DOI: 10.2507/34th.daaam.proceedings.xxx

STATISTICAL ANALYSIS OF HYDROLOGICAL PARAMETERS IN THE BOSNA RIVER BASIN

Ismira Ahmović, Halima Hadžiahmetović, Rejhana Blažević, & Mirela Alispahić

This Publication has to be referred as: Ahmović, I[smira]; Hažiahmetović, H[alima]; Blažević, R[ejhana] & Alispahić, M[irela] (2023). Statistical analysis of hydrological parameters in the Bosna River basin, Proceedings of the 34th DAAAM International Symposium, pp. xxxx-xxxx, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/34th.daaam.proceedings.xxx

Abstract

The occurrence of extreme precipitation, floods, and dry periods, according to all forecasts, will probably become more frequent both in Europe and in Bosnia and Herzegovina. For this reason, it is necessary to consider climate change when designing infrastructure facilities. Following this, this paper aims to assess the flow rate data based on the daily measured values obtained at the Reljevo hydrological station on the Bosna River. The analyses are conducted for two periods (1961-1990 and 2000-2010) to obtain the temporal distribution of relevant flow rate data. For observed periods, analysed data are compared, and the coincidence of hydrological parameters along the perceived changes is observed. Significant monthly and yearly variations are observed based on the analysis of variance (ANOVA) applied to the flow rate data for observed periods. As a result, maximum flow rates are found in the summer period (March and April mainly), which should be considered in flood management.

Keywords: climate change; analysis of variance (ANOVA); hydrological parameters; two-factorial experimental design method

1. Introduction

The hydrological cycle is part of the climate system and is sensitive to climate change. Sometimes, insignificant climate changes lead to significant changes in hydrological processes [1]. Global warming refers to the increase in the average planet's surface temperature caused primarily by the emission of gases from fossil fuel combustion since the Industrial Revolution. However, climate change refers to long-term (a period of several decades or longer) changes that concern changes in temperature, precipitation and wind [2]. According to the Intergovernmental Panel on Climate Change (IPCC), climate change is observed as statistically significant changes expressed by changes in mean values and variability of observed properties, which can last for a period of time (a decade or more) [3]. The observed climate changes, published in the sixth report of the IPCC, are as follows: from 2011 to 2020, global surface temperature increased by 1,09°C (0,95°C to 1,20°C). In that period, more noticeable increase in temperature was over land (by 1,59°C) than over the ocean (by 0,88°C). Since the 1950s the frequency and intensity of heavy precipitation events have increased over most land area for which observational data are sufficient for trend analysis, with even faster rate of increase since the 1980s. In the period from 2010 to 2019 compared to the period 1979-1988, there was an increase in the average amount of precipitation on land and a decrease in the Arctic sea ice area of about 40% in September and about 10% in March. From 1901 to 2018, as a consequence of the increase in temperature, there was a rise in the mean sea level of 0,2 m. Rise in the mean sea level during the early 1900s was due to natural factors, however since 1970s, dominant cause of global average sea level rise were human activities [4]. Hydrological cycle parameters such as evapotranspiration, soil moisture and runoff are sensitive to small changes in temperature and precipitation [5], [6], [7]. River flow forecasts are essential for extreme water management, policy-making, and sustainable water resource management practices [8], [9].

Generally, climatic changes have been observed in Bosnia and Herzegovina during all seasons since 1981. Based on previous research, from 1961 to 2010, the temperature has increased in all regions of Bosnia and Herzegovina [10]. In the last hundred years, the average annual temperature has increased by about 0.6 °C [11]. As for the precipitation quantity, from 1981 to 2010, a slight increase in annual values has been observed compared to 1961-1990 [11]. Trends of five to twenty-day periods of extreme hot/cold weather have been observed; the same trends are noticed for intense drought/rainfall periods. Intensive droughts have been recorded in 2000, 2003, 2007, 2011 and 2012. In addition to observed temperature and precipitation changes, future climate scenarios predict significant changes in the magnitude and frequency of climatic extremes, such as storms accompanied by hail, devastating effects of wind, floods, long-term droughts, heat waves, and extremely high and low temperatures. The Bosna River forms at the foot of the Igman Mountain at an altitude of about 500 meters. Figure 1 shows the basin of the Bosna River, which is 273 km long and 35-170 m wide. Its average drop is 1,48 m/km, and the average flow rate is 100 m³/s. The main tributaries on the right side of the river Bosna are Miljacka (35,9 km), Krivaja (101 km), Željeznica (26.9 km), Spreča (137,5 km) and Stavnja (30,4 km), while on the left side are the Usora (82 km), Lašva (49,4km) and Fojnička river (46km).

