April. 2016. Vol. 4. No.3 ISSN 2311-2484
International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

SPATIAL VARIABILITY OF ANNUAL RUNOFF IN ZACARPATHIAN REGION

[1]GOPCHENKO EVGENIY, [2]KATINSKAYA IRINA, BURLUTSKAYA MARIYA

Doctor of Geography, Professor, Head of Department of Land Hydrology in Hydrometeorological Institute, Odessa State Environmental University, Ukraine
Methodologist of dean's office of distance tuition, Odessa State Environmental University, Ukraine
Cand. of Geographical Sciences, Asisstant Professor, Head of Department of Land Hydrology in Hydrometeorological Institute, Odessa State Environmental University, Ukraine
E-mail: quietness7@rambler.ru

ABSTRACT

Calculated coefficients of annual runoff variation of the Tisza River basin in the boundaries of Zacarpathian region are considered in this article. Methods of maximum likelihood and moments were used to calculate these coefficients. As the result spatial generalization of coefficients of annual runoff variation was done and dependence of these coefficients from the catchments height was determined too. It was found out that the variability of annual runoff of the Tisza River basin decreases from the increase of average catchments height.

Keywords: annual runoff, statistical analysis, heights location of catchments, spatial generalization.

1. INTRODUCTION

The runoff rate refers to the fundamental characteristics of the water resources of a particular territory. It is subjected to the latitudinal regularity in the boundaries of the flat European territory, which is broken because of the presence of forest coverage on watersheds, wetlands, karst, channel type reservoirs (lakes, storage pools, ponds). Zonality of spatial distribution of rates of annual runoff is caused by the complex of climatic factors such as precipitation, air temperatures, and evaporation from the surface watersheds, reservoirs, etc.

The conditions of runoff formation in mountainous areas, which include Zacarpathian region are more difficult. The latitudinal regularity is replaced by high-altitude zone in such regions. It refers not only to precipitation and air temperature, but the characteristics of the soil and vegetation of river basins also.

The studied territory is located in the forest-steppe and steppe zones of the Carpathian mountain formations. The largest river of Zacarpathian region is Tisza River, mainly its right part, which is formed by the confluence of Black and White Tisza Rivers. Their origins are at an altitude of 1400 m above sea level. Tisza River flows westward over the territory of Zacarpathian, partly on the border with Hungary and Romania.

Network of hydrological stations by which are carried out a systematic study of regime of the Zacarpathian rivers was not constant in time. Over 70 hydrological stations were in this region in 1975. Nowadays only the principal stations exist and the others are closed.

Statistical parameters of time series have a great practical importance, for instance, coefficients of variation Cv and coefficients of skewness Cs or ration Cs/Cv.

Coefficients of variation Cv and coefficients of skewness Cs by the methods of moments are calculated in this way [1, 2]

$$Cv = \sqrt{\frac{\sum_{i=1}^{n}(k_i - 1)^2}{n-1}}, \qquad (1)$$

$$Cs = \sum_{i=1}^{n}(k_i - 1)^3 / \left(nCv^3\right), \qquad (2)$$

where $k_i = Q_i / \overline{Q}$ is the modular coefficients of water discharges Q_i to the average long-term value of water discharges $\overline{Q}$;

n – is the number of observation years.

Calculated coefficients of variation Cv and coefficients of skewness Cs by the methods of maximum likelihood are determined depending on statistics λ_2 and λ_3, which are defined by the following formulas [1, 2]:

$$\lambda_2 = \sum_{i=1}^{n} (\lg k_i) \Big/ (n-1); \qquad (3)$$

$$\lambda_3 = \left(\sum_{i=1}^{n} k_i \lg k_i \right) \Big/ (n-1), \qquad (4)$$

where k_i is the modular coefficient of studied hydrological characteristic.

Calculated coefficients of variation and coefficients of skewness are determined by auxiliary tables about obtained values of statistics λ_2 и λ_3 [3].

