WATER BALANCE IN CĂLIMAN MOUNTAINS

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Abstract. Water balance in Căliman Mountains. The water balance from the largest and most expanded volcanic massif in Romania was calculated using the equation developed by M.I. Lvovici in 1974: Xo = Yo + Zo; Xo = So + Wo = So + (Uo + Z o). The assessment of the balance components was based on data from 12 hydrometric stations, four meteorological stations and eight pluviometric stations. The range of years for which the multilingual average values were calculated was 1961-2010. The correlations between the main balance components and the altitude of the relief allowed the identification of the areas where their spatial distribution has similar peculiarities. The spatial distribution of the main components of the water balance was made on altitude intervals and hydrographic basins. For each element of the balance sheet, maps have been prepared, which allowed valuation of the values corresponding to the main river basins in the studied region (Someş, Mureş and Siret).

Keywords: balance, balance elements, Căliman Mountains, ecuation, Someş, Mureş, Siret

1. INTRODUCTION

The Căliman Mountains occupy the north-western part of the Eastern Carpathians, representing the largest and most massive volcanic massive in Romania (2099 m in Pietrosul Călimanilor Peak).

The Căliman Mountains are bordered to the north by obvious depressions (Colibiţa and Dornelor), and to the eastern border with the Bistrița Mountains can be traced to the alignment of smaller depressions (Păltiniş, Dragoiasa, Glodu, Bilbor, Secu). In the south, the limit to the Gurghiu Mountains is clear, being given by the Mureş gorge between Toplita and Deda. In the west, the transition to the Transylvanian Depression is obvious and is done through a large piedmont step.

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Estimating water resources within an area is impossible without evaluating water balance components. Balance sheet is the main tool in the management, evaluation and improvement of forecasts, scenarios and future strategies on water resources.

In the structure of the water balance, precipitations (X) are consumed in the process of surface and underground flow (U) and evapotranspiration (Z). The water resources remaining in the receiving basins after the surface runoff is the wetting of the ground (W = U + Z). In turn, surface and underground flow forms the global runoff (Y = S + U).

2. METHODS AND DATA

The evaluation of the mean values of the water balance components was made on the basis of the differential equation elaborated by M. I. Lvovici (1974): Xo = Yo + Zo; Xo = So + Wo = So + (Uo + Z o) applied to data from measurements and determinations from 1961 to 2010 carried out in the meteorological and hydrological network of the Căliman Mountains and the adjacent region. Thus, to determine the mean runoff data from 12 hydrometric stations were used, and for the determination of average rainfall data from four meteorological stations and from eight pluviometric stations (Fig. 1).

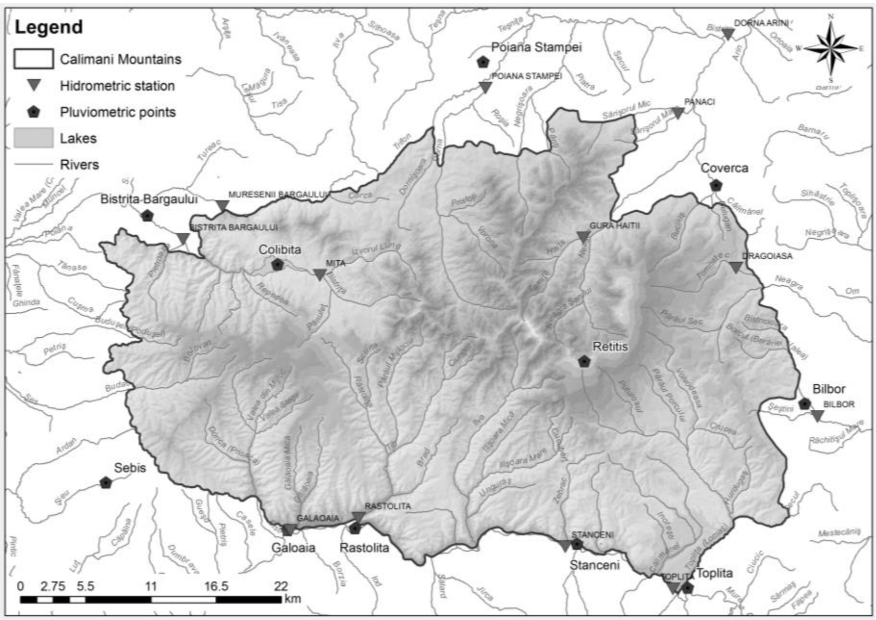

Fig. 1. Căliman Mountains hydrometric and pluviometric points

3. RESULTS AND DISCUTIONS

The correlations between the main elements of the water balance and the synthetic geographic factor (altitude of the relief) allowed us to highlight the peculiarities regarding the spatial distribution of the water balance components. The correlations between the average altitude of the receiving basins and the water balance components highlight the basic laws of water resources formation in the Căliman Mountains.

