# EVALUATION OF CHANGES IN THE CLASSIFICATION CRITERIA OF MOUNTAIN RIVERS BY FEEDING SOURCES UNDER CONDITIONS OF CLIMATE CHANGE

**N.B.Erlapasov**
*National University of Uzbekistan named after Mirzo Ulugbek,*

***Abstract.*** *The article is devoted to the issues of assessing quantitative changes in the criteria for the classification of mountain rivers, i.e. separating them according to food sources in the context of climate change. For this, the tributaries of the Amudarya and Syrdarya, located within Uzbekistan and adjacent mountainous areas, were chosen. Criteria were defined for each river, i.e. Shults coefficient (δ) proposed by V.L.Shults, relative to the annual runoff for july-september ($W_{VII-IX}$, %) and the most abundant months in the first basic climatic period (FBCP, 1961-1990) and the current climatic period (CCP, 1991-2019). The calculation results are compared with the data presented in previous studies. As a result, it was found that both the types of feeding of the studied rivers and the most abundant months did not change, however, the values of δ changed in a certain insignificant interval.*

***Keywords:*** *mountain rivers, water discharge, runoff value, food sources, classification criteria, Shults coefficient, changes, quantitative assessment.*

The main source of river saturation is atmospheric precipitation. The rest of the precipitation that falls in the form of rain is used for absorption and evaporation on the surface of the earth and forms surface runoff and is a direct source of river saturation. If the precipitation falls in the form of snow, it accumulates on the surface of the earth and begins to melt when the air temperature rises. The waters formed from the melting of snow also participate in the saturation of rivers. The snow that falls on the high mountain areas does not melt in one summer season, as a result it enriches the snow reserve in the lands, saturates permanent snows and glaciers. The water of these centuries-old snows and glaciers in the high mountains is another source of river saturation [Shults, 1965; Shcheglova, 1960; Khikmatov, Aytbayev, Adenbayev, Pirnazarov, 2017].

Part of the rainwater and the water formed by the melting of snow and glaciers seeps underground and is added to the soil and underground water. Groundwater and ground water also move towards the river bed, ensuring constant water in the rivers. Thus, there are four sources of river saturation: rainwater, snowmelt, glacier melt, and groundwater. The amount of water produced from these sources and added to the rivers will have different values in different rivers. Depending on the climatic conditions of the river basin, these amounts vary primarily between years and also seasonally [Khikmatov et al., 2017].

Today, in the conditions of climate change, the quantitative assessment of the contributions of various sources of saturation to the total flow of rivers is one of the urgent problems in the scientific field of mountain hydrology. Because of this, foreign scientists Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley, M.I. Lvovich, F.A. Makarenko, K.P. Voskresensky, B.I. Kudelin, M.N. Bolshakov, E.M. Kozik, G.P. Kalinin, T.S. Abalyan, O.V. Popov, A.Z. N.S. Amusya. The studies of Ratner, A.T. Ilyasov, A.N. Vajnov and others are devoted [Shults, 1965; Khikmatov et al., 2017; Erlapasov, 2022].

E.M. Oldekop, L.K. Davydov, V.L. Shults, Z.V. Georgiou, O.P. Sheglova, A.I. Ilin and others conducted the first researches related to the study of river saturation sources in our country. To date, studies devoted to this problem by V.E. Chub, E.I.Chembarisov, F.H. Khikmatov, S.V. Myagkov, T.A. Ahmedova, F.Ya. Artikova, B.E. Adenbaev, G.Kh. Yunusov, D.V. Nazaraliev, G.U. Yusupov, F.A. Gapparov, K.R. Rakhmonov, S.A. Khaidarov, D.M. Turgunov and others continued [Shults, 1965; Shcheglova, 1960; Erlapasov, 2022]. However, in the research carried out by the above-mentioned scientists, the changes in the criteria for the classification of rivers according to the sources of saturation in recent decades were not considered as a separate object of research.