The desired values Cv and Cs/Cv are determined by special nomograms which were worked out by S.N. Kritsky and M.F. Menkel [4, 5].

It is well known if the coefficients of variation are less than 1.0, coefficients of variation Cv are calculated by two methods do not differ from each other. These requirements correspond to data of observation for the annual runoff over Zacarpathian region.

2. LITERATURE REVIEW:

Long-term time series of observations over hydrological regime of the Zacarpathian rivers are quite limited. The first researches of coefficients of variation refer to the period of 1969, when they were published in «Surface water resources, Volume 6, Issue 1 Western Ukraine and Moldova, 1969 (SWR)». The runoff rates and coefficients of variation for the series until 1965 are generalized as the maps of isolines as well as the regional empirical dependences from the height of catchments [6].

According to SWR [7, 8] three districts (the V-VII) were marked out in the south-western slope of the Carpathians. All the right tributaries of Tisza River are located within boundaries of these districts.

Basins of Mokranka Rivers, Teresva Rivers, the uppers of Borzhava and Latorica Rivers are located in the V district and they are characterized by the highest values of runoff because of the free inflow of the western air masses. Modules of annual runoff are 30-40 $dm^3 \cdot s^{-1} \cdot sq.\ km^{-1}$. The lowest annual runoff was observed in the basins of Black and White Tisza Rivers (the VII district), it was 20-25 $dm^3 \cdot s^{-1} \cdot sq.\ km^{-1}$. Annual runoff of other Zacarpathian rivers occupies an intermediate position (the VI district).

Coefficients of variation Cv, which characterize the variability of annual runoff for the well-studied rivers in Hydrology were defined with the use of observed data by the following formula [1]

$$Cv = \frac{\sigma_q}{\overline{q}} = \sqrt{\frac{\sum_{i=1}^{n} (k_i - 1)^2}{n-1}}, \qquad (5)$$

where $\overline{q}$ is the average long-term module of annual runoff, $dm^3 \cdot s^{-1} \cdot sq.\ km^{-1}$;

σ_q is the standard deviation of annual runoff from its average value;

k_i is the modular coefficients;

n is the number of observation years.

Values of coefficients of variation were determined for individual districts of the mountainous rivers of the Carpathians depending on the module of annual runoff $\overline{q}$ and area of catchments by the following regional formulas [7, 8]:

the V district

$$Cv = \frac{1{,}23}{\overline{q}^{0{,}41} F^{0{,}019}}; \qquad (6)$$

the VI district

$$Cv = \frac{1{,}23}{\overline{q}^{0{,}30} F^{0{,}030}}; \qquad (7)$$

the VII district

$$Cv = \frac{1{,}23}{\overline{q}^{0{,}24} F^{0{,}058}}. \qquad (8)$$

The such method of generalization of coefficients of variation for the Zacarpathian rivers was accepted in the method «Building standards and rules» 2.01.14-83 [10, 11]. So, it is allowed to

April. 2016. Vol. 4. No.3 ISSN 2311-2484
International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

calculate coefficient of variation Cv for the mountainous districts by the following formula

$$Cv = \frac{A}{q_0^{\;0.4}(F+1000)^{0,10}}, \qquad (9)$$

where $\bar{q}$ is the rate of annual runoff, dm^3·s^{-1}·sq. km^{-1}.

Parameter A is recommended to determine by the method of analogy.

Authors of formula [4, 5] estimate of its exactness on the level from 10 to 30%.

It should be noted that the such science-methodical base was applied to the spatial generalization of the rates of annual runoff. Unfortunately, as it was before, we pay attention to the incorrect application to the same data at the same time of alternative methods of the spatial generalization of geographical objects. We mean the use of maps and regional formulas, which take into account except of zonal arguments some azonal arguments, for example, catchments heights $Ha.c.$ and dimensions of catchments F.