3.1. Spatial repartition of water balance components

Water balance components have an uneven distribution over time and space conditioned by the geographical particularities of the studied region.

The nuances that occur in the spatial distribution of rainfall and runoff are mainly due to the peculiarities of the air mass circulation and the morphometric (especially altitude) and morphological features of the relief. It concerns the advection of masses of wet air in the west in the areas exposed favourably to the direction of their movement, the catabatic movements felt on the eastern slope of the Căliman Mountains, respectively the increase of the altitude of the relief from the west to the east. Alternation of the mountain peaks with valley corridors and the presence of depression basins also have a role in the territorial nuance of the distribution of water balance components by amplifying or attenuating the intensity of pluviogenetic processes.

The high degree of afforestation of river basins results in slight nuances in the spatial distribution of water balance components, which could not be quantitatively assessed for lack of observations data. In such conditions, the main element that we relied on in the spatial analysis of the water balance components was the altitude of the relief.

Analysis of the spatial distribution of the main components of the water balance was made steps altitude areas both in the life of the elements of balance and relief altitude as the main basins.

Rainfalls average quantities repartition (Xo). The detailed analysis of the relations between the multiannual average rainfall and altitude quantities allowed highlighting some fairly obvious nuances in spatial distribution of annual precipitation amounts. These are conditioned by the particularities of the air mass circulation imposed by the position of the Căliman Mountains relative to the advection of the air masses in the western sector and the relief altitude.

The relationships between the multiannual rainfall and altitude quantities reveal several distinct connections (Fig. 2).
The three correlation obtained curves correspond to three areas, which are differentiated by the value of the pluviometric gradients (Fig. 2).

The 1st validity area includes the territories of the western Căliman Mountains, related to the hydrographic basins of Budac and Bistrița, which are exposed to the westerly mass air adventure. The pluviometric gradients in this area have the highest values, which explains the large amounts of precipitations falling within the basins of this area.

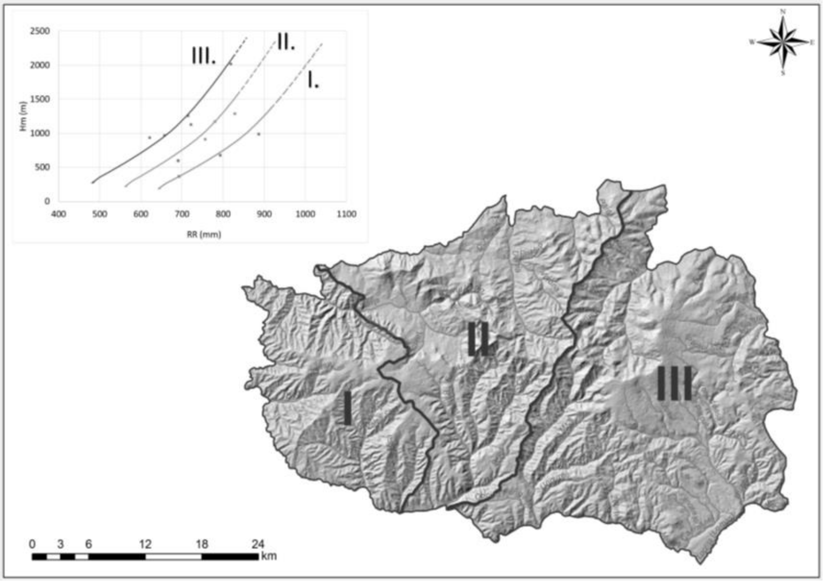

Fig. 2. X = f(Hm) relation and the areas of validity of relations X=f(Hm).