The main goal of this research work is to evaluate the quantitative changes of the criteria adopted by V.L.Shults [Shults, 1965] for the classification of rivers according to their saturation in the conditions of climate change. For this purpose, the following tasks were defined in the work: 1) selection of rivers with a natural hydrological regime as basic research objects; 2) collection of water consumption data measured at hydrological stations located on rivers, their primary processing, generalization; 3) to determine the criteria that allow to divide the rivers into different types according to their saturation, that is, the Shultz coefficient (δ), the volume of flow in July-September ($W_{VII-IX}$, %), the months in which the largest part of the annual flow flows for FBCP and CCP; 4) comparison of the results of calculations with the data of previously conducted studies; 5) assessment of changes in criteria that allow classification of rivers according to sources of saturation.

Rivers in Uzbekistan and adjacent mountainous regions, including Amudarya and Syrdarya tributaries with a natural hydrological regime, were selected as research objects. The issues of quantitative changes assessment in the criteria for dividing rivers into types according to saturation determine the research subject of the work.

**Main results and their discussion.** Classification of rivers according to the sources of saturation, that is, dividing them into appropriate groups based on certain criteria, is of great scientific and practical importance in organizing the efficient use of river water resources. As mentioned above, V.G. Glushkov, E.M. Oldekop, L.K. Davydov, and later V.L. Shults, O.P.Shcheglova, M.N. Bolshakov and other scientists were involved. For example, V.G. Glushkov first developed a method that allows determining the contributions of various sources to the river flow. Based on the application of this method, he founded the principles of classification of rivers according to their sources of saturation [Shultz, 1965; Shcheglova, 1960; Khikmatov et al., 2017].

It is known that the transition periods of maximum water consumption in rivers also indicate the sources of their saturation. Such a scientific and practical approach to the study of river saturation sources was first used by E.M. Oldekop and later by V.L. Shults [Shults, 1965]. As a result, V.L. Shults, not taking into account small rivers that are more saturated with underground water, divided the rivers of Central Asia into the following four types according to the sources of saturation: rivers that are saturated with glacial-snow waters; rivers fed by snow-glacial waters; rivers fed by snow; rivers fed by snow and rainwater.

In this classification, V.L.Shults recommended using the following criteria to determine the type of river under study: 1) months when there is the most water in the river; 2) the amount of flow during the summer flood period, formed from snowmelt water, compared to the annual flow of the river ($W_{VII-IX}$, %); 3) the ratio of the amount of flow during the summer flood period ($W_{VII-IX}$) to the amount of flow during the spring flood period ($W_{III-VI}$) formed from snow waters, that is, the Schults coefficient

$$\delta = \frac{W_{VII-IX}}{W_{III-VI}}.$$

Based on the purpose of this work, as mentioned above, for each of the rivers selected in the study, the values of the criteria adopted in the classification of V. L. Shults are the first basic climatic period (FBCP, 1961-1990) and the current climatic period (CCP, 1991-2019 was calculated for yy)s (Table 1).

***Table 1***

**The results of determining the criteria adopted by V.L.Shults for the classification of rivers for different climatic periods**

