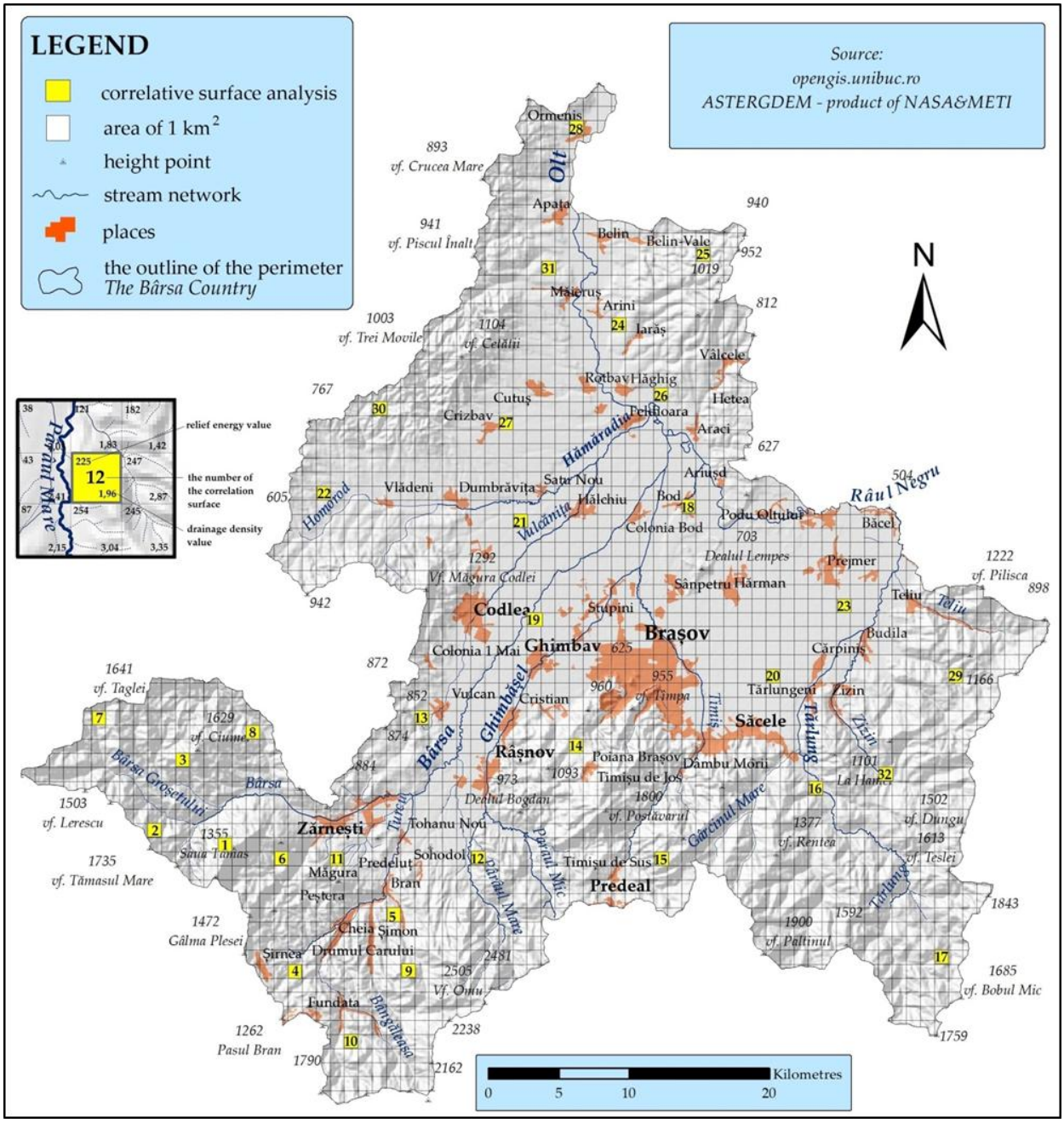


Figure 4. "Bârsa Country" – Rectangular grid

Regression analysis represents a statistical test for relationships where cause and effect are suspected between one normally distributed dependent variable and one independent variable, or between two normally distributed variables [21].

