RISCURI ŞI CATASTROFE, NR. X, VOL. 9, NR. 1/2011

CĂLIMANI MOUNTAIN'S MONTHLY AVERAGE RUNOFF CHARACTERISTICS AND THE PROBABILITY OF ITS OCCURRENCE

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ABSTRACT. Călimani Mountain's monthly average runoff characteristics and the probability of its occurrence. The Călimani Mountains represent the north-western part of the Oriental Carpathians central group, they are the most extended volcanic massive from our country. The river discharge is measured at five hydrometric stations which are distributed relative evenly around the mountains. The runoff characterization was made using the average monthly discharge values from the following stations: Toplița, Răstolița, Jelna, Mița and Gura Negrii . The used discharge data series include years between 1991 and 2006. The analysis of the runoff regimes shows that there are differences according to the topoclimatical conditions, the rivers alimentations types and the river catchments position towards the mountain. These differences refer to the extremes discharge mount and to the flow hydrographs shape. The most significant differences are between the western and northern part of the Călimani Mountains. The probability curves homogeneity makes possible the evaluation of the hazards regarding the occurrence of multiannual monthly discharge values. Hydrometric stations comparison shows that the average multiannual minim discharges hazard is higher in the eastern catchments of the mountain like in the western. Similar trends exist regarding the occurrence of the highest average multiannual discharge.

Key words: factors, river runoff, monthly average discharge, probability curve, hazard.

1. Introduction

The Neogene intense volcanic activity led to the apparition of vast lava accumulations inside the Carpathian arch, developed on 450 km length from which 375 km are on Romania's territory (Naum, Butnaru, 1989). The Călimani Mountains together with the Gurghiu and Harghita Mountains form the southern group of the youngest mountains from our country; their craters have between 1.8 and 5 million years. The Călimani Mountains represent the north-western part of the Oriental Carpathians central group, they are the most extended volcanic

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massive from our country, developed on a west - east direction. In the north they are bound by the Dornelor Depression and the small mountains of Bârgău; in the east the depression string of Păltiniş, Drăgoiasa, Bilbor and Secu separates them from the cristaline Bistrița and Giurgeului Mountains, in the south the Mureş Gorge represents the limit towards the volcanic Gurghiu Mountains and in the west they are bound by the hills of the Călimani piedmont which represents the transition towards the Transylvanian Plateau's eastern part. The massive, compact volcanic characteristics left its mark on the features of the river system, so the rivers flow in fan like patterns in all directions.

2. Genetic factors of the runoff

2.1. Climate

The geographic location and the topography are the main elements that influence directly the climate. Because of the high altitudes and the massive relief, from the different types of continental temperate climate here the dominant is represented by the high mountain areas climate. So, the main characteristics are the harsh and humid climate.The physico-geographical characteristics and the complex structure of the active subjacent surface prints a series of local particularities and differentiations in the climate which together define a multitude of complex and simple topoclimates. And these in turn influence the river runoff characteristics.

The baric depression systems movement across the country from the west determines the increased front activity on the western slopes of the Oriental Carpathian's and also the Călimani Mountains. This leads to a significant growth in the cloud and precipitation values, together with the altitude. On the slopes oriented to the east, which are sheltered, the descending air masses result in increased duration of bright sunshine and lower air humidity, so cloudiness is low and precipitation is reduced significantly. The southern slopes, exposed to solar radiation, receive on their upper parts, smaller amounts of precipitation (1200 mm) than on the northern slopes which are more cloudy and humid (rainfall over 1300 mm).The average annual temperature in most high areas is below zero degrees Celsius. Above 2000 m the lowest annual average temperature is recorded in February and highest in August. From October there are often recorded frost days, which are maintained until early May. In January the number of days with frost reaches 25. In the deep valleys and within the crater frost is possible even during the summer months. Absolute maximum temperature reached 28 ° C, while the minimum dropped to -24.5 °C. These temperature variations influence significantly the rivers discharge characteristics, primarily in winter but also the spring high water formations.