| | The river is a place of observation | FBCP | | | CCP | | | Food type[4] |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 | |
| **Amudarya basin** | | | | | | | | |
| 1 | Topalang - Zarchop | 0,43 | 26,8 | V-VI | 0,51 | 29.9 | V-VI | *SI* |
| 2 | Koratogdaryo - mouth | 0,24 | 14,9 | IV-V | 0,25 | 16,2 | IV-V | *S* |
| 3 | Sangardak - Kengguzar v. | 0,22 | 15,4 | IV-V | 0,21 | 15,6 | IV-V | *S* |
| 4 | Khalqazhar – Bozorzhoy v. | 0,10 | 7,97 | IV-V | 0,12 | 9,25 | IV-V | *SR* |
| 5 | Sherobod – Darbant v. | 0,26 | 17,8 | V-VI | 0,50 | 25,1 | V-VI | *SI* |
| 6 | Qashkadaryo – Varganza v. | 0,15 | 10,2 | III-IV | 0,13 | 8,34 | III-IV | *SR* |
| 7 | Djinnidaryo – Joes v. | 0,37 | 18,9 | IV-V | 0,23 | 13,1 | IV-V | *SI* |
| 8 | Aksuv - Hisorak | 0,68 | 34,5 | VI- VII | 0,62 | 32,8 | VI- VII | *SI* |
| 9 | Tanhozdaryo - Kattagon v. | 0,29 | 20,3 | V-VI | 0,25 | 18,4 | V-VI | *SI* |
| 10 | Yakkabog'darya – Tatar v. | 0,39 | 24,8 | V-VI | 0,42 | 27,3 | V-VI | *SI* |
| 11 | Oradaryo – Bozortepa v. | 0,24 | 15,4 | IV-V | 0,25 | 15,5 | IV-V | *S* |
| 12 | Small Oradaryo – Gumbulok v. | 0,07 | 5,37 | III-IV | 0,09 | 7,03 | IV-V | *SR* |
| 13 | Zarafshan – Dupuli v. | 1,65 | 53,4 | VII-VIII | 2,13 | 56,6 | VII-VIII | *IS* |
| 14 | Urgut - Urgut | 0,14 | 10,2 | IV-V | 0,18 | 11,2 | IV-V | *SR* |
| 15 | Amonko'tonsoy - Amonko'ton v. | 0,20 | 12,6 | III-IV | 0,21 | 12,7 | IV-V | *SR* |
| 16 | Akdaryo - Aghalik v. | 0,05 | 3,51 | III-IV | 0,09 | 5,10 | III-IV | *SR* |
| 17 | Beglarsoy - New Akchob v. | 0,07 | 5,33 | III-IV | 0,18 | 11,2 | III-IV | *SR* |
| **Sirdarya basin** | | | | | | | | |
| 18 | Sox – Sarikanda v. | 2,62 | 61,5 | VII-VIII | 2,39 | 60.4 | VII-VIII | *IS* |
| 19 | Koksuv - Kurbankol | 1,25 | 34,3 | VII-VIII | 0,98 | 35,5 | VI-VII | *SI* |
| 20 | Govasay - Gova v. | 0,24 | 16,8 | V-VI | 0,21 | 15,1 | V-VI | *S* |
| 21 | Okhangaron - the mouth of the river Ertosh | 0,16 | 12,2 | IV-V | 0,14 | 11,4 | IV-V | *SR* |
| 22 | Chotkol - the mouth of the river Khudoydotsoy | 0,51 | 28,8 | V-VI | 0,48 | 27,2 | V-VI | *SI* |
| 23 | Chiralma - mouth | 0,45 | 26,5 | V-VI | 0,41 | 25,7 | V-VI | *SI* |
| 24 | Piskom – Mullala v. | 0,79 | 37,5 | VI-VII | 0,74 | 36,2 | VI-VII | *SI* |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 25 | Oygaing - mouth | 1,06 | 43,5 | VI- VII | 0,93 | 41,2 | VI- VII | *SI* |
| 26 | Maydontol - mouth | 0,97 | 0,42 | VI-VII | 0,84 | 0,39 | VI-VII | *SI* |
| 27 | Ugom – Khodjakent v. | 0,33 | 20,4 | V-VI | 0,30 | 19,0 | IV-V | *SI* |
| 28 | Zominsow – Duaba v. | 0,51 | 25,3 | V-VI | 0,57 | 27,8 | V-VI | *SI* |
| 29 | Sangzor – Kirk v. | 0,20 | 12,4 | IV-V | 0,19 | 11,9 | IV-V | *S* |

*Note: 1 – Shults coefficient (δ); 2 – flow volume in july-september (WVII-IX, %); 3 – months with the highest amount of flow; 4 – types of saturation: GS - glacier-snow, SI - snow and ice, S - snow, SR - snow and rain. v-village.*

According to the analysis of table data, the value of the coefficient of V.L.Shults was δ=1.65 in the Zarafshan (Dupuli) river belonging to the Amudarya basin in FBCP. During this climatic period, 53.4 percent of the average multi-year flow volume of 4841.4 106 $m^3$, or 2585.3•$10^6$ $m^3$, was observed in July-September. The largest volume of flow in the river was observed in July, when 24.8 percent of the annual flow (1200.7 $10^6$ $m^3$) flowed in this month.

