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THE POTENTIAL OF SURFACE RUNOFF MANIFESTATION OBTAINED ON THE BASIS OF THE DIGITAL ELEVATION MODEL. CASE STUDY: THE SUBCARPATHIAN SECTOR OF BUZĂU CATCHMENT AREA

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ABSTRACT. The Potential of Surface Runoff Manifestation Obtained on the Basis of the Digital Elevation Model. Case study: the Subcarpathian Sector of Buzău Catchment Area. The analyzed sector of Buzău catchment area is situated in the Curvature Subcarpathians, recognized as one of the areas in Romania with the highest values of potential surface runoff. The digital elevation model is one of the most important environmental variables used in the analysis of surface runoff. Thus, the present study tries to quantify the manifestation potential of surface runoff exclusively on the basis of the digital elevation model, determining seven morphometric and hydrographic indicators derived from it. Under these circumstances, the present work represents a preliminary analysis of the potential of surface runoff of the analyzed area. The final susceptibility of surface runoff depends on other important factors such as lithology, soil texture and land cover. According to the spatialisation of the Surface Runoff Index, obtained by superimposing the seven factors derived from the digital elevation model, areas within the basin with high susceptibility of surface runoff were delineated. They represent the genetic premises of risk hydrological phenomena such as flash-floods.

Keywords**:** digital elevation model, surface runoff, Buzău catchment area.

1 INTRODUCTION

Knowing the pattern of surface runoff is essential because it represents the genetic premises of risk hydrological phenomena such as flash-floods, events ranked in the category of natural hazards with the highest degree of danger. Globally, it is estimated that flash-floods, the final product of surface runoff, represent one of the most important natural hazards with extremely adverse consequences on the socio-economic elements (Lumbrosso & Gaume, 2012).

In the global context, the extreme events of surface runoff are caused mainly by the global climate change context with negative implications on rainfall conditions (IPCC, 2007), and on changes in the land use (Marchi *et al.*, 2010). Regional and local surface runoff depends on both climate peculiarities, but especially on the characteristics of the geographical area (geological, morphometric and hydrographic peculiarities of the landforms, land cover, etc).

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Although there are several scientific methodologies for estimating the pattern of surface runoff and thus the assessment of flash-flood risk, their rigorous forecasting is one of the most difficult tasks in operational hydrology (Javelle *et al.*, 2010). This is due to the large number of environmental variables needed to be taken into account both in terms of static and dynamic point of view. Most methodologies are based on the analysis of two fundamental components responsible for the surface runoff: precipitation and geographical bedrock with its peculiarities mentioned above.

One of the fundamental components of geographical bedrock with a major role in shaping the surface runoff on slopes is the digital elevation model (Matei, 2012). This paper aims to analyze in terms of static the potential of surface runoff in the analyzed Subcarpathian area, taking into account the most important geographical factors, derived solely from the digital elevation model.

2 GEOGRAPHICAL FEATURES IN TERMS OF DIGITAL ELEVATION MODEL AND THE IMPACT ON THE REGIME OF SURFACE RUNOFF

The Subcarpathian sector of Buzău catchment area is located in the central South-Eastern Romania, and is spread out entirely over the Curvature Subcarpathian unit (Fig. 1). It has an area of about 1600 km^2, representing a third of the entire drainage basin of Buzău River whose area amounts to approximately 5000 km^2. The entire catchment area of Buzău forms an integral part of Siret catchment area, as it is a first order tributary. Altitudes of the study area range from 114 m, recorded at the entrance to the plain of Buzău River, and 950 m in the North-East, in Bisoca Hills.

Terrain slope, a very important indicator in defining the potential of water drainage on slopes, falls between 0.06° and 29.7°, while its average value is 8.9°. The highest values are recorded generally at the contact with the mountains while low values are registered in Cislău, Pătârlagele, and Pârscov basins. Slopes over 15° are most favorable for surface runoff (Bilașco, 2008) and they cover about 11% of the study area.