The second area of validity includes the western central part of the Căliman Mountains corresponding to the river basins of Bistriţa Ardeleana, Dorna and Rostoliţa. The values of the pluviometric gradients remain fairly elevated. In contrast, in the third area of validity, located in the eastern part of the Căliman Mountains, the values of the pluviometric gradients are the lowest due to the predominantly descending character of the air masses in this part of the studied region. This area corresponds to the hydrographical basins of some tributaries of Mureş r (Ilva, Călimanel, Toplita with Puturosul, Crucea and Hurdugaş) and of Bistrița Aurie rivers (Bistricioara with Borcut, Neagra with Tomnatec, Neagra with Haita)

The analysis of the distribution of the multi-year average quantities over the altitude ranges in the X = f (Hm) relations areas highlights the spatial differences imposed by the law of the altitude zone.

Depending on the exposure of the relief to the adhesion of the wet air masses, the increase of the altitude precipitation quantities occurs differentiated in the three areas of validity of relations X = f (Hm) (Table 1).

Table 1. Distribution of multiannual average quantities of precipitations in the areas of validity of relations X=f (H_m)

No-crt	Altitude	Area of validity		
		III	II	I
1.	492-500	500	620	740
2.	500-600	560	670.0	780.0
3.	600-700	600	705.0	820.0
4.	700-800	630	740.0	857.5
5.	800-900	668	770.0	887.5
6.	900-1000	693	795.0	912.5
7.	1000-1100	723	815.0	935.0
8.	1100-1200	748	835.0	952.5
9.	1200-1300	773	852.5	967.5
10.	1300-1400	790	867.5	980.0
11.	1400-1500	800	880.0	990.0
12.	1500-1600	810	890.0	995.0
13.	1600-1700	818	897.5	997.5
14.	1700-1800	823	902.5	1000.0
15.	1800-1900	825	907.5	1002.5
16.	1900-2000	825	910.0	1005.0
17.	2000-2100	833	930.0	1027.5

The differences between the rainfall quantites corresponding to the altitude intervals in the adjacent areas are kept between 100 and 150 mm, and in the distant areas they reach over 200 mm, which shows obvious contrasts in the distribution of precipitation quantities imposed by the pluviogenetic conditions specific to the analysed areas. The rainfalls repartition by altitudinal intervals in the X + f (Hm) relationship areas reveals the zonal character distribution of rainfall quantities, conditioned by the altitude and exposure of the relief to the mass of air masses in the western sector (Table 2)

Table 2. Multiannual average water volumes (mil. m^3) by altitude intervals from validity areas of the relations $X = f(H_m)$

Altit. intervals (m)	Areas of validity X=f(Hm)			Total	% from total volume
	I	II	III		
492-500	-	7081	-	7081	0.0
500-600	62799	172576	78675	314050	0.2
600-700	519612	411011	842941	1773564	1.4
700-800	1707137	1228525	2703944	5639605	4.4
800-900	3071541	2517061	4014132	9602734	7.4
900-1000	4460994	3975083	4909208	13345286	10.3
1000-1100	4752769	6325553	6677678	17756000	13.8
1100-1200	4222814	6994942	7922188	19139943	14.8
1200-1300	3806787	5970892	7062515	16840193	13.1
1300-1400	3404395	5283410	6633155	15320960	11.9
1400-1500	2579474	4256304	5012063	11847841	9.2
1500-1600	996027	3059363	3925469	7980859	6.2
1600-1700	-	1681797	2774021	4455819	3.5
1700-1800	-	950127	1915586	2865713	2.2
1800-1900	-	365493	1090357	1455850	1.1
1900-2000	-	28398	539205	567603	0.4
2000-2100	-	-	48373	48373	0.0
Total	29584348	43227615	56149510	128961474	100.0

The multi-year average rainfall distribution map based on the X = f (Hm) relationships highlights the altitude zone shown in Fig. 3).

