HYPSOMETRIC REGIONALIZATION OF WATER IN THE CASE OF UNA BASIN

Aida Korjenić
University of Sarajevo, Faculty of Science, Department of Geography
Zmaja od Bosne 33-35, Sarajevo, Bosnia and Herzegovina
aida.k@pmf.unsa.ba

Contemporary regionalizations in hydrogeography today include almost all elements of the river regime, from the classical river basin classification by the way of their feeding, the time of occurrence of characteristic waters, the spatial distribution of water resources to hypsometric regionalisations, the regionalisation of the thermal regime, the amplitude of waters and the pollution of waters. Hydrological regionalization has great importance in the country's economic development plans, especially spatial plans. The most complex hydrological indicator is outflow, and in practice, the most commonly used is the specific outflow (q), which best expresses the general wealth of the territory with water and completely eliminates the impact of the size of the basin.

In this paper analyzed the aspect of waters regionalization based on the relationship between the islet outflow - altitude in the Una basin. The quantity and distribution of water in the altitude zones was determined, as well as the percentage share of the hypsometric zones in the formation of the total outflow, and then from the aspect of spatial regionalization, it was possible to perceive the distribution of water in the basin itself.

Key words: *altitude regionalization, hypsometric zones, precipitations, outflow, the Una River Basin*

INTRODUCTIONS

The first beginnings of hydrological regionalization in the region of former Yugoslavia, including Bosnia and Herzegovina, appeared in the second half of the 20th century and related to the analysis of the river regime. In regional and spatial planning, water and water resources analysis has a very high importance, in particular its location, exploitation and protection. According to Lj. Gavrilović (1988), starting from the fact that hydrological factors are the basic elements of the natural environment, hydrological research is one of the initial phases of spatial planning. They should provide fundamental results on the basis of which a range of human activities will be foreseen, with the aim of meeting the main needs of the population and the economy for water. Of all the natural potentials of the country, water is most endangered and contaminated, because they are most used. Therefore, this problem must come from several aspects. In addition to the regionalization of river regimes, it is necessary to conduct regionalization according to elements of water balance, altitude zoning of water, groundwater, sources, lakes, hydrographic network and water pollution. One of the special aspects of the study of the water regime is the determination of altitude layout and relations with users and pollutants (M. Ocokoljić, 1996). This scientific problem is very current today because man can find less healthy and drinking water in the lower, inhabited, and increasingly in mountainous areas. Here, the circumstance is used that the abundance of the river basin grows with height, and the number of pollutants decreases. Contemporary scientific methodology and practice require new regionalization based on one or more physicalgeographic parameters of the environment. From hydrographic objects, except the river, can be regionalized lakes (natural and artificial), groundwater sources, all elements of the water balance (precipitation, runoff, evaporation, infiltration, surface and subsurface runoff). The hydrographic network and its numerous features can also find places in mapping and separating homogeneous regions on various issues of its processing. Hydrological regionalization in Bosnia and Herzegovina was carried out in the wider context of the analysis of the basins that belong to the Black Sea and Adriatic basin according to various aspects, but specific regionalization towards the potamological elements of individual basins was not performed. Altitude regionalization in the Una basin is the first of its kind in Bosnia and Herzegovina.

HYDROGRAPHICAL SYSTEM OF UNA

The Una Basin is situated mostly in the territory of Bosnia and Herzegovina and, to a lesser extent, enters the territory of the neighboring Croatia. The spring of Una River, according to M. Spahic (1988), is a typical example of the watery and generous spring, from which the water flows from the outlet channels from the depth to the topographic surface. Most often this spring is found along the bottom of the karst sections where the underground channels were karstified from the surface to the interior. From the spring to Bihać, Una flows in the Dinaric direction, ie. from the southeast to the northwest, and then the flow of the river turns towards the northeast and continues to flow deep-sewed, wide valley. This direction retains all the way to Bosanska Kostajnica, from where it flows east to Bosanska Dubica. From this part to the mouth in Jasenovac, the Una occupies the meridian direction. The Una Basin covers an area of 9979.5 km^2. The right side of the basin is more developed, it has an area of 7451.8 km^2 and is richer with the river network, while the left side covers an area of 2527.7 km^2. The degree of asymmetry is 74.7: 25.3 (%) for the benefit of the right drainage area. The pronounced asymmetry of the basin stems from the complex geotectonic and geological structure of the terrain and the arrangement of certain morphostructures. Asymmetries to the Una Basin are greatly contributed by the basin of its tributary Sana, which if left out, the Una River Basin gets a symmetrical appearance. The Una and Sana valleys developed on the eastern and western periphery of the basin, thus framing the mountainous morphostructures of Grmeč. In addition to Sana, Una on her right side also receives her other larger tributary, Unac, which also affects large quantities of water coming from the right drainage area. The symmetry coefficient in this way indicates the size of the pluviometric regime in the basin. The