3. MAIN RESULTS:

It was used the data of observational network of Hydrometeorological Department of Ukraine for the period from 1948 to 2010 year inclusive (Table 1) in this analysis. The catchments area is from 0,28 sq. km (Deep Yar brook – Mezhgore village) to 9140 sq. km (Tisza River – Vilok village), duration of time series is from 23 years (Ug River – Zhornava village) to 55 years (Latorica River – Mukachevo town, Ug River – Ughorod town), range of heights is from 300 m (Stara River – Znyacevo village) to 1200 m (White Tisza River – Luha town).

As it has been noted, the method of moments and maximum likelihood are the most commonly used methods of statistical analysis of time series of runoff characteristics. These methods both were applied at the beginning stage of researches over the Zacarpathian rivers. Regardless of calculation method, coefficients of variation Cv change from 0,49 (Rika River – Hust town, F =1130 sq. km) to 0,20 (Tisza River – Rakhov town, F =1070 sq. km). It means that application of both of these calculation methods for this range is not relevant.

exactness of initial information about coefficients of variation of time series is equal to 10,25% [4, 5].

As it has been mentioned above the mapping or representation of coefficients of variation Cv depending on one (catchment area), two (catchment area and modules of annual runoff) or more arguments (altitude, dimensions of catchments) are used when it is needed to generalize these coefficients spatially.

Initially it was plotted dependence of coefficients of variation Cv from the potentially possible factors which influence the variability of annual runoff in the mountainous conditions. Such as, $Cv = f(H)$; $Cv = f(H-1000)$; $Cv = f(\lg F + 1)$; $Cv = f(\bar{q})$ (Figure 1-4), where H is the average catchments height (m); F is the area of catchments, (sq. km); $\bar{q}$ is the rate of annual runoff (dm^3·s^{-1}·sq. km^{-1}).

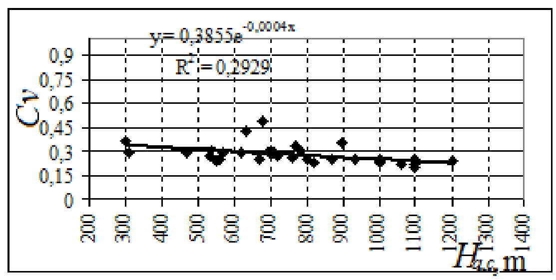

Figure 1 – The dependence of coefficients of variation of annual runoff in Zacarpathian region from the average catchments height

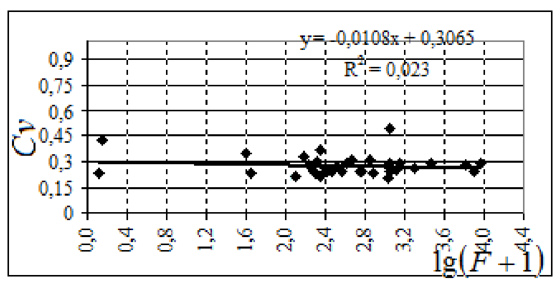

Figure 2 – The dependence of coefficients of variation of annual runoff in Zacarpathian region from the area of catchments

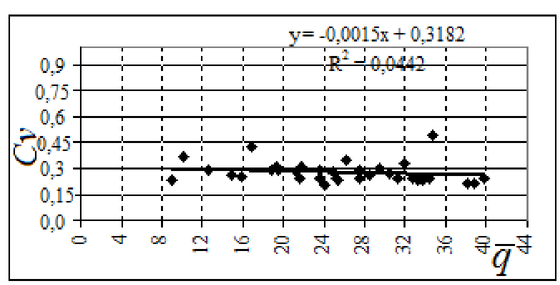

Figure 3 – The dependence of coefficients of variation of annual runoff in Zacarpathian region from the module of annual runoff

April. 2016. Vol. 4. No.3 ISSN 2311-2484
International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