In this river, the determined value of V.L. Shults coefficient for CCP was equal to δ=2.13. Compared to the average multi-year flow of 5094.8 $10^6$ $m^3$ that flowed through the river during this accounting period, the amount of flow recorded in July-September was 56.5 percent or 2878.6 $10^6$ $m^3$. In this period, the largest amount of flow compared to the annual flow (1221.1 106 m3) was equal to 24% and was observed in July.

Another important issue should be noted here: as can be seen from the above figures, the amount of Zarafshan river flow in CCP was 253.4 $10^6 m^3$ (or 5.2%) more than in FBCP. This number should be taken into account when planning and organizing the work of water management and economic sectors in all regions that use Zarafshan river water.

In FBCP, the values of Shults coefficient determined for Yakkabog'darya, Sheroboddarya, Jinnidarya, Tankhozdarya, Topalangdarya in the Amudarya basin varied in the range of 0.43÷0.26 (Table 1). It is known that, according to the classification criteria of V.L.Shults, these numbers of d indicate that the above-mentioned rivers are in the type of rivers saturated with snow-ice water. However, it is well known that the Sherobddarya and Jinnidarya basins are free of glaciers. The interesting thing is that in these rivers, except Jinni Darya, the second criterion, that is, the months when the water is the most abundant, also coincides with May-June, apparently, shows that they belong to the type that is saturated with snow and ice water. If the calculated values of the Schultz coefficient in JID vary between 0.23÷0.51, the months when there is the most water in the rivers (except Jinnidarya) correspond to May-June, as above.

The values of Schultz's coefficient (d) determined for FBCP in Oradaryo, Karatog'daryo, Sangardak rivers in the basin vary between 0.22÷0.24. These numbers indicate that these rivers belong to the type of snow-fed rivers according to the classification of V.L.Shults. The fact that the highest values of the flow amounts in them correspond to the months of April-May confirms the above-mentioned points once again. The values of d change in CCP are in the range of 0.21÷0.25. Also, the months with the highest flow rates remain unchanged (Table 1).

According to the results of the calculations, the values of the Shultz coefficient that fulfill the condition $\delta \leq 0.17$ corresponded to the Kashkadarya, Kichik Oradaryo, Khalkajar and Urgutsoy, Okdarya and Beglarsoy rivers of the Middle Zarafshan basin, which are saturated with snow and rainwater. According to the values of the criteria determined by us for both accounting periods, these rivers, as in V.L.Shults, belonged to the type of rivers saturated with snow-rainwater (Table 1).

Calculations based on the above sequence of determining the criteria for dividing rivers into types according to the classification of V.L. Shults for different climatic periods and their analysis were also carried out on the example of the rivers of the Syr Darya basin (Table 1).

The results of the calculations made during the research are based on previous studies, including Resursy poverkhnostnyx vod SSSR [Resursy, 1969; Resursy, 1971] and compared with the data of V. E. Chub [Chub, 2007] (Table 2).

Table 2

Comparison of Schults coefficient (δ) values with the results of previous studies