For the two cartographic representations I randomly chose 32 pairs of values, called correlation surfaces (Figure 4). If the number of pairs of values is greater, the accuracy of the analysis increases.

The aim of the paper is to use mathematical formulas to obtain a model of linear regression, of estimation of a relief energy based on drainage density. In a graph, the causal interdependence relationship is determined in a Cartesian plane xOy, where X axis represents the drainage density and is considered the causal or interdependent axis, and Y axis represents the relief energy and is considered the effect or dependent axis.

The basic equation is that of linear regression line [11] [15] [17] [21], which is Y=a×X+b, where:

-X and Y are geographical variables

-a and b are the coefficients of the regression equation, a is the so called interception term, and b represents the slope of the regression line according to Y values.

The coefficients of the regression equation are calculated with the help of the following formulas [11] [17] [21]:

$$a = \frac{\mathrm{n} \times \sum_i X_i Y_i - \sum_i X_i \times \sum_i Y_i}{\mathrm{n} \times \sum_i X_i^2 - (\sum_i X_i)^2}$$

$$b = \frac{\sum_i Y_i - a \times \sum_i X_i}{n}$$

Where n represents the number of the value pairs of the two considered indices. The shape of the point cloud in relation to the line of the linear regression equation, which results in the Cartesian graph, emphasizes the intensity of the variable dependence relationship. The arrangement of points around the regression line may be thoroughly interpreted calculating a dimensional statistics index, called correlation coefficient (r), which has the next formula [11] [17] [21]:

$$r = \frac{\mathrm{n} \sum_i X_i Y_i - \sum_i X_i \times \sum_i Y_i}{\sqrt{n \sum_i X_i^2 - (\sum_i X_i)^2} \times \sqrt{n \sum_i Y_i^2 - (\sum_i Y_i)^2}}$$

The values of the correlation coefficient ranges between -1 and +1. When interpreting these values three general situations may be identified [11] [17] [21]:

- in some cases, when **r=0**, there is not a direct correlation between variables.

- when **r** is positive, the Y variable depends on the X variable, high X-values corresponding to high Y-values. There can be particular situations, when the points are collinear and coincide with the regression line, but in the case of the natural environment this is impossible.
- when **r** is negative, the y variable is dependent on the X variable in negative correlation, high X-values leading to low Y-values.

The closer to extreme values X (-1 and +1) is, the higher the dependence degree of Y variable in relation to X variable is, values close to 0 highlighting the fact that there is not a high dependence relationship between variables [11] [17] [21].

When interpreting r values we must also take into account the critical points in the table of the signification levels of the correlation coefficient, that is 0.567 [11][17][21], values which highlight the fidelity of the analysis according to the size of the sample (n), in other words, the number of value pairs taken into account. The larger the number of measurements is, the higher the fidelity of the analysis is. The number of value pairs should be greater than or equal to 30 [11].

Table 1 Calculation of parameters of linear regression equation

Parameters of linear regression equation					
No. i	X_i	Y_i	$X_i \times Y_i$	X_i^2	Y_i^2
1	7,19	853	6133,07	51,6961	727609
2	4,53	565	2559,45	20,5209	319225
3	2,15	281	604,15	4,6225	78961
4	1,28	170	217,6	1,6384	28900
5	0,88	100	88	0,7744	10000
6	1,9	205	389,5	3,61	42025
7	2,58	243	626,94	6,6564	59049
8	3,26	380	1238,8	10,6276	144400
9	4,53	449	2033,97	20,5209	201601
10	2,18	225	490,5	4,7524	50625
11	2,29	210	480,9	5,2441	44100
12	1,96	225	441	3,8416	50625
13	1,13	143	161,59	1,2769	20449
14	0,99	58	57,42	0,9801	3364
15	2,9	301	872,9	8,41	90601
16	2,43	214	520,02	5,9049	45796
17	2,18	227	494,86	4,7524	51529
18	0,78	59	46,02	0,6084	3481
19	0,15	12	1,8	0,0225	144
20	0,23	20	4,6	0,0529	400
21	0,19	15	2,85	0,0361	225
22	0,49	52	25,48	0,2401	2704
23	0,25	16	4	0,0625	256
24	1,28	118	151,04	1,6384	13924
25	2,9	235	681,5	8,41	55225
26	0,5	43	21,5	0,25	1849
27	0,12	19	2,28	0,0144	361
28	1,2	129	154,8	1,44	16641
29	2,31	240	554,4	5,3361	57600
30	1,27	106	134,62	1,6129	11236
31	0,35	30	10,5	0,1225	900
32	1,17	115	134,55	1,3689	13225
Sum	**57,55**	**6058**	**19340,61**	**177,0453**	**2147030**