Table 1. – LIST OF HYDROLOGICAL STATIONS

№ stations	River – station	n, years	F, sq. km	Hm, m	Cv	$\bar{q}$, $dm^3 \cdot s^{-1} \cdot sq.\ km^{-1}$
1	Borzhava River – Dolgoe village	62	408	620	0,29	27,40
2	Borzhava River – Shalanki village	37	1100	470	0,29	18,72
3	Brusturanka River – Lopukhov village	41	257	1100	0,24	34,28
4	Vecha River – Nelipyno village	51	241	760	0,26	28,38
5	Deep Yar brook – Mezhgore village	26	0,28	550	0,24	8,89
6	Yoykovets brook – Mezhgore village	26	0,39	630	0,43	16,79
7	Kosovskaya River – Kosovska Polyana village	46	122	1060	0,22	38,11
8	Latorica River – Mukachevo town	62	1360	570	0,29	19,43
9	Latorica River – Podpoloze village	62	324	720	0,27	30,34
10	Latorica River – Svalyava town	47	680	700	0,31	21,82
11	Latorica River – Chop town	52	2870	310	0,29	12,57
12	Lopuszno River – Lopuszno town	28	37,3	897	0,36	26,27
13	Luzhanka River – Neresnitsa village	33	149	770	0,33	32,01
14	Lute River – Chornogolova village	33	169	700	0,28	24,85
15	Mokranka River – Russian Mokraya village	47	214	1100	0,22	38,83
16	Pylypets River – Pylypets village	53	44,2	820	0,23	33,71
17	Repinka River – Repino village	63	203	780	0,30	29,51
18	Rika River – Mezhgore village	63	550	800	0,24	25,29
19	Rika River – Hust town	48	1130	680	0,49	34,71
20	Stara River – Znyacevo village	57	224	300	0,37	10,13
21	Tereblya River – Kolochava villge	47	369	1000	0,24	39,78
22	Teresva River – Dubovoe town	42	757	1000	0,23	33,20
23	Teresva River – Neresnitsa village	38	1100	930	0,25	31,29
24	Teresva River – Ust-Chorna village	60	572	1100	0,24	32,69
25	Tisza River – Vilok village	55	9140	–	0,29	23,49
26	White Tisza River – Luhi village	54	189	1200	0,24	27,62
27	Tisza River – Rakhov village	62	1070	1100	0,20	24,06
28	Tisza River – Tyachev town	36	6470	–	0,28	21,28
29	Tisza River – Hust town	45	7690	870	0,25	21,59
30	Black Tisza River – Yasinya town	46	194	1000	0,24	25,41
31	Turia River – Simer village	51	464	540	0,31	19,33
32	Ug River – Zhornava village	57	286	670	0,25	23,50
33	Ug River – Zarichevo village	62	1280	560	0,25	15,94
34	Ug River – Ughorod town	62	1970	530	0,27	14,89

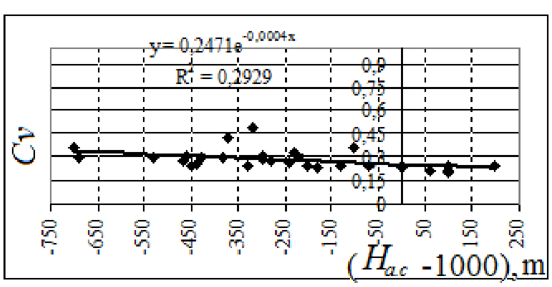

Figure 4 – The dependence of coefficients of variation of annual runoff in Zacarpathian region from the average catchments height H -1000 m

The Pearson correlation coefficients r are equal to 0.54; 0.15; 0.21 respectively. According to the prevailing correlation coefficient dependence $Cv = f(H - 1000)$ is described by the following exponential equation

$$Cv = 0{,}25 \exp\left[-0{,}4 \times 10^{-3}(H - 1000)\right]; \qquad (10)$$

Further all the initial data of coefficients of variation Cv should lead to some nominal catchments heights (for example, $H = 1000m$) by Equation (10). Then it is possible to define the dependence of coefficients of variation from the