In addition to slope gradient, an essential role in surface runoff analysis is played by LS factor ratio, an indicator that quantifies the relationship between slope and slope length. If the two sides have the same slope but different lengths, their behavior will be different in hydrological modeling processes (Constantinescu, 2006). The surface runoff has higher values as the LS factor ratio value is higher. Study area index values range from 0 in meadow areas and depressions and reach values of over 6 on slopes of the main hilly units.

Also, areas characterized by surface runoff are outstanding and with profile curvature values. Convex areas with surface runoff represent 42% of the total, while the 55% of surface leakage occurs less accelerated. The remaining 3% of the areas of study are the stable areas.

Also, high values of drainage density (over 4 km/km^2) recorded along the main valleys of the study area, Buzău, Slănic, Sărățel, near their confluence with tributaries, represent an important factor in delineating areas with high susceptibility in the occurrence of hydrological risks. A dense hydrographical network makes high water and flash-floods regime to become a torrential type (Bilașco, 2008).Besides drainage density, an important role in the manifestation of surface flow has the convergence of the drainage network, which has higher values in the northern half of the catchment area.

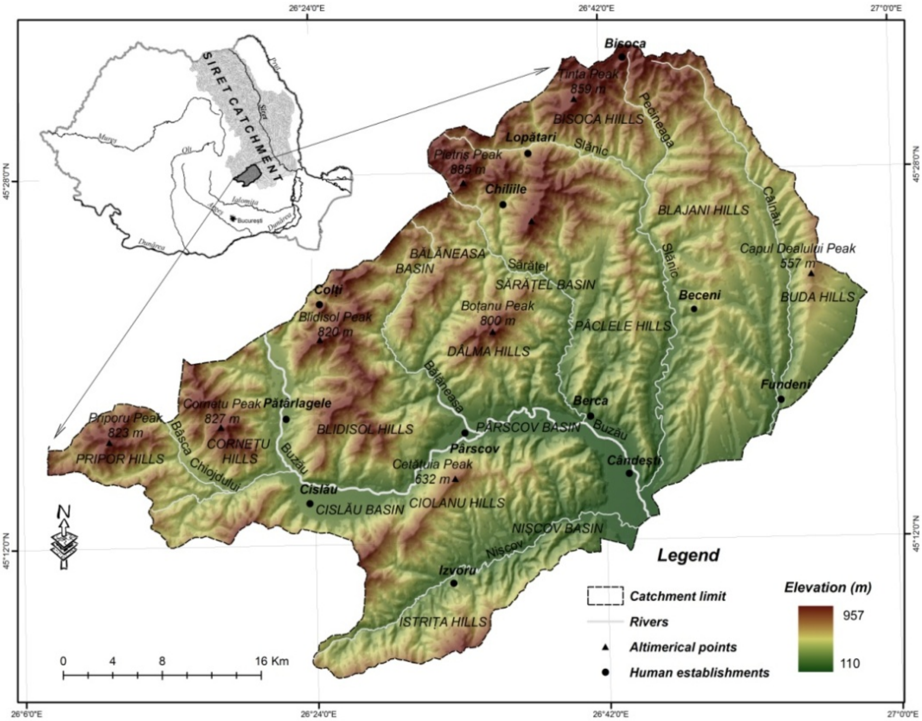

Fig. 1. Location of the Subcarpathian sector of Buzău catchment area in Romania

Slope aspect is an important factor with direct influences on the flow regime. Generally, slopes with southern exposure are favorable for increasing upward thermal convection and therefore to the formation of torrential rains especially in summer afternoons (Roșu, 1980). In the Subcarpathian sector of Buzău catchment area, over 40% of the slopes have a general southern aspect. The shape of secondary basins has also vital significance in defining the time of water concentration in the mainstem. Thereby, the more circular the shape of the basins, the lower the time of water concentration (Pișota *et al.*, 2010). The highest values of the circularity index are found in the secondary drainage basins of Valea Boului, Olari, Comisoaia, Pecineaga Murătoare.

3 METHODOLOGY

To highlight the surface runoff exposed areas in the Subcarpathian sector of Buzău catchment area in terms of the digital elevation model, the Surface Runoff Index was defined and spatialized. It was obtained in GIS by summing up seven indicators derived from the digital elevation model, playing an essential role in defining the manifestation potential of surface runoff: slope of the land, LS factor, profile curvature, slope aspect, drainage density, convergence index and the shape of secondary drainage basins (fig. 2).