The value pairs in Table 1 have been randomly yet uniformly chosen from the rectangular grid with a reference unit of 1km^2 (Figure 4) of the drainage density maps (column X_i) and the energy relief maps (column Y_i), obtaining average values for each km^2 by converting reclassified rasters into shapefiles. The values necessary in the formulas above for the linear regression equation are found on the last row of the Table2.

After creating the database using Microsoft Excel, the next step is to solve the mentioned formulas in order to obtain results that will be interpreted:

$$a = \frac{\mathrm{n} \times \sum_i X_i Y_i - \sum_i X_i \times \sum_i Y_i}{\mathrm{n} \times \sum_i X_i^2 - (\sum_i X_i)^2} = \frac{32 \times 19340{,}61 - 57{,}55 \times 6058}{32 \times 177{,}0453 - 3312{,}003} = 0{,}126$$

$$b = \frac{\sum_i Y_i - a \times \sum_i X_i}{n} = \frac{6058 - 0{,}12621 \times 57{,}55}{32} = 189{,}539$$

3. RESULTS AND DISCUSSIONS

Having these results we can represent the regression line formula to obtain a model of linear regression, of estimation of a relief energy based on drainage density:

$Y = a \times X + b$ => $Y = 0{,}126 \times X + 189{,}539$

We can represent in cartesian plane (Figure 5) the cloud of value points and the linear regression line ,which has formula mentioned above, by selecting the values from the two geographical variables columns (X_i – the drainage density and Y_i – the relief energy).

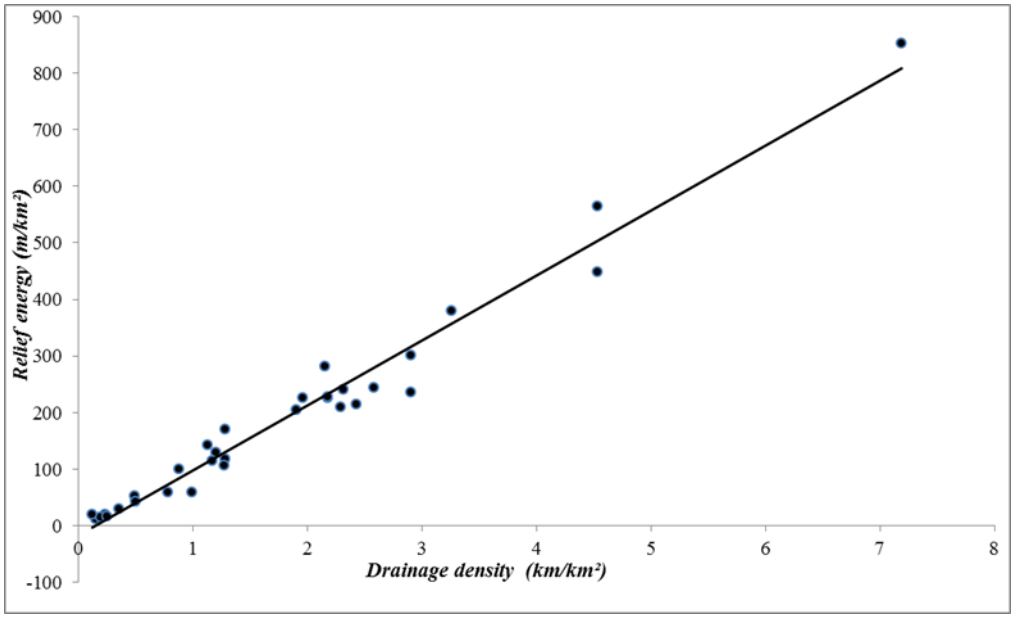


Figure 5. "Bârsa Country" The representation of linear regression equation for drainage density and relief energy

The graphical representation can also be rendered with the help of Microsoft Office in the form of the exponential (Figure 6), the logarithmic (Figure 7) or the polynomial model (Figure 8). Each of the resulted graphs reflects a close connection between drainage density and relief energy.