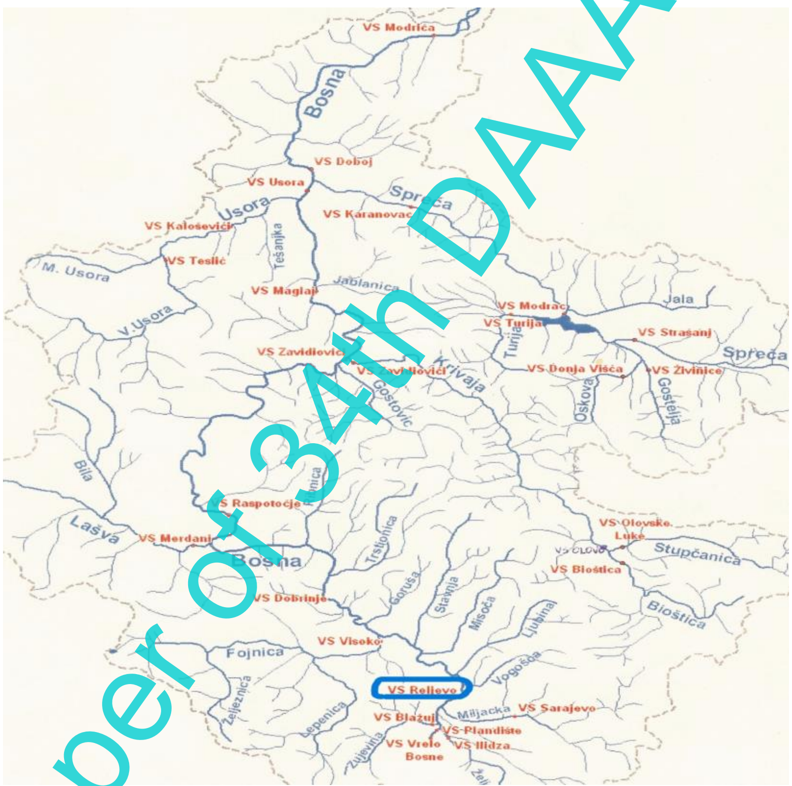

Fig. 1. River Bosna basin [12]

In this paper, the impact of climate change on the flow rate on the Bosna River is analysed. For this purpose, a statistical analysis of the flow parameters was carried out based on the measured values of daily flows at the Reljevo hydrological station on the Bosna River. The analysis was conducted for two different time periods (1961-1990 and 2000-2010) to obtain the temporal distribution of relevant flow rate data.

2. Research method

Different techniques are used to analyse the data sets collected during long periods (10 or 30 years). For the study, the two-factor factorial experimental design techniques was used where one factor was years (*a*-level), and the other was months (*b*-level). Statistical analysis provides a temporal distribution of relevant flow rate in two periods, 1961-1990 and 2000-2010, and warns of possible scenarios in the future [13], [14]. The experiment's purpose is to check whether a certain variable affects a clearly defined phenomenon as the dependent variable. An independent variable (experimental variable) is a factor that is intentionally varied in the experiment to see if it affects the dependent variable. The analysis includes flows at the Reljevo hydrological station. The statistical analysis of the two-factor factorial involves only two factors, say A and B, one factor being years (a-level) and the second factor being months (b-level). Analysis of variance (ANOVA) is shown in Table 1. It is assumed that A and B are fixed factors, and a is the level of factor A and b is the level of factor B, specially selected by the researcher and the conclusions are limited to these levels only.

Source of variation	Sum of Squares	Degrees of Freedom	Mean value	F_0
A Treatment	SS_A	$(a-1)$	$MS_A = \frac{SS_A}{a-1}$	$\frac{MS_A}{MS_E}$
B Treatment	SS_B	$(b-1)$	$MS_B = \frac{SS_B}{b-1}$	$\frac{MS_B}{MS_E}$
Interaction	SS_{AB}	$(a-1)(b-1)$	$MS_{AB} = \frac{SS_{AB}}{(a-1)(b-1)}$	$\frac{MS_{AB}}{MS_E}$
Error	SS_E	$ab(n-1)$	$MS_E = \frac{SS_E}{ab(n-1)}$	
Total	SS_T	$(abn-1)$		

Table 1. ANOVA table two-factor factorial experimental design [12]

The hypothesis that were tested are [15]:

1. H_0: $\tau_1 = \tau_2 = ... = \tau_a = 0$ (no effect of factor A)
   H_1: at least one $\tau_i \neq 0$
2. H_0: $\beta_1 = \beta_2 = ... = \beta_b = 0$ (no effect of factor B)
   H_1: at least one $\beta_i \neq 0$
3. H_0: $(\tau\beta)_{11} = (\tau\beta)_{12} = ... = (\tau\beta)_{ab} = 0$ (no interaction)
   H_1: at least one $(\tau\beta)_{ij} \neq 0$

Analysis of Variance (ANOVA) is a hypothesis testing procedure used to decompose the total variability of the data into its components and then compare the different decomposed elements. The total variability is calculated according to the expression (1) [15]:

$$SS_T = SS_A + SS_B + SS_{AB} + SS_E \tag{1}$$

From the previous equation, it can be seen that the overall sum of squares (SS_T) consists of the sum of squares for factor A (SS_A), the sum of squares for factor B (SS_B), the sum of squares for the interaction between factors A and B (SS_{AB}) and residual sum of squares (i. e. the sum of squares error, SS_E). The total number of degrees of freedom is $(abn-1)$. The main effects of factors A and B have $(a-1)$ and $(b-1)$ degrees of freedom, while the interaction effect of factor AB has $(a-1)(b-1)$ degrees of freedom. In each of the ab cells, in Table 1, there are $(n-1)$ degrees of freedom between n repetitions. Observations in the same cell may differ only due to random error, and we have $ab(n-1)$ degrees of freedom for error. Therefore, the degrees of freedom are distributed according to equation (2) [15]:

$$abn - 1 = (a-1) + (b-1) + (a-1)(b-1) + ab(n-1) \tag{2}$$

If each sum of squares on the right side of the equation is divided by the corresponding number of degrees of freedom, the mean square value for AB, interaction and error is obtained [15].

$$MS_A = \frac{SS_A}{a-1} \qquad MS_B = \frac{SS_B}{b-1}$$
$$MS_{AB} = \frac{SS_{AB}}{(a-1)(b-1)} \qquad MS_E = \frac{SS_E}{ab(n-1)} \tag{3}$$

In order to test that all effects of factor A are equal to zero (H_0: $\tau_i = 0$), the following relationship is used:

$$F_0 = \frac{MS_A}{MS_E} \tag{4}$$

which has F – distribution with $(a-1)$ and $ab(n-1)$ degrees of freedom if H_0: $\tau_i = 0$ is true.

This null hypothesis is rejected at α significant level if $f_0 > f_{\alpha,a-1,ab(n-1)}$. Similarly, to test the hypothesis that all effects of factor B are equal to zero (H_0: $\beta_i = 0$), the relationship is used:

$$F_0 = \frac{MS_B}{MS_E} \tag{5}$$

which has F – distribution with $(b-1)$ and $ab(n-1)$ degrees of freedom if H_0: $\beta_i = 0$ is true.

This null hypothesis is rejected at α significant level if $f_0 > f_{\alpha,b-1,ab(n-1)}$. Finally, to test the hypothesis H_0: $(\tau\beta)_{ij} = 0$, i.e. hypothesis that all interaction effects are equal to zero, the relationship is used:

$$F_0 = \frac{MS_{AB}}{MS_E} \tag{6}$$

which has F – distribution with $(a-1)(b-1)$ and $ab(n-1)$ degrees of freedom if H_0: $(\tau\beta)_{ij} = 0$ is true. This null hypothesis is rejected at α significant level if $f_0 > f_{\alpha,(a-1)(b-1),ab(n-1)}$.

It is usually better to test for interaction first and then estimate main effects. If the interaction is not significant, interpretation of tests for main effects is required. However, when the interaction is significant, the effects of the main factors involved in the interaction may not have significant practical interpretive value [16].

2.1. Application of t-test

The t-test is used to determine if there is a statistically significant difference between the means of two samples and is valid only when both samples are obtained from a normally distributed population. It is true in many practical cases where there has been a change in working conditions with a need to determine if there is a significant change in those conditions. The first step is to determine the means of $\overline{x}_1$ and $\overline{x}_2$ for the two samples. The standard deviation is obtained based on the expression:

$$s^2 = \frac{\sum(x_1 - \overline{x_1})^2 - \sum(x_2 - \overline{x_2})^2}{n_1 + n_2 - 2} \tag{7}$$

Where x_i refers to any experimental value in the first sample and x_2 to any in the second sample, and the sample sizes are n_1 and n_2, respectively.