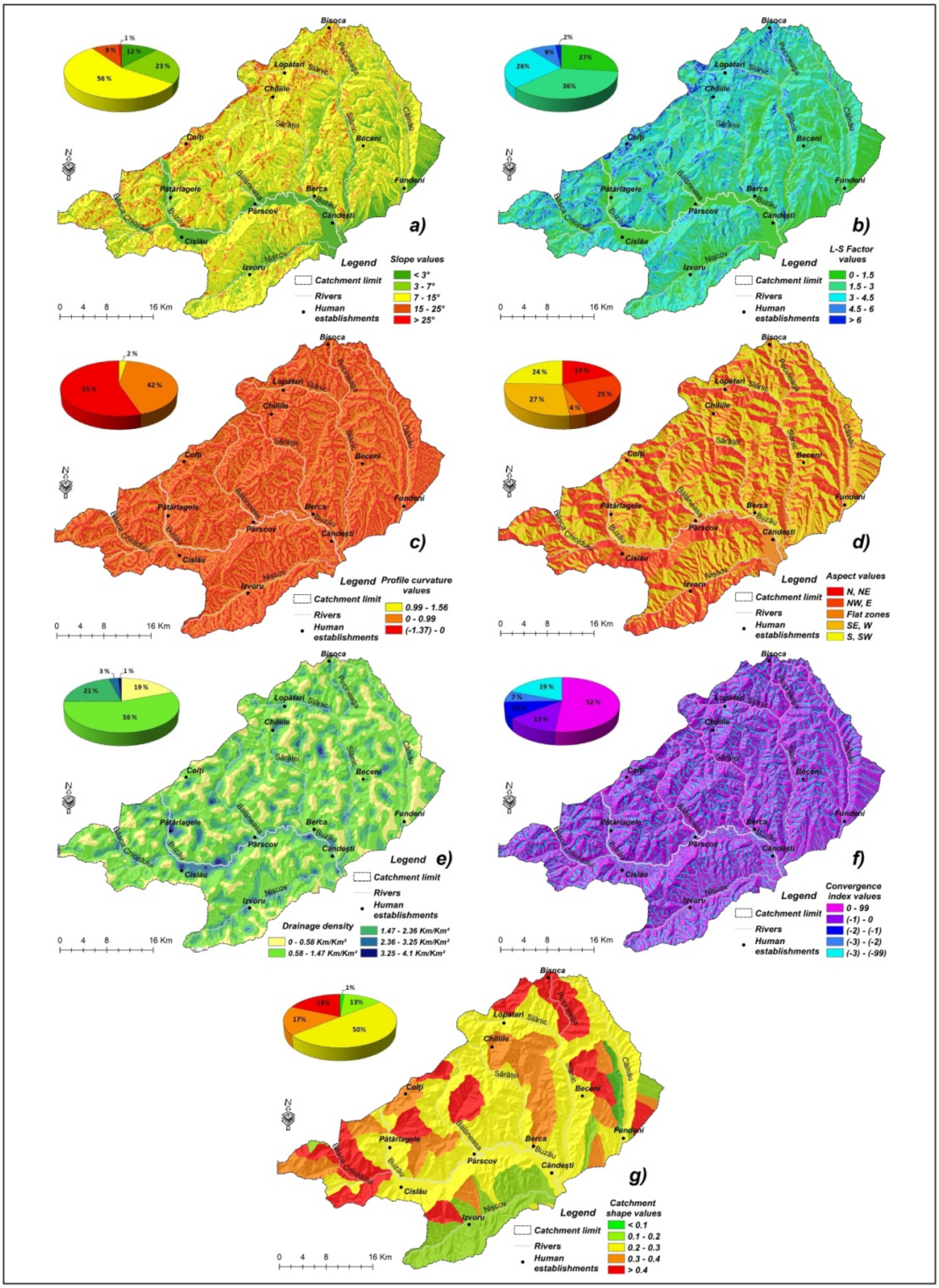

Fig. 2. Spatial representation of slope values (a), LS Factor index (b), profile curvature (c), slope aspect (d), drainage density values (e), convergence index (f) and catchment area shape index (g)

Because their influence on the flow process is different, each indicator was given a different weight in the final index delineation. Thus, factors such as terrain slope or profile curvature have been assigned greater importance than the shape of secondary drainage basins or slope aspect, influencing less the surface runoff.