2.2. Relief

The Călimani Mountains have approximately the shape of a rectangle with a length of 60 km and average width of over 30 km, representing an area of about 2.000 km^2.

The landscape is characterized by two relatively distinct units: the central axial area, consisting of andesite, and the sedimentary-volcanic area surrounding the central area looking like a plateau. Over the 1200 m altitude the topography is highly jagged, is shaped by sub-aerial agents and bounded by steep slopes. Here stands the huge crater its northern part has been impaired by the regressive erosion of rivers, from here springs the Neagra Şarului River. With a 300-400 m step below the plateaus are formed by volcanic and pyroclastic conglomerates with predominantly structural features.The mountain is attacked from all sides by rivers; their source is situated at elevations sometimes exceeding 1500 m. The valleys were formed in volcanic sedimentary rocks.The compact nature of the massif and the high altitudes of the discharge formation have put their mark on the river runoff regime laws. Being a major obstacle in the movement of the air masses, the slopes with different orientation produce distinct river runoffs.

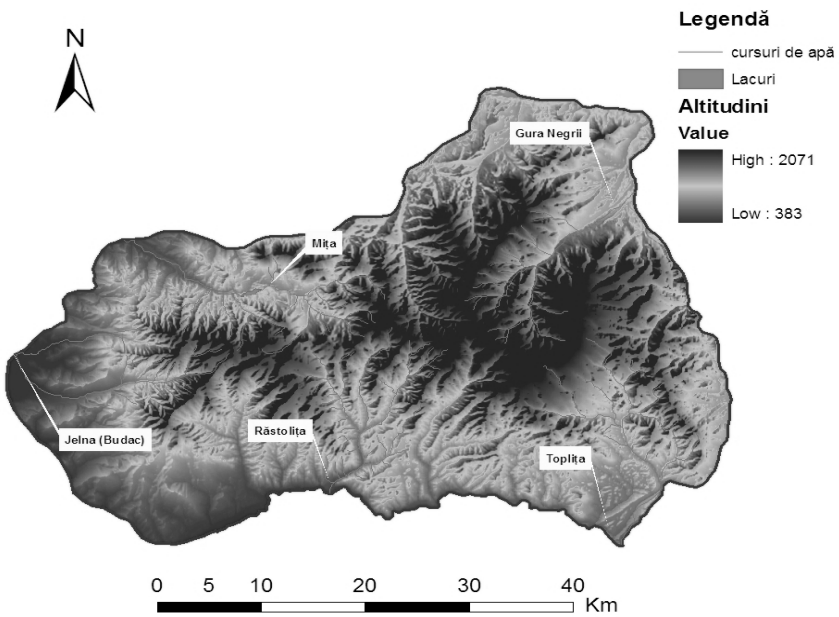

Figure 1. Călimani Mountains hypsometrical map

2.3. Hydrography

The Călimani Mountains represent an important area regarding the formation of water resources, the radial hydrographic system supplies water to three important river catchments of Romania: Someş, Mureş and Siret.

In the south the rivers are direct tributaries of the Mureş. The most important, from the west to the east, are Bistra with Stega and Donca, Răstolița with Tih and Brad, Ilva with Ilişoara, Toplița with Voivodeasa and Pârâul Sec. They are flowing in to the collector in the area of the Mureş Gorges.

Under the Moldovanca and Țiganca peaks is the spring of Răstolița. Its catchment area has 172 km^2. In its 19 km it collects the waters of streams with narrow valleys, bordered by steep slopes, and gorge aspect, where the waters intersect the stacks of volcanic conglomerates.

In the south-eastern part of the mountain springs the Toplița River, together with its tributaries, drains an area of 212 km^2. Springs under the peaks Retitiş and Bradul Ciont, reaching the Mureş River after 28 km. In the upper catchments the tributaries flow in narrow valleys, which widen in the middle and lower sectors. The lower sector of the Toplița River forms the homonym micro-depression.