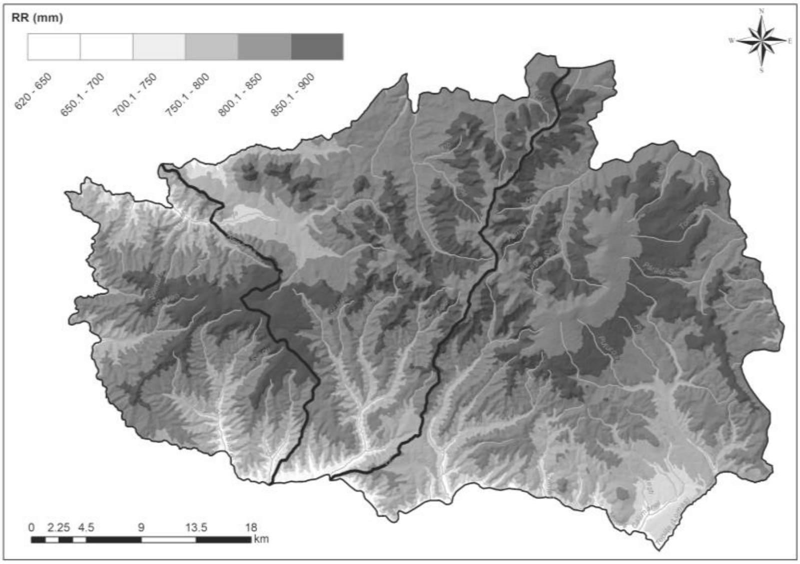

Fig. 3. Multiannual average rainfall map

Determining the surfaces of each altitude range, the average quantites of rainfall and the resulting volume of water (Table 2) could be assessed for each area of validity. Depending on the surface area and the amount of precipitation, each interval participates with a certain percentage on the volume of water flowing to an area (Table 2). Thus, the highest percentages range from 1100 to 1200 m (14.8%), followed by those between 1000 and 1100 m (13.8%). At lower altitudes (with intervals of 800m) and the over 1690m are formed less than 5% of the total rainfall water volume.

Analyzing the spatial distribution of precipitation at the level of the main hydrographic basins, there are remarkable differences. Thus, the largest amounts of precipitation were determined for the Siret basin and lower for the Mureş Basin (Table 3).

At the level of the researched region, the multiannual average water volume resulting from the liquid atmospheric precipitation was estimated at 128.9 billion m^3, corresponding to an average of 814.6 mm.

Compared to the average situation evaluated at the level of the researched region there are significant differentiations between established areas of validity due to the different weight of their surfaces and the pluviogenetic conditions (Table 3).

The spatial distribution of water volumes from precipitation is different, depending on the weight of the areas owned.

Table 3. Distribution of multiannual average rainfall (mm) over altitude intervals in main river basins

Altitude intervals (m)	Hydrographic basin			Average
	Someş	Mureş	Siret	
492-500	0	620	0	620.0
500-600	0	656.2	0	656.2
600-700	785.1	662.8	0	676.5
700-800	806.5	681.2	0	710.0
800-900	830.1	721.8	0	753.5
900-1000	859.2	753.5	733.9	786.0
1000-1100	876.2	781.0	772.2	803.9
1100-1200	893.1	807.7	783.7	817.6
1200-1300	914.8	839.6	799.6	838.6
1300-1400	930.4	859.2	815.2	853.0
1400-1500	944.4	871.2	828.2	864.3
1500-1600	931.8	861.7	841.4	859.6
1600-1700	897.5	831.0	850.2	846.0
1700-1800	902.5	838.9	849.6	847.4
1800-1900	907.5	841.8	841.6	844.3
1900-2000	910	827.3	825.5	828.9
2000-2100	0	832.5	832.5	832.5
Total	883.5	786.2	811.6	814.0

The distribution of global mean runoff (Yo) is determined by the oro-aero-dynamic conditions of rainfall and by the influence of some physico-geographic factors. Of these, the relief has its most substential influence on the distribution of the average runoff, determining the altitude marked in the two areas with different drainage gradients (Fig. 4)

