STATISTICAL ANALYSIS OF ANNUAL WATER DISCHARGE OF JABLANICA AND TOPLICA RIVERS

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Abstract: The rivers of Jablanica and Toplica are left tributaries of the Južna Morava. Their catchment area comprises left of the west half of the Južna Morava basin. Regionally-wise, it represents Topličko-Jablanička micro-region, which is a part of meso-region of Southern Pomoravlje. The paper discusses the data on discharge from the hydrological station Pečenjevce (on Jablanica river), which is located 3 km from the confluence with the Južna Morava and hydrological station Pepeljevac (on Toplica river), located at 69.5 km from the confluence with the Južna Morava. The data used for the analysis of flow are taken from the Hydrological Yearbook RHSS and cover the period 1950-2012 (Jablanica) and the period 1951-2012 (Toplica). The evidenced statistically significant changes in annual water discharge were examined using the following non-parametric tests: Pettit test, Standard Normal Homogeneity test, Buishand range test, von Neumann test and Mann Kendall test.

The results showed that on the river Jablanica there is a declining trend in water discharge while non-parametric tests: Pettit test, Standard Normal Homogeneity test, Buishand range test show that the change-point in average annual water discharge data occurred in 1987 and 1982. On other hand, on river Toplica is not established trend changes in annual water discharge or change-point.

Key words: discharge, trend, statistical homogenity tests, Jablanica, Toplica

1. Introduction

The rivers of Jablanica and Toplica are left tributaries of the Južna Morava. Their catchment area comprises left of the west half of the Južna Morava basin. Regionally-wise, it represents Topličko-Jablanička micro-region, which is a part of meso-region of Južno Pomoravlje. This micro-region comprises only of the basins of the Jablanica and the Toplica, where the basins of Veternica and the Pusta river are joined to the Jablanica.

Topličko-Jablanička micro-region extends on the surface of 4172 km^2. It is bounded by Kosovsko Pomoravlje in the south, Jastrebac and the Rasina in the north, Južno Pomoravlje in the east, whereas it is bounded by Ibar-Kopaonik area in the west (Marković, 1966; 1995).

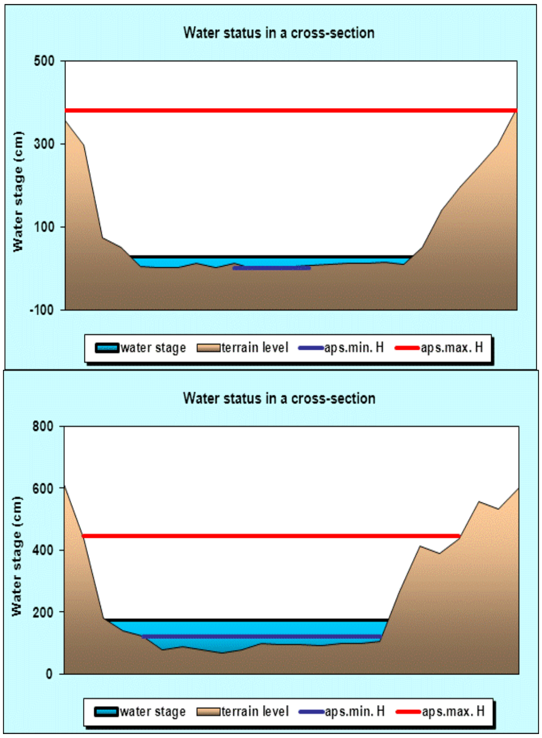

Figure 1- The shape of the cross section of the river Jablanica at hydrological station Pečenjevce (left); and Toplica River at the hydrological station Pepeljevac (right) (Source: RHSS)

The river of Jablanica emerges from the Banjska and Tularska river which join at the village of Maćedonce at sea level of 375 m. It is 75.3 km long, while it is 94.8 km long from the spring of the Banjska river, its longer constituent. The Jablanica flows into the Južna Morava 3 km downstream from Pečenjevce (Gavrilović, Dukić, 2013). This study examines the data on the discharge from hydrological station Pečenjevce, which is situated 3 kilometers from the confluence of the Jablanica. The surface of the basin on the Pečenjevce profile is 891 km at 205.82 m sea level. The data used for analysis comprise the period from 1950 to 2012. The data for the first and the second month of 1990 were interpolated on the basis of the Južna Morava discharge, the station Korvingrad. The surface of the Jablanica basin is

909.74 km^2. The basin is asymmetric. The upper part of the basin, up to Lebane is of serrated, almost circular shape, while the lower part is elongated and narrow, mostly in the direction of southwest - northeast. It completely belongs to Serbian-Macedonian mass. It is bounded by the mountain of Goljak in the south and southeast which separates the basin of Jablanica from Kosovsko Pomoravlje. In the east, the Kukavica and the Poljanica separate it towards the basin of Veternica. There is the mountain of Radan in the southwest which separates it from the basin of the Toplica and Kosanica, as well as the branches of Radan towards the north, northeast and the basin of the Pusta river. In the east and northeast, the basin is broadly open towards Bošnjačko field, the west part of Leskovac basin and the valley of the Južna Morava.