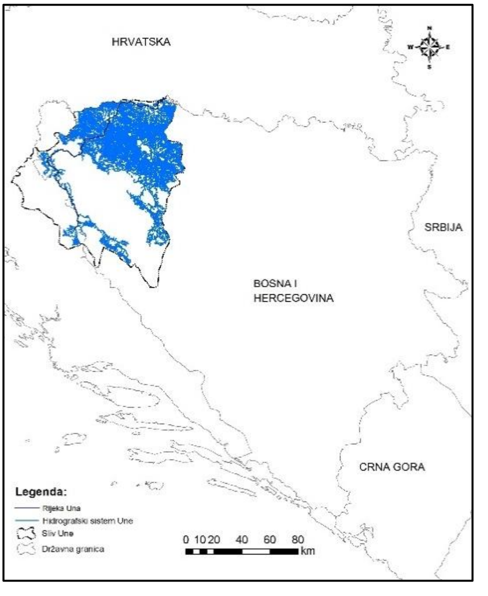

Fig.1. Geographical positions hydrographic system of Una

average height of Una is 598.98 m. The altitudes in the basin, i.e. the distribution of drainage areas according to the hypsometric levels, can be represented by the hipsographic curve of the Una River Basin (Figure 2).

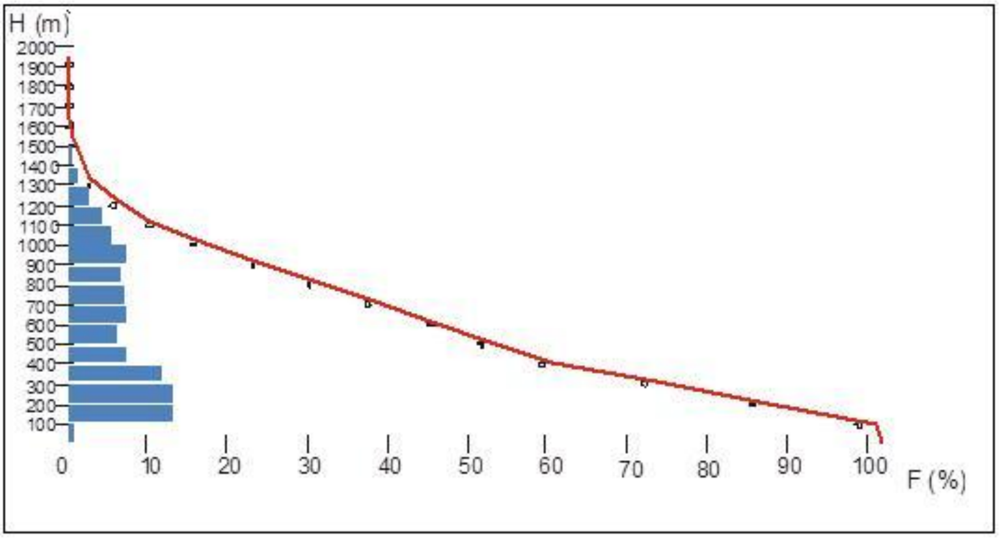

Fig. 2. Hypsographic curve of the Una River Basin

DISCUSSION AND RESULTS

For the purpose of hydrological regionalization, a comprehensive analysis of the territory of the Una Basin was carried out, i.e. all natural elements that influence the baseline are taken into account. These are primarily physicalgeographic factors - climate, geology, relief, soil and vegetation cover, and then the elements of water balance - precipitation and evaporation. The results of this paper, based on the analysis of the available water quantity on the surface of each zone of 100 m and relative outflows - elevation, were the leading factor for the regionalization of waters in hypsometric zones from the aspect of their quantity estimation and the share in the formation of the total flow of Una. The flow chart of the hypsometric zones in the Una Basin is calculated using the available amount of water per surface of each zone in the unit of time. Based on the amount of rainfall per 100 m of hypsometric zones and their surface, there was a breakdown of the available amount of water along the height zones, that is, to the conclusion that each hypsometric zone is involved in the water supply of the river flow. Outflows is in direct relation with the surface covered by a particular hypsometric zone. The geological base that dominates within each zone tends to have a predominant influence when it comes to outflows.