| **T.p.** | **Rivers** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|---|
| Amudarya basin | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 1 | To'palang | 0,47 | 0,47 | 0,43 | 0,51 |
| 2 | Sangardak | 0,26 | 0,25 | 0,22 | 0,21 |
| 3 | Xalqajar | 0,10 | 0,12 | 0,10 | 0,12 |
| 4 | Qoratog'darya | 0,57 | 0,22 | 0,24 | 0,25 |
| 5 | Sheraboddarya | 0,26 | 0,30 | 0,26 | 0,50 |
| 6 | Qashkadarya | 0,18 | 0,16 | 0,15 | 0,13 |
| 7 | Jinnidarya | 0,26 | 0,33 | 0,37 | 0,23 |
| 8 | Oqsuv | * | 0,67 | 0,68 | 0,62 |
| 9 | Tanghozdarya | 0,38 | 0,29 | 0,29 | 0,25 |
| 10 | Yakkabagdarya | 0,46 | 0,44 | 0,39 | 0,42 |
| 11 | O'radarya | 0,30 | 0,25 | 0,24 | 0,25 |
| 12 | Kichik O'radarya | 0,05 | 0,13 | 0,07 | 0,09 |
| 13 | Zarafshan | 1,84 | * | 1,65 | 2,13 |
| 14 | Urgut | 0,23 | 0,181 | 0,14 | 0,18 |
| 15 | Omonkotonsay | 0,18 | 0,210 | 0,20 | 0,21 |
| 16 | Okdarya | * | 0,069 | 0,05 | 0,09 |
| 17 | Beglarsay | * | * | 0,07 | 0,18 |
| Syrdarya basin | | | | | |
| 18 | Sox | 2,50 | * | 2,62 | 2,39 |
| 19 | Koksu | 1,14 | * | 1,25 | 0,98 |
| 20 | Gavasay | 0,27 | 0,25 | 0,24 | 0,21 |
| 21 | Ahangaran | 0,17 | 0,14 | 0,16 | 0,14 |
| 22 | Chatkal | 0,69 | 0,52 | 0,51 | 0,48 |
| 23 | Chiralma | * | 0,47 | 0,45 | 0,41 |
| 24 | Piskom | 0,80 | 0,81 | 0,79 | 0,74 |
| 25 | Oygaing | 1,11 | 1,09 | 1,06 | 0,93 |
| 26 | Maydantal | 1,01 | 1,00 | 0,97 | 0,84 |
| 27 | Ugam | 0,35 | 0,34 | 0,33 | 0,30 |
| 28 | Zominsu | 0,52 | 0,55 | 0,51 | 0,57 |
| 29 | Sangzor | 0,26 | 0,22 | 0,20 | 0,19 |

***Note:*** *1 - Information given in "Resource..." (1971); 2 - V.E. Chub (2007) data; 3 - by the author ББИД and 4 - the information determined for the ЖИД; * - empty cells indicate that δ has not been calculated.*

As shown in the table, in one of the large tributaries of the Amudarya - the Sangardak river in the Surkhondarya basin, the value of the coefficient (d) of V.L. Schultz is d=0.26 according to the information of "Resursy...", d=0.25 according to the information of V.E.Chub is equal to The results of our calculations showed that its value is equal to d=0.22 in FBCP and d=0.21 in CCP. Therefore, these values of d are evidence of certain changes in it. We can see similar situations in Kashkadarya and Tankhozdarya. The value of Schultz's coefficient in FBCP was equal to δ=0.15 in Kashkadarya, δ=0.29 in Tankhozdarya, and 0.13 and 0.25 in

CCP, respectively.

The analysis of the results of the calculations of the Shultz coefficient on the example of the rivers of the Syrdarya basin shows that in most cases the determined values of d for CCP are slightly lower than for FBCP. In particular, in the Sokh river, the value of this coefficient was equal to δ=2.62 in FBCP, and δ=2.39 in CCP. We can see similar situations in the case of rivers such as Piskom, Chotkal, Ugom, Sangzor belonging to the Syrdarya basin (Table 2).

Summarizing the analysis of the results obtained in the study, the following should be noted as a conclusion:

1. The criteria proposed by V.L.Shults for the purpose of dividing the rivers into different types according to their saturation, including the Shults coefficient (δ), the flow volume in July-September ($W_{VII\text{-}IX}$, %) and the months with the largest river flow, FBCP and CCP determined for As a result, it was shown that the months in which there is the most water in the studied rivers and their types according to the sources of saturation have not changed, but d has changed in certain values;

2. One of the main criteria for classification of mountain rivers by sources of saturation - Shultz coefficient (δ) values were calculated for FBCP and CCPs. The obtained results were compared with each other and with the data of previous studies;

3. According to the analysis, with the exception of Sherabad (Darbant) and Zarafshan (Dupuli) rivers, sharp changes in the values of d were not detected. For example, in the right tributary of the Surkhondarya - the Sangardak River, the values of the Schultz coefficient are δ=0.26 according to "Resursy...", δ=0.25 according to V.E.Chub, δ=0.22 in BBID, And in CCP it was equal to δ=0.21. The smallest values of this coefficient (δ≤0.17) corresponded to Okdarya and Beglarsoy rivers in the Middle Zarafshan basin and Kashkadarya basin rivers.

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