Usually, it is easier to calculate with a modified expression:

$$s^2 = \frac{\sum x_1^2 + \sum x_2^2 - \frac{1}{n_1}(\sum x_1)^2 - \frac{1}{n_2}(\sum x_2)^2}{n_1 + n_2 - 2} \tag{8}$$

After determining standard deviation, ***t*** is obtained as follows:

$$t = \frac{\overline{x_1} - \overline{x_2}}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \tag{9}$$

The obtained value for *t* is compared with the tabled value for t_α, at the required confidence level with $(n_1 + n_2 - 2)$ degrees of freedom. If $t > t_\alpha$ there is a significant difference between the mean values.

2.2. Hydrological and meteorological analysis

The analysed temperature and precipitation data in [12] didn't indicate extreme climatic events, like heat waves or heavy precipitation. The analysis of climatic conditions for the previously discussed periods shows moderate high temperatures in summer and moderate low temperatures in winter, with seasonal variations. Also, this affects the hydrological cycle (occurrence of droughts and floods). Water and climate variability already pose a risk due to flooding. The Bosna River basin is exposed to occasional floods, which cause significant damage to the economy.

The Reljevo hydrological station is located on the downstream side of the bridge over the Bosna River in the Reljevo settlement. It was founded in 1904. It stopped working in 1991 and was rebuilt at the end of 1998 with the same profile and the same ground-level zero. The area of the basin is 1094 km^2 [12]. There are anthropogenic effects on the Bosna River upstream of the Reljevo hydrological station, but there are insignificant on the river flow at the Reljevo site. Željeznica River, the right tributary of the Bosnia River (ca. 8,5 km upstream from Reljevo hydrological station), is affected by the Bogatići hydroelectric power plant.

3. Results and discussion

The cumulative monthly and annual flow rate data at the hydrological Reljevo station are investigated. By comparing data for two periods, possible changes in distribution can be observed, as well as significant changes that occurred in the past in the observed area. The mean flow rate values during the two analyzed periods, 1961-1990 and 2000-2010, are shown in Tables 2 and 3.

Num.	WB / vatercourse	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Qm.a.
1	Reljevo / Bosna	29,2	33,4	40,3	51,5	43,4	24,2	15,8	11,7	13,9	20,5	28,8	34,8	28,9

Table 2. Average monthly and annual flows (m^3/s) from 1961-1990

Table 2 shows the values of average monthly and annual flows for the period from 1961 to 1990. Based on a thirty-year analysis, it is evident that the average monthly flow rate values are high in the spring season (March, April and May), followed by a gradual decrease in the summer season. The maximum mean monthly flow rate value is in April, 51,5 m^3/s. After a gradual drop in flow rates in June, July and August, the increase is observed again in September. The increase in flow rates continues in October, November and December. A slight drop in flow rates is noticed in January, after which flow rate values increase in February. The average annual flow rate based on a thirty-year analysis is 28,9 m^3/s.

Num.	WB / vatercourse	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Qm.a.
1	Reljevo / Bosna	32,5	28,5	49,9	54,5	31,1	20,4	13,0	10,8	16,0	24,3	29,0	40,6	29,2

Table 3. Average monthly and annual flows (m^3/s) from 2000-2010

For the period from 2000-2010, the average monthly and annual flow rates are shown in Table 3. Based on the ten-year analysis, it is evident that the average monthly flow rate values follow the same trend as previously discussed: higher values in March, April and May, with a maximum mean monthly flow rate in April (54,5 m^3/s), followed by a gradual decrease during the summer season. The growth trend continues during September, October, November and December, followed by a slight drop in flow in January. The average monthly flow based on a ten-year analysis is 29,2 (m^3/s).

According to the current Water Law [17], the ecologically acceptable flow rate is determined as the minimum average monthly flow is 95 % of the probability of occurrence based on the hydrological characteristics of the water body for observed seasons. The ecologically acceptable flow rate for the Reljevo hydrological station is 4,96 m^3/s.

By comparing the monthly mean and annual mean flow rate values for the observed periods at the Reljevo hydrological station, a decreasing trend in mean values can be observed from May (V) to August (VIII) in the 2000 to 2010 period and the opposite trend from March (III) to April (IV) and then from September (IX) to December (XII). However, no significant differences are observed in average annual flow rates for 1961-1990 compared to the 2000-2010 period.

Statistical analysis factorial experiment includes only two factors A and B. For factor A it is always 36 (number of months, b = 12, times number of repetitions, n = 3). For factor B, it is 90 or 30 (number of years a = 30 or 10 and n = 3). The variance analysis (ANOVA) of the flow rate data measured at the Reljevo hydrological station for the two analysed periods from 1961 to 1990 and from 2000 to 2010 is shown in Tables 4 and 5.