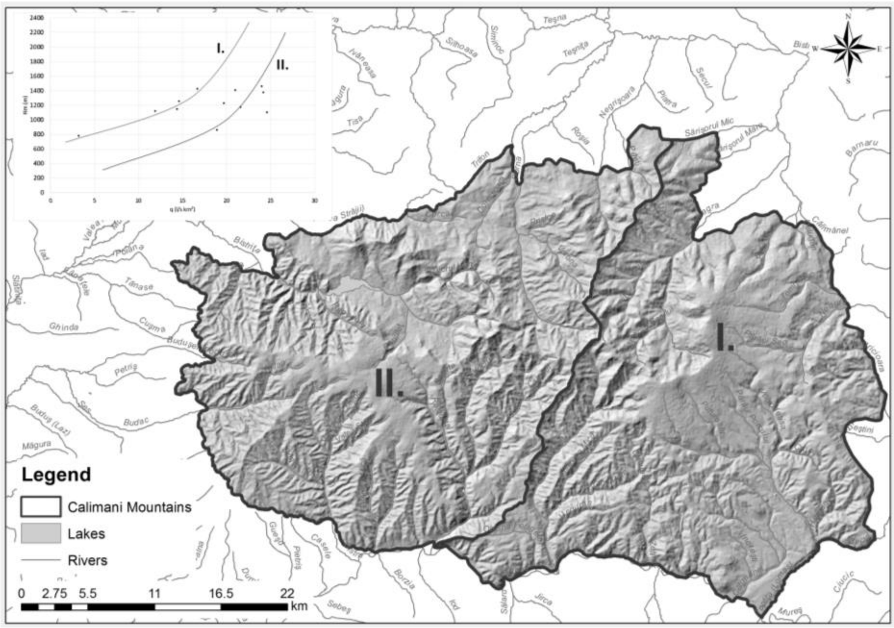

Fig. 4. Y = f(Hm) relation (a) and the validity areas (b).

From the analysis of the correlation curves, some peculiarities can be distinguished. The higher gradients of runoff occur in the western part of the Căliman Mountains, corresponding to the basins of the rivers Bistra Budacului and Bistriţa Ardeleana (Fig. 4), and the lowest in the eastern Căliman Mountains respectively - an area located at the shelter of the main summit of the Călimani Mountains, corresponding to the basins afferent to Mureş River (Topliţa) and Bistrița Aurie (Neagra, Bistricioara, Buciniş etc.). Thus, at low altitudes of 700-800 m the average water layer is 325 mm in the Someș basin, respectively 209 mm in the Mureş basin.

At higher altitudes, between 1200-1300 m, the average water layer is maintained at 604.0 mm in the Someș basin and 562 mm in the Mureş basin and 574 mm in the Siret basin (Table.4).

Table 4. The distribution over the altitude ranges in the main river basins of the layer (Y-mm) and the volume (V-mil.m3) of the multi-annual average lean water

Altitude interval (m)	Someş		Mureş		Siret		Total		% from total vol.
	V	Y	V	Y	V	Y	V	Y	
492-500	0.0		0.0	100.5	0	0	0.0	100.5	0.0
500-600	0.0		0.6	135.1	0	0	0.6	135.1	0.1
600-700	0.7	250.3	3.7	159.0	0	0	4.4	169.3	0.6
700-800	5.9	325.2	12.8	209.9	0	0	18.8	236.4	2.4
800-900	15.2	408.4	25.7	284.5	0	0	40.9	320.7	5.2
900-1000	25.1	475.6	40.6	359.6	1.6	398.7	67.3	396.6	8.5
1000-1100	29.7	518.6	50.2	424.4	19.6	434.7	99.6	450.9	12.6
1100-1200	27.8	561.6	52.2	499.0	41.1	515.7	121.1	518.0	15.3
1200-1300	24.1	604.6	45.3	562.2	46.0	574.3	115.4	575.4	14.6
1300-1400	19.4	628.4	43.7	598.6	45.8	606.8	108.9	607.2	13.8
1400-1500	16.1	632.9	28.3	613.6	40.3	617.4	84.8	619.0	10.7
1500-1600	7.7	637.4	17.7	612.8	32.3	620.9	57.6	620.5	7.3
1600-1700	1.3	641.9	10.1	608.7	21.4	625.6	32.7	620.9	4.1
1700-1800	0.9	646.4	8.4	616.2	11.9	633.6	21.2	627.1	2.7
1800-1900	0.4	651.0	4.6	622.1	5.9	643.7	11.0	634.7	1.4
1900-2000	0.1	655.5	1.5	622.1	2.7	655.3	4.4	643.4	0.6
2000-2100	0.0		0.3	627.5	0.1	660.0	0.4	632.9	0.0
Total	174.5	528.1	345.9	440.8	268.8	574.0	789.2	498.4	100.0

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The relations between the mean drainage and the altitude of the receiving basins indicate a more obvious vertical zone up to 1200-1600 m, after which there is a decrease of the average runoff gradients, indicating the reduction of the drained water, the phenomenon was reported since 1972 by Professor I. Ujvari.