In the early stage, to obtain the digital elevation model, the 1:25000 topographical map was used as cartographic support from which contour lines were extracted. The geo referencing of the topographical maps corresponding to the study area was made using the Global Mapper 13 software with the Romanian specific projection system, Stereo 70.

The digital elevation model was obtained using ArcGIS 9.3 software and contour lines were interpolated to a cell size of 20 m, recommended for hydrological studies (Bilașco, 2008). Indicators such as slope, profile curvature, slope aspect and secondary basins were derived using specific extension tools from ArcGIS 9.3.

The catchment area shape factor was based on F/L^2 formula, where F-basin area is given in km^2, while the L-basin length in km. The more the shape factor has values close to 1, the more circular is the basin, so that surface runoff will occur more intensely (Pișota *et al.*, 2010).

The assessment of drainage density was based on the determination of the hydrographic network in the form of raster based on digital elevation model using Flow Accumulation tool from ArcGIS 9.3. Next we calculated the sum of the lengths of river sectors on a unit of one km^2, this operation being performed by means of Statistics Block tool from ArcGIS 9.3. The other two indicators derived from digital elevation model, LS Factor and Convergence Index of hydrographic network were obtained using SAGA GIS 2.0.8 software. The determinant of relationship between slope gradient and length is based on the formula: $LS = (m+1)*(As/22, 13)^m (\sin\beta / 0.0896)^n$, where m = 0.4 and n = 1.3 (Moore *et al.*, 1993). Values close to 0 indicate a low slope combined with a small length of the slope, while high values express a high slope combined with a large length of the slope, which increases water flow rate (Constantinescu, 2006).

After obtaining the seven indicators, they were reclassified into five classes of values depending on how their characteristics affect water drainage on slopes (table 1).

Table 1

Classification and indexing of environmental factors to obtain the final Surface Runoff Index

Environmental parameters /Percent of total final index	Type/values				
Slope (°) - 25%	0 - 3	3 - 7	7 - 15	15 - 25	> 25
L-S Factor - 15%	0 - 1.5	1.5 - 3	3 - 4.5	4.5– 6	> 6
Profil curvature (radiani/m) - 25%			0.99 - 1.51	0 - 0.99	(-1.8) - 0
Slope aspect - 5%	N. NE	NW. E	Flat Zones	SE.W	S. SW
Drainage density (km/km²) - 10%	0 - 0.86	0.86 - 1.69	1.69 - 2.51	2.51 - 3.34	3.34 - 4.17
Convergence index - 10%	> 0	0 - (-1)	(-1) - (-2)	(-2) – (-3)	(-3)- (-100)
Catchment shape index - 10%	0.09	0.18 – 0.19	0.21 – 0.3	0.31 – 0.38	0.42 – 0.67
Score given	1	2	3	4	5
Surface Runoff Index (class)	Very low 17.5- 20.8	Low 20.8 - 28.4	Medium 28.4 - 32.2	High 32.2- 36	Very high 36 - 45

The granting of different weights to analyzed factors (table 1) according to their importance on surface runoff and their overlapping in GIS environment is the last step in the determination of the Surface Runoff Index proposed in this paper.

4 RESULTS AND DISCUSSIONS

The spatialisation of the Surface Runoff Index in the Subcarpathian sector of Buzău catchment area was obtained by overlapping the analyzed factors. Its values, ranging between 17.5 and 45, have been grouped into five classes according to the standard deviation: very low 17.5 - 20.8, low 20.8 - 28.4, medium 28.4 - 32.2, high 32.2 – 36 and very high 36 - 45 (fig. 3).