In Tables 4 and 5, in addition to the obtained F_o values for individual factors, values for F_t were also calculated (two-tailed t-test). The obtained F_o values are higher than F_t values, and there is a significant difference at the new confidence level of 95 % (α= 0.05). The F_o values for treatment B are higher than F_t as expected because changes in precipitation quantity are significant during the observed period.

Source of variation	**Sum of Squares**	**Degrees of Freedom**	**Mean value**	F_o	F_t
A Treatment	39939,952	29	1377,240	6,732	1,47
B Treatment	152299,701	11	13845,427	67,672	1,80
Interaction	184252,684	319	577,595	2,823	1,18
Error	147308,847	720	204,596		
Total	523801,184	1079			

Table 4. ANOVA two-factor factorial experimental design (flow rate for the period 1961-1990)

Source of variation	Sum of Squares	Degrees of Freedom	Mean value	F_o	F_t
A Treatment	7186,780	9	798,531	2,764	1,92
B Treatment	62152,786	11	5650,253	19,561	1,81
Interaction	46928,783	99	474,028	1,641	1,31
Error	69324,880	240	288,854		
Total	185593,229	359			

Table 5. ANOVA two-factor factorial experimental design (flow rate for the period 2000-2010)

All cumulative values presented in the paper were obtained as part of the output in the programming language C++ for the two-factorial experimental design. Figure 2 shows the cumulative yearly flow rate values at the Reljevo hydrological station from 1961 to 1990 period. The minimum cumulative flow rate recorded in 1990 is 644, while the maximum cumulative flow value recorded in 1978 is 1599,3.

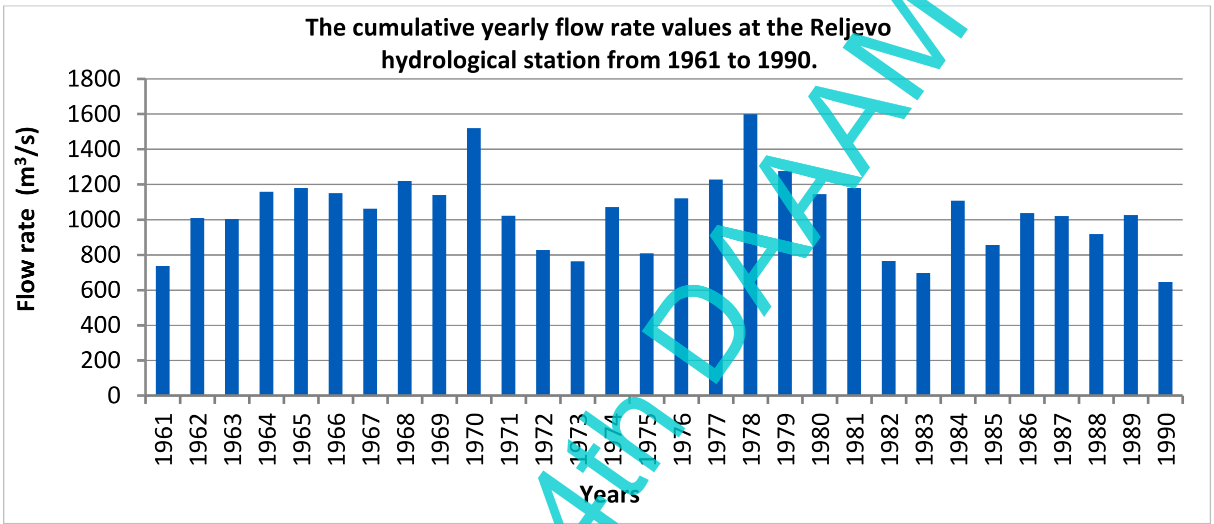

Fig. 2. The cumulative yearly flow rate values at the Reljevo hydrological station from 1961 to 1990

Figure 3 shows the cumulative flow rate values at the Reljevo hydrological station from 2000 to 2010. The maximum cumulative value flow rate recorded in 2006 is 1369,5 m^3/s, while the minimum value recorded in 2004 is 788 m^3/s.