The Şieu River gathers up its streams from the western slopes of the mountains. Springs under the Duca peak and its most important tributaries in the region are Budac and Budăcel, whose source is below the peaks of Poiana Cireşi respectively Vulturu. Budacu's catchment area is 234 km^2 and has a length of 38 km. North of Beclean City the Şieu flows into the Someşul Mare River.

On the north-western slopes springs the Bistrița, which in the upper sector has the name of Colibița, being the most important tributary of Bistița. The three significant tributaries spring out in a string between the Moldovanca and Bistriciorul peaks. Further down the Bistrița valley separates the Călimani and Bârgăului mountains. Its valley has alternating narrow sectors, with gorge aspect cut in the volcanic conglomerates and wider sector (Colibița Depression and the reservoir with the same name).

On the northern side of the Călimani Mountains from west to east string the following rivers, Dorna with Dornişoara, Negrişoara, Neagra Şarului with Tarnița, Retitiş and Pietricelul. The Neagra Şarului River gathers its waters from the north-eastern flank of the Călimani, inside the volcanic caldera, in which has deeply sawed in to. It springs under the Pietrosul Peak, from an altitude of 1700 m. It has a highly branched upper basin, with many tributaries whose waters tumble over rapids and sparkling waterfalls. The valleys are narrow and deep and are flanked by steep slopes. In its middle sector the river runs through the Şarului Depression and flows in to the Bistrița, a tributary of the Siret, in the Dorna Depression. Its catchment area is 311 km^2, and its course length is 33 km.

3. Database and work method

The river discharge was analyzed using five hydrometric stations situated in different parts of the radial hydrographic system, Toplița on Toplița River, Răstolița on Răstolița River, Jelna on Budac River, Mița on Bistrița and Gura Negrii on the Neagra Şarului River. The used discharge data series include the years between 1991 and 2006.

The stations are well distributed is space and control relatively small catchments with significant average height. The Călimani Mountains runoff characteristics can be evaluated based on these existing discharge data.

Table 1. Hydrometric stations morphometric characteristics

Hydrometric station	River	Area (km^2)	Hmed (m)
Toplița	Toplița	211	1200
Răstolița	Răstolița	158	1155
Jelna	Budac	157	781
Mița	Bistrița	84	1240
Gura Negrii	Neagra Şarului	308	1253

For each hydrometric station the 16 year data series allowed the creation of probability curves and the assessment of the discharge values with different occurrence probability. Comparing the results with the average monthly multiannual runoff values lead to assessment of hazard regarding these values occurrence.

4. River runoff regime

Comparing the multiannual monthly discharge, on the five rivers, show that there are significant differences in the characteristics of the runoff in different parts of Călimani Mountains. Despite the fact that rivers flow from the same mountain area and the river basins have similar characteristics regarding the area and the altitude, the five rivers runoff is different. The most obvious differences were observed by comparing the rivers in the north with those in the south and those in the east with the rivers situated in the west.

So, we compared between the runoff characteristics at Jelna hydrometric station located in the west with the Toplița stations in south-east and Gura Negrii in the north-east. At Jelna station the highest discharge values are recorded in April, significantly higher than in the adjacent months (5.04 m^3/s, respectively 3.01 and 3.17 m^3/s) due to the high rainfall that overlap the early melting under the direct influence of the western circulation. At Toplița April's values (6.82 m^3/s) are close

to that of May (5.38 m^3/s) and at Gura Negrii the values of April are set slightly lower than in May (7.21 m^3/s to of 7.70 m^3/s). In these catchments the snowmelt occurs latter due to persistent east European anticyclone.

The winter months presents an interesting difference between the west and the northeast and southeast. The lowest values are recorded in late summer and autumn (1.2-1.5 m^3/s) in the west, as a result of milder winters, when the discharge values are greater than 1.5 m^3/s. Colder winters in the east generate annual minimum runoffs during the cold season (between 1 and 2 m^3/s), in the summer-autumn period the values are between 2-4 m^3/s. Differences can be observed even during the winter months. On the Budac River the discharge values are higher in February but on the Neagra Şarului and Toplița Rivers they are recorded in January.