The distribution of the average water layer drained over the altitude ranges in the studied basins highlights the zone induced by the altitude of the relief.

Analyzing the distribution of the average layer drained at the level of the hydrographic basins, there are significant differences, the values being .528 mm in the basin, Someş, 440 mm in the Mureş basin and 574 mm in the Siret basin.

At the level of the studied region, the multiannual average water volume resulting from the total runoff was estimated at 789 million m^3, corresponding to an average water layer of 498.4 mm. As with precipitations, the spatial distribution of water volumes resulting from global average drainage is different, depending also on the share of the areas owned by each hydrographic basin. Thus, the share of the three basins in achieving the multiannual average volume of water resulted from the total runoff is different: Someș basin participates with 22.2% of the total water flow, while Mureş basin with 43.8% and Siret with 34.0%.

Besides the vertical zoning, it is also noted that at the same attitude, the runoff gradually decreases from the west to the east. Thus, the differences between the runoff values between west and east of the region investigated at altitudes of 1000 m exceed 80 mm. The average runoff is maintained between 500-550 mm on the western slope of Căliman Mountains and 400-450 mm on the eastern (Fig. 5).

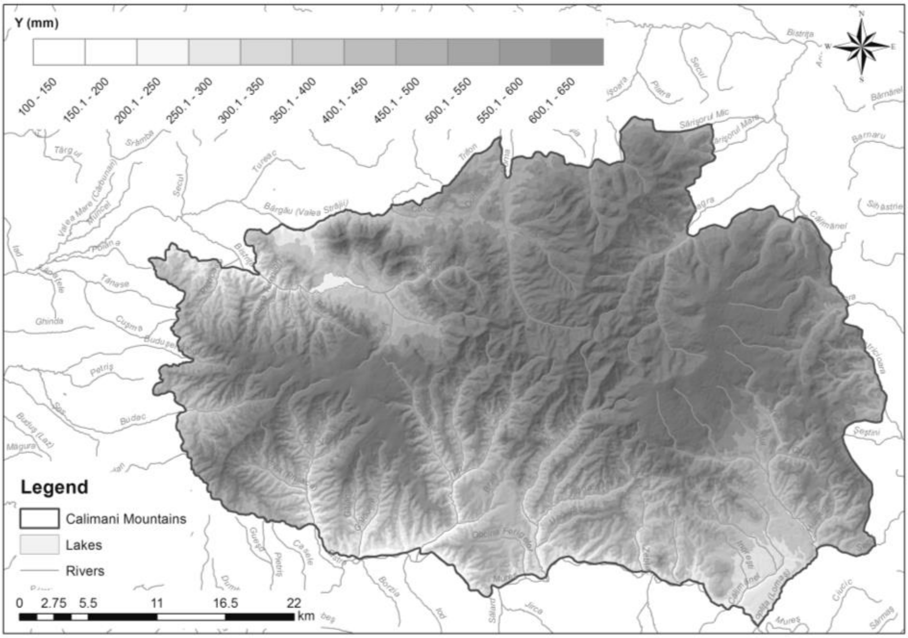

Fig. 5. Map of total average flow

The distribution of superficial runoff layer (S0) is subject to the same distribution laws as in the case of total runoff. Thus, the values of the superficial discharge are higher in the Someş basin than in the Mureş and Siret basins.

The underground drainage (Uo) as well as the other elements of the water balance, denotes a zone conditioned by the increase of humidity and the intensity of the drainage from the axis of the main valley to the interfluvial peaks. On the rivers in the Siret basin, the average underground spill values are lower, between 50 and 100 mm, while on the Someş and Mureş basins are between 100 and 200 mm. Higher values are explained by the relatively abundant and constant input from the water sources accumulated in the more permeable sedimentary formations in these basins.

The evapotranspiration (Zo) determined as the difference between the average precipitation (Xo) and the global average water layer (Yo) depends on the evaporation potential and the amount of moisture in the soil capable of evaporating. Thus, the value of the evapotranspiration is more indicative due to the lack of data from direct observations, which are influenced by local conditions specific to each subunit (degree of afforestation, soil types, exhibition and inclination of the slopes, etc.). The evapotranspiration values oscillate within narrow limits (mm). The evapotranspiration decreases with the altitude, reaching the high peaks of the Căliman Mountains at 200 mm (Fig. 6).