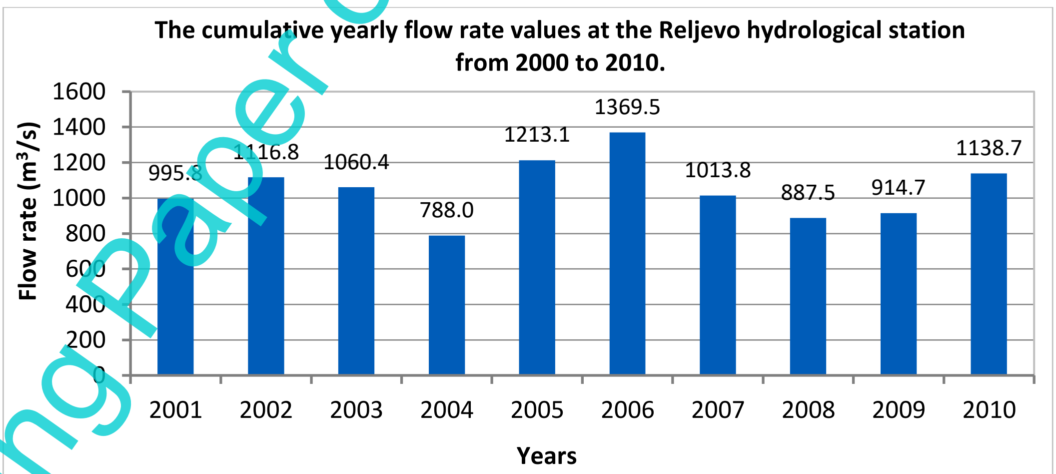

Fig. 3. The cumulative yearly flow rate values at the Reljevo hydrological station from 2000 to 2010

Based on the analysis of both periods, the change in absolute maximum flows from 1961 to 1990 hasn't been observed. Figure 4 shows the cumulative monthly value at the Reljevo hydrological station from 1961 to 1990. In January, the measured value of the flow was 2638,9 m^3/s, followed by a slight increase in the flow rate in February to 3011,5 m^3/s. In

March and April, the trend of increasing flow rates continues. The cumulative flow value from 1961-1990 reached its maximum in April as 4630,9 m^3/s. The possible reason for the increase in the flow rate is the rise in temperatures and the snow melting. From May to September, the flow rate gradually decreases. There is a slight increase in the flow rate due to rainfall in September. The trend of increasing flow rates continues in October 1847,6 m^3/s, November 2596,3 m^3/s and December 3126,2 m^3/s.

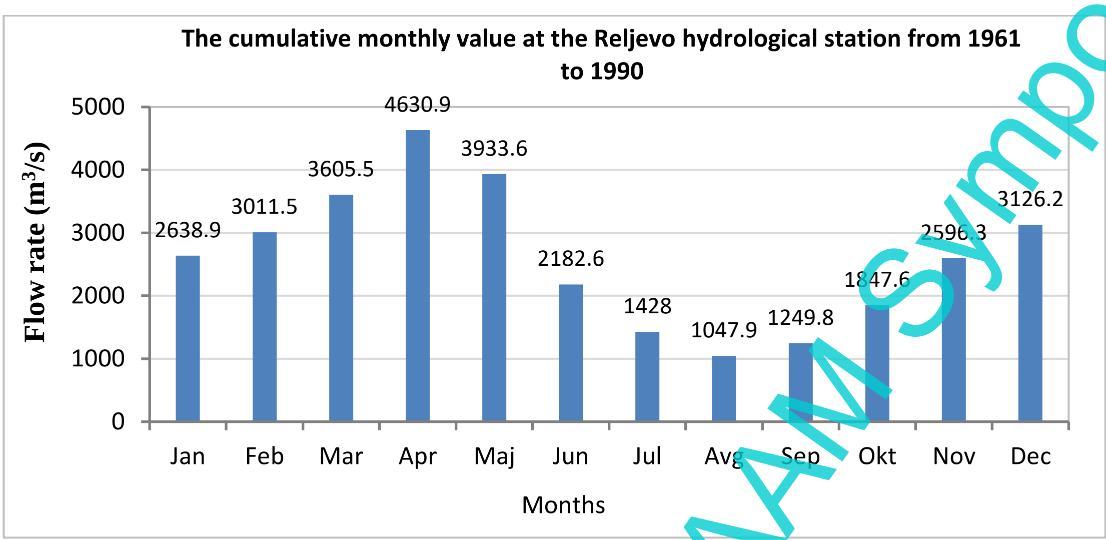

Fig. 4. The cumulative monthly value at the Reljevo hydrological station (1961-1990)

Figure 5 shows the cumulative monthly value at the Reljevo hydrological station from 2000 to 2010. In January, the measured value of the flow rate was 971,9 m^3/s, followed by a slight decrease in the flow rate in February to 856,5 m^3/s. In the following months (March and April), the flow rate values were increased to 1484,7 m^3/s and 1634,9 m^3/s, respectively. The flow rate values reached their maximum in March and April due to the sudden rise in temperatures and melting snow. In May, the measured value of the flow rate was 938,9. In June (611 m^3/s), July (391,3 m^3/s) and August (323 m^3/s), the trend of decreasing flow rates continues. There was a slight increase in flow rate in September (479 m^3/s). This increasing trend continues from October (724,1 m^3/s) until the end of the year.