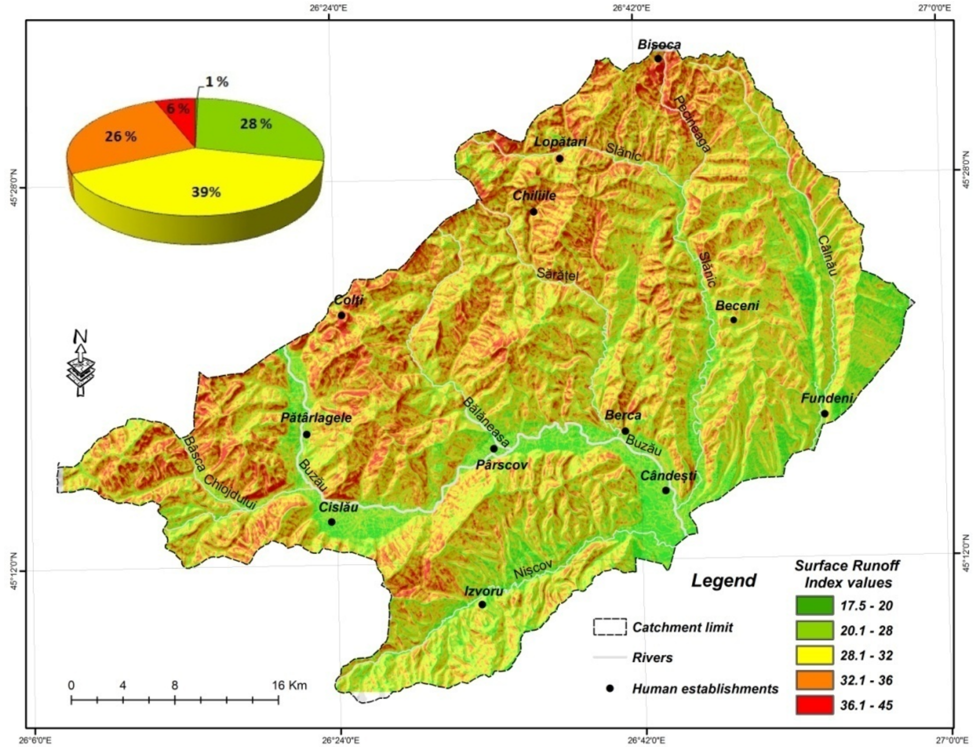

Fig. 3. Spatial representation of Surface Runoff Index values in Buzău catchment area

The Subcarpathian sector of Buzău catchment area has high and very high values of Surface Runoff Index, over 32.2 on approximately 32% (approximately 500 km^2) of its total area. These occur especially in areas of steep slope, over 15°, where convergence of torrential organisms is higher, in convex areas of the landscape, generally slopes with southern exposure. Most such areas occur in hilly units (Bisoca Hills, Corneţu Hills, Pripor Hills, Dâlma hills and Bocu Hills) near the mountains, especially at the contact with them. These areas, where there is no forest vegetation cover, are exposed to the occurrence of hydrological risk phenomena such as flash-floods and others caused by surface runoff like intense erosion of soil and landslides.

The largest share in the study area corresponds to average values (28.4 - 32.2) of the Surface Runoff Index, which is present in 39% of the area. These values are characteristic for the slopes with an average gradient between 7° and 15° situated generally in hilly outer units.

Areas with low and very low values of Surface Runoff Index appear on 29% of the Subcarpathian sector of Buzău catchment area. Generally, low manifestation potential of surface runoff occurs on lands with a slope below 3°, depressions located in basins with an elongated shape. These correspond to Cislău, Pătârlagele, Nișcov and Pârscov basins.

An analysis of Surface Runoff Index values on the drainage basins of the tributaries of Buzău River in the Subcarpathian sector, clearly highlights that basins with a shape index close to 1, placed near the Curvature Carpathians, are the most exposed to high manifestation potential of surface runoff. Weights close to 60% of high and very high values of Surface Runoff Index occur in the basins of Sibiciu, Plăvăț, Pănătau, Rușăvăț and Jghiab rivers (fig. 4). Generally, these basins cover a small area. High values of the weights of the two critical classes of over 40% occur in basins like Bălăneasa, Bâsca Chiojdului and Sărățel (fig. 4).