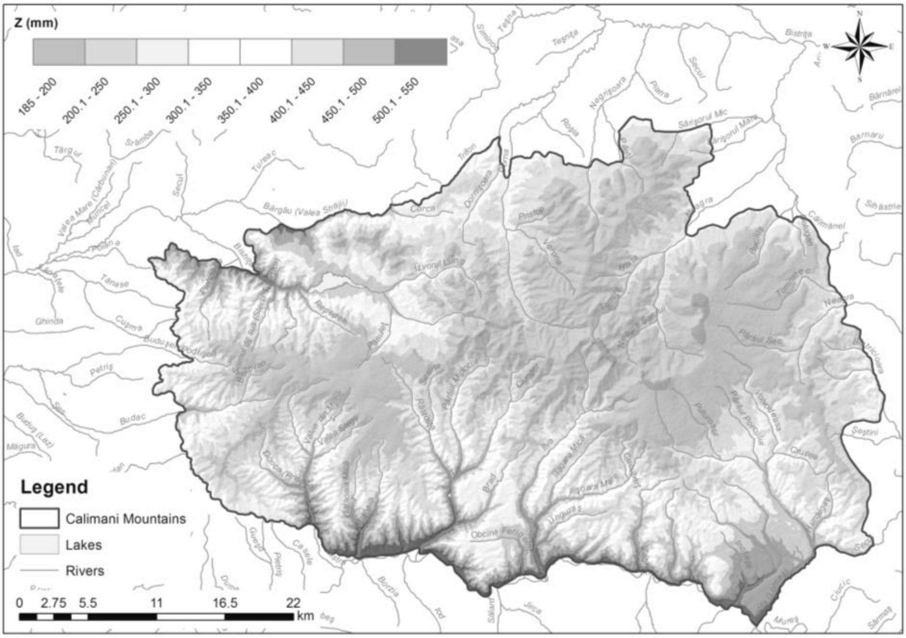

Fig. 6. Evapotranspiration map

The total soil moisture (Wo) was obtained from the sum of the underground runoff with the evapotranspiration value, representing the part of the rainfall that fails to flow to the surface of the land. The value of total soil moisture depends primarily on air humidity, showing differences from one hydric basin to another, which is around 100 mm. Thus, the lowest values of total soil moisture were determined for the Siret basin. (352 m), and large ones for Someș (461 mm) and Mureș (435 mm) basins.

3.2. Global water balance

The water balance assessed at the level of the Căliman Mountains can be expressed on the basis of the multiannual mean values of the main components as follows. The input includes 814 mm from atmospheric precipitation, of which 498 mm is consumed in global average runoff formation and 316 mm by evapotranspiration (Table 5).

From the average runoff, 422 mm represents the surface runoff, and the underground 106 mm. This results in the relatively low participation of underground resources in global wetting of the land, which accounts for 57.2% of the fallen rainfall, ie 461 mm.

Table 5. Structure of water balance in the main hydrographic basins of the Căliman Mountains.

Name of basin	Elements of water balance (mm)					
	X_o	Y_o	S_o	Z_o	U_o	W_o
Someș	883.5	528.1	422.5	355.4	105.6	461
Mureș particularităţi similar.	786.2	440.8	352.6	345.4	88.2	433.6
Siret	811.6	574	459.2	237.6	114.8	352.4
Călimani Mountains	814	498.4	398.7	315.6	99.7	415.3

4. CONCLUSIONS

The relationships between the altitude of the relief and the main elements of the water balance have allowed the identification of the area in which the spatial distribution of the peat elements.

The altitude distribution of the appropriate balance sheet values highlights the law of vertical zoning imposed by the altitude of the relief, which is a synthetic parameter of the conditions of spatial formation and distribution of the water balance in a territory.

The water balance maps drawn up on the basis of these correlations also highlight the law of the vertical zone, as well as the contrasts that appear between the western and the eastern regions of the studied region.

The water balance analysis on hydrographic basins shows that more than two-thirds of the water resources occur in the western and central areas of the Căliman Mountains, where the water circuit is more intense, which has favoured the creation of reservoirs that fill the deficit water from the Transylvanian Depression.

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