Based on an analysis of geological and hydrogeological characteristics, in the Una Basin, seven hydrogeological units, different permeability and transmissibility are distinguished: aquifers of crack-caucasian porosity, distinct karst aquifers, hydrogeological complexes predominantly without aquifer, intergranular porosity aquifers, cracking porosity aquifers, permeable rocks without aquifers and hydrogeological complexes with aquifers of mixed porosity (A. Korjenic, 2015).

Water permeability of the rocks directly influences the flow of water into the river flows from each altitude zone and then to the total participation in the Una flow. The greatest influence of the geological structure on the outflow of precipitation is in the basins whose larger or smaller areas are exposed to the karstification process, as is the case in the Una basin. The most intense is the impact in the lower part of the basin, where there are not many surface watercourses. Streams with deep-cut valleys of the canyon type are distinguished in this area. Precipitation rapidly sinks through numerous cracks and forms underground watercourses, which then spill onto the surface in the form of abundant karst springs. Evaporation of precipitation is low, and underground swelling is high. By analyzing the precipitation gradient in the Una Basin, according to monitoring data, it has been established that the legitimacy of the increase in precipitation with the rise of altitude may be defined. At the annual level, the average gradient value established by the link altitude - precipitation is 47.7 mm / 100 m.

Tab. 1. Participation of aquifer types in hypsometric zones in %

	intergranular porosity aquifers	**cracking porosity aquifers**	**aquifers of crack-caucasian porosity**	**hydrogeological complexes predominantly without aquifer**	**hydrogeological complexes with aquifers of mixed porosity**	**distinct karst aquifers**	**permeable rocks without aquifers**
0-100	0,00	0,00	1,26	1,90	96,84	0,00	0,00
100-200	4,14	13,96	16,95	52,49	7,94	0,03	4,49
200-300	10,27	30,94	19,03	11,38	12,63	0,79	14,96
300-400	28,16	32,53	10,81	2,64	12,63	0,50	12,73
400-500	34,19	25,46	9,50	1,22	17,40	0,44	11,79
500-600	36,03	19,90	7,49	3,24	28,18	0,72	4,44
600-700	39,58	17,85	2,64	13,55	25,37	0,50	0,51
700-800	53,28	13,91	3,20	3,11	25,90	0,49	0,11
800-900	52,89	13,27	2,28	1,26	28,00	2,29	0,01
900-1000	52,13	15,05	1,17	2,69	26,20	2,76	0,00
1000-1100	54,19	12,54	1,40	0,20	26,19	5,48	0,00
1100-1200	51,71	8,91	1,99	0,21	29,80	7,38	0,00
1200-1300	51,83	9,46	1,02	0,13	33,42	4,14	0,00
1300-1400	46,76	4,67	0,49	0,00	44,89	3,19	0,00
1400-1500	41,04	3,68	0,06	0,00	51,78	3,44	0,00
1500-1600	32,68	2,11	0,00	0,00	63,17	2,04	0,00
1600-1700	26,33	1,74	0,00	0,00	71,93	0,00	0,00
1700-1800	36,31	1,55	0,00	0,00	62,14	0,00	0,00
1800-1900	18,03	0,00	0,00	0,00	81,97	0,00	0,00
1900-2000	0,00	0,00	0,00	0,00	100,00	0,00	0,00

Source: Korjenić, Sivac, Okerić (2017)

Based on the amount of rainfall per 100 m of hypsometric zones and their surface, there was a breakdown of the available amount of water along the height zones, that is, to the conclusion that each hypsometric zone is involved in water supply of river flow. In order to obtain data on the effective amount of water, it was necessary to take into account the amount of water that evaporated from the Una basin area.