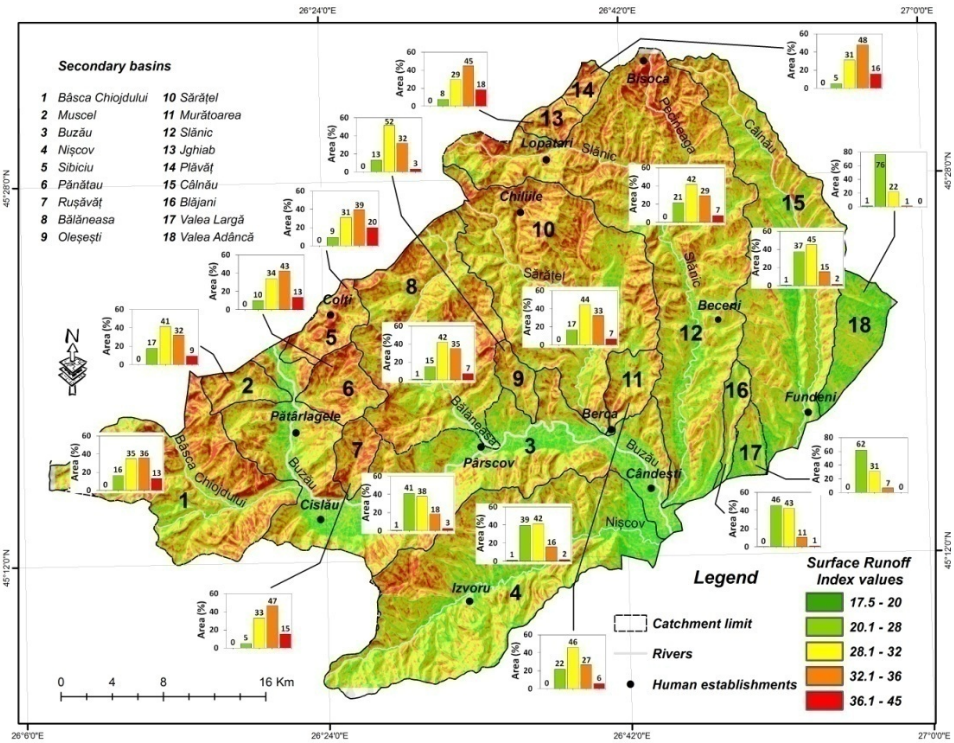

Fig. 4. Spatial representation of Surface Runoff Index values in the secondary drainage basins of Buzău catchment area

The Slănic drainage basin presents overall weights of 36% of high and very high values of the potential of surface runoff. This lower weight than the ones above mentioned is due to the more extensive area of Slănic basin, but most of the upper sector shows very high values of the Surface Runoff Index, particularly in Pecineaga tributary basin. For this reason, flash-floods may form especially in the northern part of the basin. From there, they spread to the lower sector generating floods.

The less exposed basins to surface runoff, in terms of indicators derived from the digital elevation model, are those with an elongated shape, generally at the contact with the plain, such as Nișcov, Blăjani, Valea Largă, Valea Adâncă and Valea Buzăului.

However, it should be noted that this assessment of surface runoff values is relative to the Buzău catchment area as a whole and to the delineated secondary basins. Generally, besides the digital elevation model, the potential of surface runoff depends on other important factors such as lithology, soil texture and land cover so that the final results depend to a large extent on these factors.

5 CONCLUSIONS

The analysis of the digital elevation model, using indicators derived from it, is one of the major components necessary in evaluating the potential of the surface runoff. Because it is an environmental component that is constant over time, unlike the climatic factor which is characterized by high dynamics, the digital elevation model is very useful in analyzing the potential of the surface runoff from a static point of view.

In these conditions, the digital elevation model can provide important information in the case of modification of relatively unchanging environmental components like land cover data. In other words, if Surface Runoff Index shows high values especially in secondary basins of the northern half of Buzău catchment area, it is imperative to maintain there a high weight of forests. In the opposite event, continued deforestation (specific to this Carpathian area in the last century) will be in the future an important cause in surface flow acceleration and in increased frequency of flash-floods, the worst affected areas being mostly those defined on the basis of the digital elevation model.

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