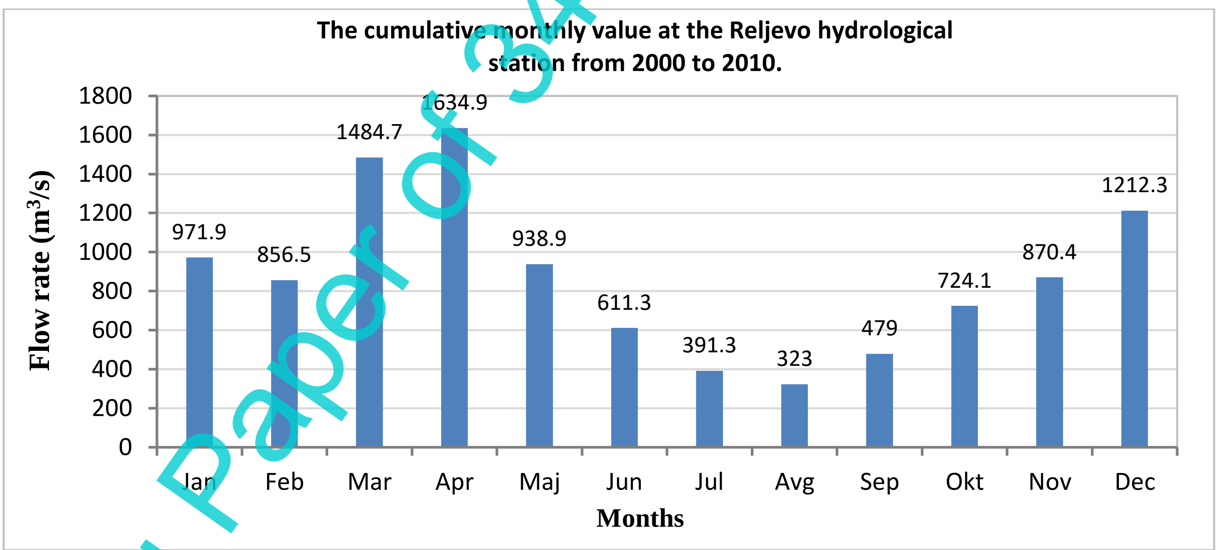

Fig. 5. The cumulative monthly value at the Reljevo hydrological station (2000-2010)

4. Conclusion and further work

Climate change represents one of the main challenges of today. Many relevant institutions (IPCC) have recognized the problem of climate change with its complexity. Bosnia and Herzegovina is involved in several studies, but a regional climate assessment model still does not exist. Since climate models have advantages and disadvantages, we cannot expect them to "predict" the future. However, the global models of the future climate for Bosnia and Herzegovina indicate significant changes in climate conditions. During the 20th century, a trend of decreasing precipitation was observed, and it is difficult to understand if it is the result of natural climatic fluctuations or is due to human influence. Water and climate variability already represent a risk due to floods, and Bosnia and Herzegovina have been exposed to occasional floods that cause significant damage to the economy.

In this paper, based on the ANOVA tables for flow rates for both observed periods in Reljevo station, there have been variations by year and more significant by month. The approximation of the flow rates by a parabola is not satisfactory due to the existence of maxima and minima, and for this purpose, a third-order polynomial should be used. The analysis showed that the maximum flows are mainly in March and April. The increase in flow rates in spring months is due to increased precipitation and snow melting due to a rise in air temperature. As a result of statistical analysis, the increasing flow rate is observed from 2000 to 2010 compared to the period from 1961 to 1990.

The cause of the increase in precipitation in most cases, and therefore water rise and floods, is climate change due to the increase in the concentration of greenhouse gases. The construction of large hydrotechnical systems causes changes in water regimes and also influences the occurrence of floods. Authorities that prepare water resource management plans should include the possible effects of climate change in their planning. This problem may require further development of specific information – such as regional climate models development in flood protection planning, groundwater recharge and river flows. There is very little data on the effects of climate variability, either direct or indirect, so in the future, it would be useful to analyse other climate variables (temperature and precipitation) to get a clearer picture of climate yearly variability.