The actual evapotranspiration was calculated according to the Turc method, where up to the average annual temperature and temperature coefficient in the hypsometric zones was based on the vertical thermal gradient. By analyzing the actual evapotranspiration in hypsometric zones, the amount of available water in the catchment area is lower and amounts to 61.3% of the total quantity (A. Korjenić, 2014).

Tab. 2. Distribution of the available amount of water through hypsometric zones, including effective rainfall losses

Hypsometric zones	F (m^2)	Pef mm - l/m^2	m^3	m^3 (%)
0-100	86 830 000	400,0	34732000	0,47
100-200	1 373 310 000	448,9	616478859	8,41
200-300	1 374 310 000	502,6	690728206	9,43
300-400	1 207 630 000	595,0	718539850	9,80
400-500	781 470 000	664,1	518974227	7,08
500-600	633 760 000	730,0	462644800	6,31
600-700	785 460 000	776,9	610223874	8,32
700-800	749 530 000	839,7	629380341	8,58
800-900	674 680 000	900,5	607549340	8,29
900-1000	755 520 000	959,7	725072544	9,89
1000-1100	558 900 000	1029,0	575108100	7,84
1100-1200	454 110 000	1084,9	492663939	6,72
1200-1300	302 410 000	1149,4	347590054	4,74
1300-1400	148 710 000	1211,5	180162165	2,46
1400-1500	60 880 000	1271,8	77427184	1,06
1500-1600	24 950 000	1329,3	33166035	0,45
1600-1700	4 990 000	1375,4	6863246	0,09
1700-1800	2 000 000	1450,1	2900200	0,04
1800-1900	1 000 000	1510,2	1510200	0,02

The results of the calculation of the available amount of water in hypsometric zones, along with the actual losses of water by actual evapotranspiration, are shown in Table 2. By evapotranspiration is loss of 38.7 % of the total amount of precipitation per year. According to the obtained data, 7.3 billion m^3 of precipitation flow in the Una River, which is 4.6 billion m^3 less than the total amount of precipitation that is excreted in the catchment area. The average flow of the Una basin obtained through the Q = qF/1000 dependency is 232.5 m^3/s, while the average flow rate in the zones is 232.43 m^3/s.

It is noticeable that with the increase in the landing area, the flows increase. Given the small surface area of certain zones, regardless of the abundance of drainage area, the flows are small, for example, at a height of 1800 - 1900 m, it forms only 0.05 m^3/s of flow. The highest flow rate is given by the zone from 300 to 400 m, 22.8 m^3/s, although the largest coverage has a basin area on altitude 200-300 m. Flows increase with height increase, but in the mentioned zone, higher flow rate is affected by higher abundance of the basin and only slightly smaller area of the zone than the previous one. The summarized water survey in hypsometric zones shows that over 600 m (average height of the 598 m basin) forms 135.93 m^3/s of flows, or 58.5 % of the total Una water of the Una Basin.

Tab. 3. Flows and specific outflows according to effective precipitation (Pef), in hypsometric zones

Hipsometrijske zone	**Qef** *(m^3/s)*	**ΣQef** *(m^3/s)*	q_{ef} *(l/s/km^2)*
1800-1900	0,05	0,05	50,0
1700-1800	0,09	0,14	45,0
1600-1700	0,22	0,36	44,1
1500-1600	1,05	1,41	42,1
1400-1500	2,5	3,91	41,1
1300-1400	5,7	9,61	38,3
1200-1300	11,02	20,63	36,4
1100-1200	15,6	36,23	34,4
1000-1100	18,2	54,43	32,6
900-1000	22,9	77,33	30,3
800-900	19,3	96,63	28,6
700-800	19,9	116,53	26,5
600-700	19,4	135,93	24,7
500-600	14,7	150,63	23,2
400-500	16,5	167,13	21,1
300-400	22,8	189,93	18,9
200-300	21,9	211,83	15,9
100-200	19,5	231,33	14,2
0-100	1,1	**232,43**	12,7
Sliv Une	**232,5**		**23,3**