April. 2016. Vol. 4. No.3 ISSN 2311-2484
International Journal of Research In Earth & Environmental Sciences

http://www.ijsk.org/ijrees.html

dimensions of catchments F and the rate of annual runoff $\bar{q}$. Equation (10) takes the following form

$$Cv = (Cv)_{H=1000} \exp\left[-0,4^{-3}(H-1000)\right] \quad (11)$$

Where adjusted value $(Cv)_{H=1000}$ is equal to

$$(Cv)_{H=1000} = Cv / \left\{\exp\left[-0,4\times10^{-3}(H-1000)\right]\right\} \quad (12)$$

After that it is possible to continue studying the factorial conditionality $(Cv)_{H=1000}$ by other local variables (F and $\bar{q}$).

However, from a practical point of view, it should be estimated the exactness of equations which are got at each step and compared results with the exactness of the initial information before the calculated scheme will be detailed.

Obviously, detailing of research procedures makes sense when the calculated values Cv at a given step significantly differ from the initial data.

That is why, at first the exactness of Equation (10) was verified with the use of materials of 34 objects. The average deviation of the calculated coefficients of variation $(Cv)расч.$ from the initial data Cv is equal to 11.25%, which almost coincide with the mean square error of calculating coefficients of variation Cv with the use of available time series (δ_{Cv} = 10.25%).

So, it means that we can use dependence (10) for calculation of coefficients of variation Cv of annual runoff for Zacarpatian rivers.

The ration between coefficients of skewness Cs and variations Cv can be accepted as the averaged normative characteristics in the boundaries of studied territory. Values of coefficients of skewness Cs and variations Cv are equal to Cs=0,49, Cv=0,28 for the Tisza River basin in Zacarpatian region.

4. CONCLUSION:

Generally, the variability of annual runoff over the territory of Zacarpatian region is characterized by low coefficients of variation, which change from 0.49 (Rika River – Hust town, F=1130 sq. km) to 0.20 (Tisza River – Rakhov town, F=1070 sq. km).

It can be concluded when the average catchments height increases, regularity of decreasing of the variability of annual runoff is observed in studied region.

Results of this study can be recommended for the practical use, exactness of the proposed formula is 10-12%.

REFRENCES:

1. Chebotarev N.P. Hydrology and river flow calculations. – Leningrad: Gidrometeoizdat, 1953. – 564 p. (rus).
2. Rogdestvensky A.V., Chebotarev O.I. Statistical methods in hydrology. – Leningrad: Gidrometeoizdat, 1974. – 423 p. (rus).
3. Sokolovsky D.L. River flow (Basics of the theory and methods of calculation). – Leningrad: Gidrometeoizdat, 1968. – 540 p. (rus).
4. Kritsky S.N., Menkel M.F. Calculations of river flow. – Moskow- Leningrad: ONTI, Gosstroiizda, 1934 – 260 p. (rus).
5. Kritsky S.N., Menkel M.F. Hydrological foundations of river runoff management. – Moscow: Publishing House «Science», 1981 – 254 p. (rus).
6. Gopchenko E.D., Katinskaya I.V. Variability of annual runoff over Zacarpathian territory // European Applied Sciences. – № 11. – 2014. – P. 65-68.
7. «Surface water resources. Vol. 6, №. 1. Western Ukraine and Moldova». – Leningrad: Gidrometeoizdat, 1964. – 245 p. (rus).
8. Surface water resources of the USSR. Vol. 6. Ukraine and Moldova. Issue 1. Western Ukraine and Moldova / Ed. by M.S. Kaganer. – Leningrad: Gidrometeoizdat, 1969. – 900 p. (rus).
9. Voskresensky K.P. Norma and variability of annual runoff of rivers of the USSR. – Leningrad: Gidrometeoizdat, 1962. – 546 p. (rus).
10. Manual for the definition of the calculated hydrological characteristics. – Leningrad: Gidrometeoizdat, 1984. – 448 p. (rus).
11. Determination of the calculated hydrological characteristics. – «Building standards and rules» 2.01.14-83. – Moscow, 1985. – 36 p. (rus).