5. References

[1] Hattermann, F. F.; Vetter, T., Breuer, L.; Su, B., Daggupati, P.; Donnelly, C.; Fekete, B.; Florke, F.; Gosling, S. N.; Hoff-mann, P.; Liersch, S.; Masaki, Y.; Motovilov, Y.; Muller, C.; Samaniego, L.,; Stacke, T.; Wada, Y.; Yang, T. & Krysnaova, V. (2018). Sources of uncertainty in hydrological climate impact as-sessment: A cross-scale study. Environmental Research Letters, Vol. 13, No. 1, 015006. https://doi.org/10.1088/1748-9326/aa9938.

[2] Leiserowitz A.; Maibach E.; Rosenthal S.; Kotcher J.; Carman J.; Neyens L.; Myers T.; Goldberg M.; Campbell E.; Lacroix K. & Marlon J. (2022). Politics & Global Warming, April 2022. Yale University and George Mason University. New Haven, CT: Yale Program on Climate Change Communication.

[3] IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team; Pachauri, R.K. & Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

[4] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.; Zhai, A.; Pirani, S. L.; Connors, C.; Péan, S.; Berger, N.; Caud, Y.; Chen, L.; Goldfarb, M.I.; Gomis, M.; Huang, K.; Leitzell, E.; Lonnoy, J. B. R.; Matthews, T. K.; Maycock, T.; Waterfield, O.; Yelekçi, R. Yu & B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi: 10.1017/9781009157896.001

[5] Chattopadhyay, N. & Hulme, M. (1997). Evaporation and Potential Evapotranspiration in India under Conditions of Recent and Future Climate Change. Agricultural and Forest Meteorology, Vol. 87, No. 1, pp. 55-73. http://dx.doi.org/10.1016/S0168-1923(97)00006-3.

[6] Milly, P.C.D.; Dunne, K.A. & Vecchia, A.V. (2005). Global Pattern of Trends in Streamflow and Water Availability in a Changing Climate. Nature, Vol. 438, pp. 347-350. http://dx.doi.org/10.1038/nature04312

[7] Seneviratne, S. I.; Corti, T.; Davin, E. L.; Hirschi, M.; Jaeger, E. B.; Lehner, I.; Orlowsky, B. & Teuling, A. J. (2010). Investigating soil moisture-climate interactions in a changing climate: A review, Earth Science Reviews, Vol. 99, No. 3-4, pp. 125–161, doi:10.1016/j.earscirev.2010.02.004.

[8] Meresa, H. K. & Gatachew, M. T. (2019). Climate change impact on river flow extremes in the Upper Blue Nile River basin. Journal of Water and Climate Change, Vol. 10, No. 4, pp. 759-781. https://doi.org/10.2166/wcc.2018.154.

[9] Meresa, H. K. & Romanowicz, R. J. (2017). The critical role of uncertainty in projections of hydrological Extremes. Hydrology and Earth System Sciences, Vol. 21, No. 8, pp. 4245–4258. https://doi.org/10.5194/hess-21-4245-2017

[10] Ahmovic, I.; Dzaferovic, E. & Hadziahmetovic, H. (2018). Analysis of Temperature Data in the Area of the City of Sarajevo (Bjelave) in Period From 2000-2010, Proceedings of the 29th DAAAM International Symposium, pp. 0260-0266, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-20-4, ISSN 1726-9679, Vienna, Austria. doi: 10.2507/29th.daaam.proceedings.037

[11] Radusin, S.; Oprašić, S.; Cero, M.,; Abdurahmanović, I. & Vukmir, G. (2013). Climate change adaptation and low-emission development strategy for Bosnia and Herzegovina. Sarajevo: Ministry of Foreign Trade and Economic Relations, 82, pp. 17-21.

[12] Ahmović, I. (2014). Climate change and their influence on the water regime in Bosnia and Herzegovina, with special focus on the Sarajevo field, Master thesis, Faculty of Mechanical Engineering Sarajevo, Sarajevo, Bosnia and Herzegovina.

[13] Bajramović, R. (2003). Determination of critical values in normal and *t* - distribution, Mašinstvo, Vol. 2, No. 7, pp. 93-104.

[14] Hayter, A.J. (2012). Probability and Statistics for Engineers and Scientists, Thomson Brooks/Cole, ISBN 9781133112143, Boston, USA.
[15] Montgomery, D.C. & Runger, G.C. (2018). Applied Statistics and Probability for Engineers, 7th Edition, John Wiley & Sons, Inc., ISBN 978-1-119-40036-3, New York, USA.
[16] Montgomery, D.C. (2001). Design and Analysis of Experiments, 5th Edition, John Wiley & Sons Ltd., ISBN 978-0471316497, New York, USA.
[17] Zakon o vodama FBiH (2006). Službene novine FBiH", br. 70/06.