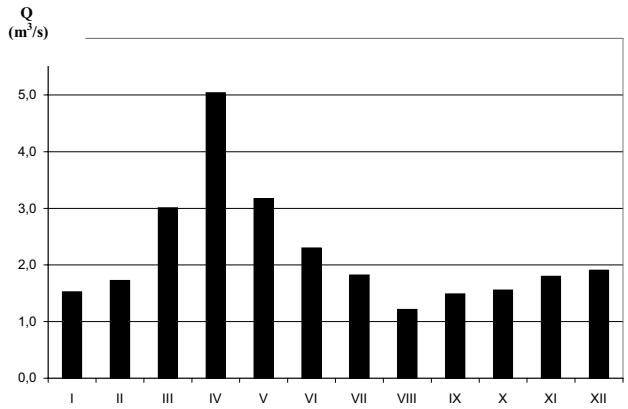

Figure 2. Jelna hydrometric station average monthly discharge values.

These characteristics conferee differences in the average monthly multiannual discharge hydrographs shape. If on the rivers in the eastern part of the mountain there is a continuous decrease in the discharge values from the high spring waters to the summer minimum, in the west in the summer appears an inflection in the evolution of the values. Also, the differences between the winter minima and the spring maxima are more pronounced in the east (6.40 m^3/s at Gura Negrii and 5.82 m^3/s at Toplița) than in the west (3.52 m^3/s at Jelna).

The monthly specific discharge also presents different characteristics. It is richer in the western catchments than in those with eastern orientation. This observation is valid both at maximum (44.6 $l/s.km^2$ at Mița, 43.7 $l/s.km^2$ at Răstolița, and only 32.3 $l/s.km^2$ at Toplița and 24.6 $l/s.km^2$ at Gura Negrii) and minimum values (8.1 $l/s.km^2$ at Mița, 11.3 $l/s.km^2$ at Răstolița, and 4.9 $l/s.km^2$ at Toplița, 4.2 $l/s.km^2$ at Gura Negrii).

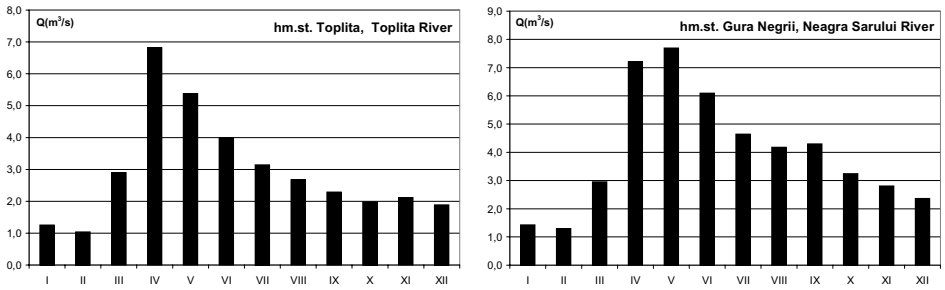

Fig.3. Toplița and Gura Negrii hydrometric stations average monthly discharge values.

The differences between the northern and southern part of the mountains are not so obvious because of smaller extension in this direction, however, some specific characteristics can be observed. At stations in the north- Mița and Gura Negrii – the April's and May's discharge values are closer (less than 1 m^3/s) than at the south stations Toplița and Răstolița (over 1-2 m^3/s). The ratio between multiannual monthly average maximum and minimum discharge is significantly higher at Mița (5.5) and Gura Negrii (5.9) located in the north than in Răstolița (3.8) in the south.

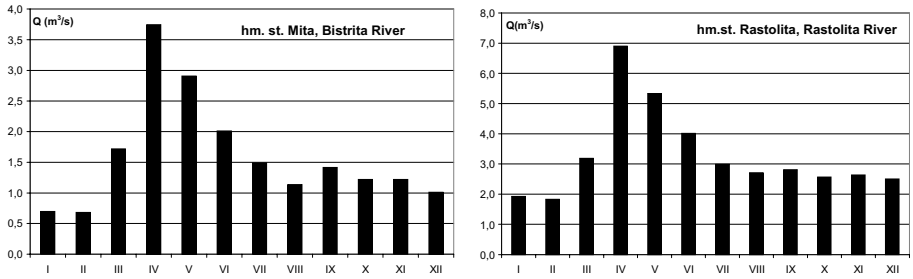

Figure 4. Mița and Răstolița hydrometric stations average monthly discharge values.