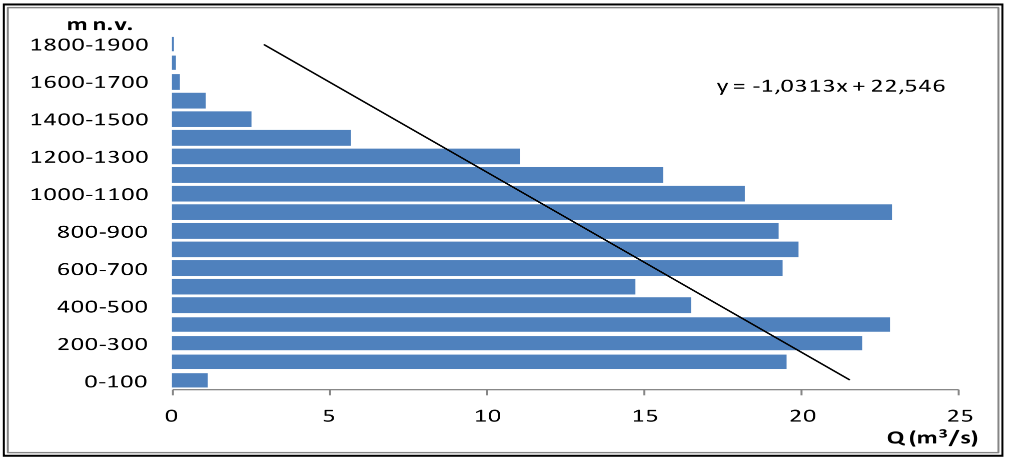

Fig. 3. Hypsohydrogram of flow

The average specific outflows for the Una basin is 23.3 l/s/km^2, according to the obtained flow. As the amount of precipitation decreases, the value of the specific outflow decreases. Reduces non-linearly, so for example, the basin area at altitudes of 1800 - 1900 m gives 50 l/s/km^2, and the lowest areas (up to 100 m) 12.7 l/s/km^2.

In the zone up to 400 m, which makes up about 40% of the surface of the basin, and about 28% of the precipitation is excreted to it, the most frequent are the cracking porosity aquifers that are poorly water permeable, as well as the hydrogeological complexes predominantly without aquifers, which causes higher a surface river network on this hypsometric level. In an area above 400 m above sea level, which includes for almost 60 % of the total area of the basin, around 72 % of the total precipitation is distributed across all zones. In these zones above 400 m above sea level, in hydrogeological terms, predominantly are the aquifers of intergranular porosity and hydrogeological complexes with mixed porosity aquifers that are characterized by good water permeability.

Tab. 4. Regional units in the Una Basin

Regional units	**Zone to 400 m**	**400 – 1400 m**	**Above 1400 m**
Participation in the total area of the basin (%)	40,5	58,6	0,9
Participation in the total amount of precipitation (%)	28,1	70,2	1,7
The dominant type of aquifer	Aquifers of crack-caucasian porosity which are low permeability to impermeable, as well as impermeable hydrogeological complexes without aquifers (a larger surface river network)	Intergranular porosity aquifers and permeable rocks without aquifers and of mixed porosity	
q (l/s/km^2)	< 20	20 – 40	> 40
Q (m^3/s)	65,3 ili 28,1 %	163,2 ili 70 %	3,91 m^3/s ili1,9%

According to the obtained flow values, the average specific outflow for the Una basin was derived, and based on the obtained calculations, it can be concluded that the specific outflow of the catchment is growing from the lowest to the highest point. Although the gradient of the specific outflow is nonlinearly increased, on average by 1.99 l/s/km^2 for every 100 m, its changes are not the same at all heights. There is a steady increase in zones between 400 m and 1400 m, while below 400 m and above 1400 m these changes are uneven (larger or less than average).

By analyzing the listed parameters of the river regime in the Una basin, three regional units can be distinguished when it comes to hypsometric water zoning (Figure 4). Depending on the area they occupy, these units differ, except in the amount of available precipitation and in the structure and the course of specific outflows and flows.