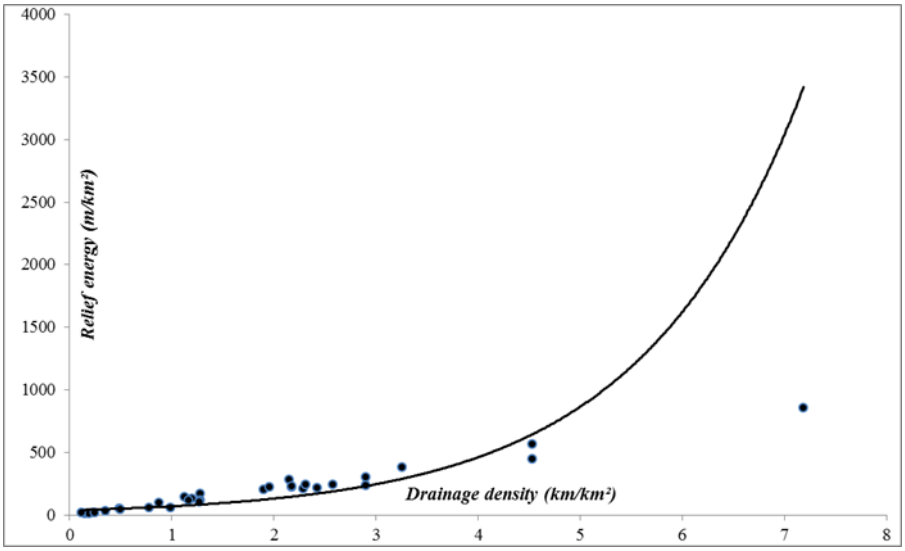


Figure 6. "Bârsa Country" – The representation of exponential regression model equation

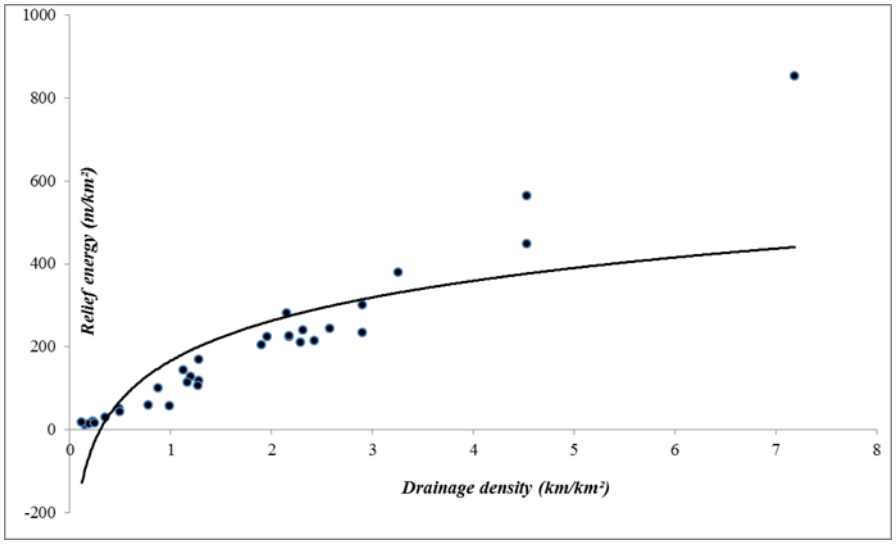


Figure 7. "Bârsa Country" - The representation of logarithmic regression model equation