At the hydrometric stations in the south the variation of the hydrograph shape is more uniform than at the north stations. This shows a greater regularity of the climatic elements variation - temperature and rainfall - on the southern slopes than those exposed to the north, which are strongly influenced by cyclonic activity.

5. Multiannual average monthly discharge probability of occurrence

With the average monthly discharge values, for the study period, empirical probability curves were plotted for each hydrometric station. According to the

instructions of N.I.H.W.M. (National Institute of Hydrology and Water Management), we used formula:

$$p = \frac{m - 0.3}{N + 0.4} * 100 \qquad (\%)$$

The number of 192 values in a station's data series allowed covering probabilities in the range of 0.36 and 99.6 %.Like all natural phenomena, the variation of river discharge is subject to laws regarding the probability of occurrence. In this context, the occurrence of some discharge value has a necessity character, and his appearance is bound. The element of chance in the occurrence of a discharge value is found due to the large number of variables and the sensitivity of the runoff evolution. Even if the river runoff regime implies the existence of well-defined regularities, the randomness also appears, due to disturbant factors. In this aspect the occurrence of a discharge value can be analyzed in terms of probability, which gives the probability the aspect of hazard.

Since the probability curves contain the same number of discharge values, their homogeneity is ensured. This allows the comparison of average multiannual monthly discharge at different hydrometrical stations. The analysis was performed by extracting the probability of maximum and minimum monthly average values occurrence from the five stations.

Table 2. Extreme discharge values and their corresponding occurrence probability

Hydrometric station	Average monthly maximum Q (m^3/s)	p (%)	Average monthly minimum Q (m^3/s)	p (%)
Toplița	6,82	6	1,04	85
Răstolița	6,90	9	1,83	72
Jelna	5,04	5	1,21	65
Mița	3,75	8	0,68	74
Gura Negrii	7,70	11	1,30	89

The rivers watershed orientation, towards the mountain massif, influences the monthly average extreme discharge values probability of occurrence. Clearer regularities can be observed in case of the minima. In the eastern part of the mountain, at Gura Negrii and Toplița stations, the probability of occurrence is higher (89 %, respectively 85 %) than in the western part (65 % at Jelna station). This means that the probability of winter minima occurring in the east is higher than the summer minima in the west. This distinction is also felt in comparing the stations in north-east and the south-east with those in the north-west and south-west. If the probabilities are over 85 % at Gura Negrii and Toplița, at Mița and Răstolița these values are below 74 %.Similar differences occur by comparing the results from

stations in the northern and southern part of the mountains. At Gura Negrii in the north-east the probability is 89%, and in south-east at Toplița 85 %. Similarly, in the north-west Mița has a probability of 74 %, and in the south-west Răstolița 72 %. Note that at all these stations the lowest monthly discharge values are recorded in winter, so the influence of orientation regarding the mountain is even more evident.

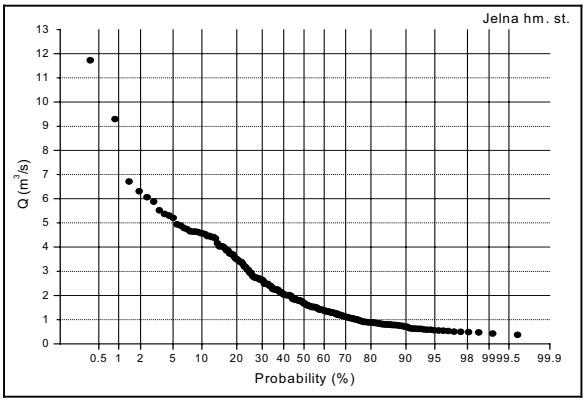

Figure 5. Jelna hydrometric station probability curve.