The first unit is a zone that covers an area of up to 400 m above sea level, with a specific outflow up to 20 l/s/ km^2. This is a space that comprises 40.5 % of the total area of the basin, and on which a total flow of 65.3 m^3/s or 28.1 % is formed. The second regional unit is a zone from 400 m to 1400 m. It covers 58.6 % of the territory of the basin, with average annual specific outflows of 20-40 l/s/km^2 and the amount of flows that is 163.2 m^3/s, which is 70 % of the total flow. Of the total Una basin area, only 0,9 % belongs to the third regional unit, zone above 1400 m, with specific outflows greater than 40 l/s/km^2 and the smallest total flow of only 3.91 m^3/s or 1.9 %.

When it comes to the total amount of precipitation that is excreted over these units, the first zone participates with 28.1 %, in the second one 70.2 % is eliminated, while in the third region unit only 1.7 % of the precipitation is excluded.

CONCLUSION

Modern studies have to deal with the aspect of hypsometric water regionalization, which has not been the case for the Una basin area. In this sense, the need to determine the quantity and distribution of water in the hypsometric zones, as well as the percentage share of the hypsometric zones in the formation of the total outflow, was imposed. The second aspect of the analysis was related to the altitude distribution of the specific outflow depending on the representation of individual lithologic-hydrological complexes, or types of aquifers. Also, the aspect of spatial regionalization made it possible to overview the distribution of water in the basin itself, on the basis of which a wider picture of the status of the wateriness of individual regional units was obtained.

Drawing on the solution of the problems related to obtaining the value of the elements of the river regime in hypsometric zones, the basic parameter was the determination of the value and variability of the precipitation quantity. At the same time, insufficient number of monitoring stations have been identified as the main problem, especially those at higher altitudes. In order to determine the altitude distribution of water, the hypsogram of basin and the regional dependence of the specific outflow from the average altitude of the basin were used.

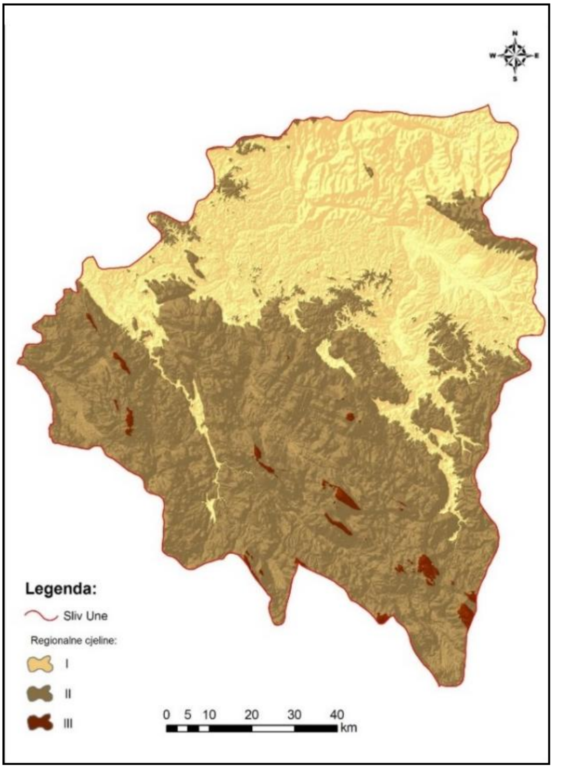

Fig. 4. Regional units in the Una River Basin according to the hypsometric distribution of the waters who participating in the Una flow

The results of the basic hydrological studies find the greatest application in the exploitation of water for the supply of settlements and various branches of economy, water and watercourse regulation, preservation and protection of water quality, consideration of the impact of urbanization on the entire hydrological cycle, forecasting the utilization of water resources and hydrological phenomena and processes, hydrological regionalization and mapping hydrological objects and phenomena. The taking of hydrological indicators for the basis of regionalization has a good side in that they are essentially quantitative and exclude subjective assessments in the allocation of hydrological regions, and therefore, hydrological regionalization, as a special type of physical-geographic regionalization, gives a special scientific quality.

In the end, it should be emphasized that for all further comprehensive research, not only this, but also other basins in the territory of Bosnia and Herzegovina, it is necessary to establish continuous monitoring in all hypsometric zones.

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Author

Aida Korjenić, doctor of geographical sciences, assistant professor at the Faculty of Science, University of Sarajevo, Bosnia and Herzegovina. Scientific Area - physical geography, regional and spatial planning. Held classes from Hydrography, Oceanography, Climat and Water in the regional and spatial planning.