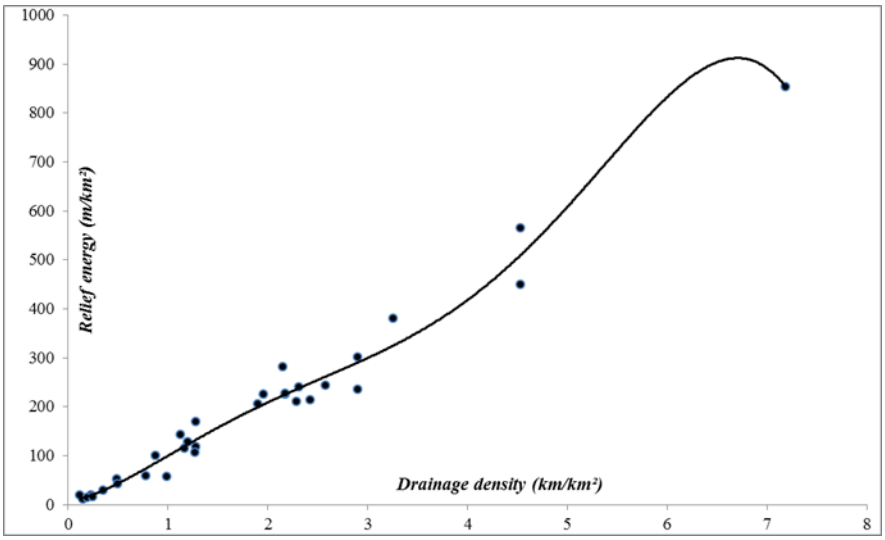


Figure 8. "Bârsa Country" – The representation of regression equation as a polynomial of the 5th degree

Thus, high relief energy values, of more than 500m/ km^2, correspond to high drainage density, of above 7km/ km^2, such as in Piatra Craiului, Bucegi, Postăvaru and Piatra Mare Massifs. Low drainage density values, of below 1km/km^2, such as in the Bârsa or Prejmer depressionary plains, correspond to low relief energy values, of below 50 km/ km^2. However we can observe that for average drainage density values of 3-5 km/km^2, such as in Bran-Fundata Corridor, Lempeș Peak, the Perșani Mountains, the Baraolt Mountains, Clăbucetele Întorsurii or Clăbucetele Predealului, the relief energy values range between 50 – 150 m/km^2 and 150 – 300 m/km^2, this aspect being remarked in the graphical representation too, as the points are arranged on both sides of the regression line, at slightly longer distances than the rest.

In areas with high drainage density and relief energy (Bucegi, Piatra Craiului Mts), the hydrographical network eroded and fragmented the adjacent piedmontan areas, unlike the well-preserved cones of dejections in Săcele Piedmont, situated at the foot of the Clăbucetele Intorsurii Mts., where the two indicators have moderate values.

Even if the graphical representation already offers us the perspective of some conclusions, we will also calculate the value of the correlation coefficient between the drainage density and the energy relief, using the formula as shown below:

$$\boldsymbol{r} = \frac{32 \times 19340{,}61 - 57{,}55 \times 6058}{\sqrt{32 \times 177{,}0453 - 3312{,}003} \times \sqrt{32 \times 2147030 - 36699364}} = \mathbf{0{,}984}$$

Comparing the obtained value to the one from critical value, 0,567 , corresponding to at least 30 value pairs taken into account [11][17][21], we observe that it is far superior, our result being close to 1.

4. CONCLUSIONS

Consequently, the analysis of the graphical representation and the correlation coefficient value leads to the conclusion that there is a close dependence relationship between the relief energy and the drainage density, the correlation being linearly positive and directly proportional.

The relief energy is determined almost entirely by the drainage density. The paleographic evolution of the area and the role of orographic barrier of the Curvature Carphatians in front of the oceanic air masses determine the correlation value. The accuracy of the result might slightly vary if we raised the number of pairs taken into account. Regional variations could exist between the hydrographical basins of the study area.

Although works designed to reduce flood risk, resulting in earth dams, were particularly concentrated in the floodplain of the Olt river, the climate paroxysms sometimes turn into real hydrological hazards for the towns and infrastructure of surrounding areas.

The rich hydrographical network situated in the south of the study area requires the resizing of the improvements in the floodplains with flooding risk in the depressionary area, especially on the following rivers: Olt, Ghimbăşel, Timiş, Bârsa. The dammed areas need resizing, bringing the existing dams to the current rate of danger by uplifting them in most sectors, building new dams in the sectors where they are missing.

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