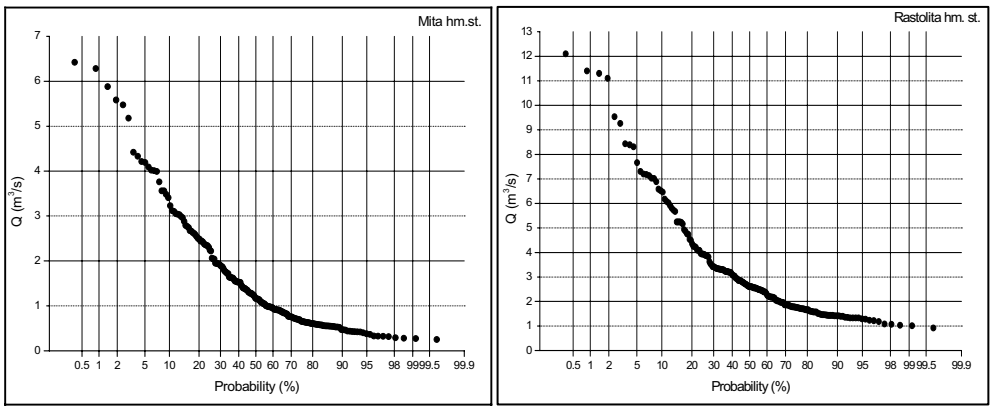

Figure 6. Mița and Răstolița hydrometric stations probability curves.

It can be concluded that on the rivers in the eastern and northern part of the Călimani Mountains the probability of minimum discharge occurrence is higher than in the western and southern catchments.In case of the maximum discharge we observe that the probability increases from west to east. Exception is the Toplița station, which has a low value, only 6 %. The extremes are found at Jelna 5 % and Gura Negrii 11 %. The intermediate stations, Mița in the north-west and Răstolița in the south-west, have values of 8 % and 9 %. Differences between north and south are

observed only at the hydrometrical stations on the eastern part of the mountains. So, at the Gura Negrii station the probability is 11 % versus Toplița with only 6 %.

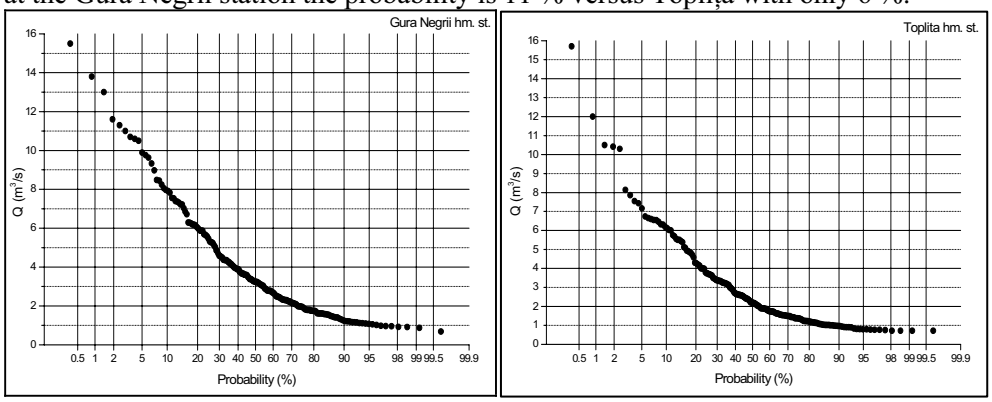

Figure 7. Gura Negrii and Toplița hydrometric stations probability curves.

6. Conclusions

From the analysis of the Călimani Mountains rivers runoff regimes variation we conclude that the topoclimatic conditions, determined by the massiveness and height of the mountains, are the most important genetic factors of the runoff. Significant differences are observed regarding the runoff between the eastern and western part of the massif. Also, there are differences between the runoff regimes characteristics in the north and south.

The probability curves analysis shows that the smallest average multiannual monthly discharge occurrence is higher on the eastern slopes of the mountain, than on the western. Similar regularities appear by following the occurrence of the highest multiannual average monthly discharge.

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