The river of Toplica emerges from several rivulets on the eastern slopes of Kopaonik, the biggest of which are the Lukovska river and the Đerekaruša river, which are joined at the village of Merćez. The Toplica is 130 km long, with basin surface of 2180 km^2. It is the biggest left tributary of the Južna Morava in which it flows into at Korvingrad (Gavrilović, Dukić, 2013). This study examines the data on the discharge from the hydrological station Pepeljevac, which is situated 69.5 km from the confluence of the Toplica. The surface of the basin on the profile is 986 km^2, at 329.9 m sea level. The data used for the analysis comprise the period from 1951 to 2012.

The basin of the Toplica can be divided into three parts: the upper Toplica, upstream from Kuršumlija, the middle or even Toplica and the lower Toplica with the village of Dobrič (Marković, 1966). The valley of the Toplica is composite; it consists of several expansions and gorges. Up to Kuršumlija the Toplica runs through deep and narrow valley, it is prone to flooding, with frequent rapids and whirlpools. From Kuršumlija the valley is broader and shallower. From the village of Pločnik the valley of the Toplica becomes broader and shallower than its upstream part. At Prokuplje its valley is gorge-like, while downstream it enters the spacious and flat Dobrič. The basin of the river is symmetrical, because the right and left tributaries are approximately equally long (Stanojević, 2001). The relief of the Toplica basin belongs to Serbian-Macedonian mass, the oldest part of the continent of the Balkan Peninsula and Dinaric zone of folded mountains. It was formed in the time of Alpine orogenesis. Topličko-kosanička basin with its rim was formed in the middle of Oligo-Miocene. It is situated between the mountains of Mali and Veliki Jastrebac in the north, Kopaonik and Požar in the west, Prolomske mountains, Sokolovica, Arbanaške mountains, Vidojevica and Pasjača in the southwest and west (Rudić, 1978).

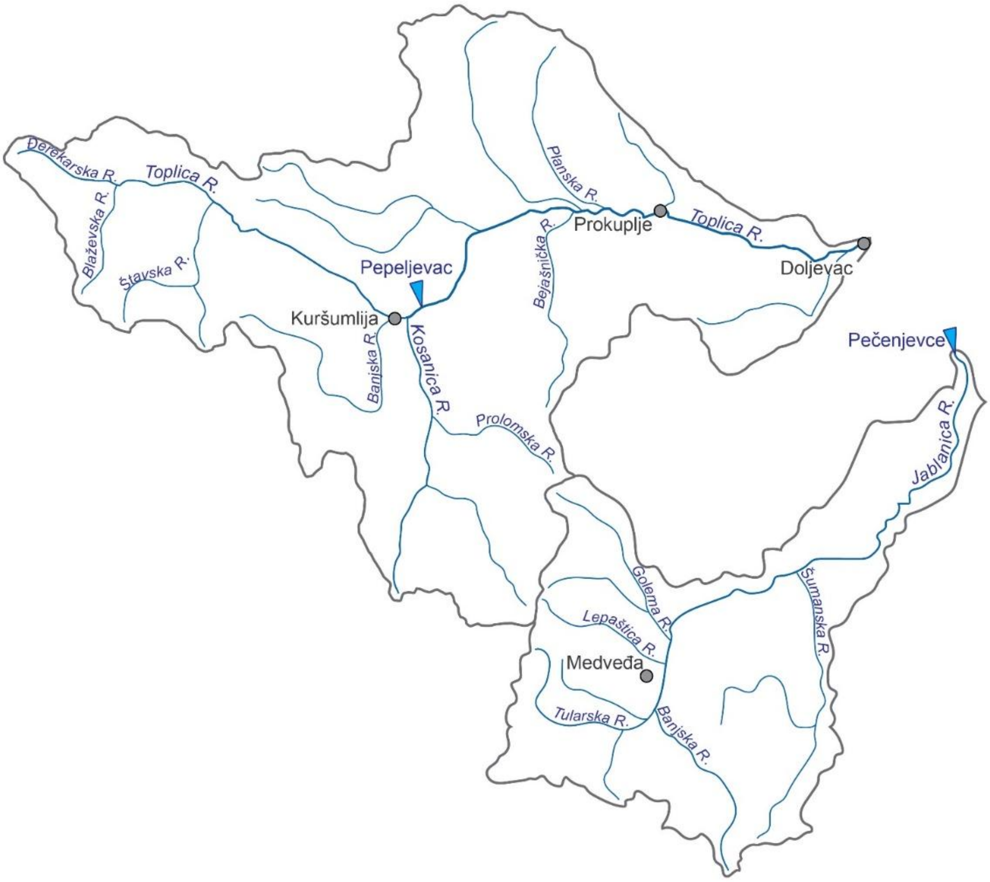

Figure 2– Map of catchment areas of Jablanica and Toplica rivers

The Toplica has a very unstable water regime. The highest discharge occurs in March and April, when the discharge is more than doubled because of snow melting from the surrounding mountains, while the lowest discharge occurs in August and September, when there is often less than 1 m^3/s flowing through its river-bed. The whole territory of the Toplica is much drained in that period, its tributaries almost dry out, which leads to the problems in water supply of the settlement (Rudić, 1978).

The Jablanica has a very unstable water regime, too, although it has a large basin. It is distinguished by high fluctuations in the discharge during year, where there is a shorter period of high waters and a longer period of low waters (below 1 m^3/s)(Rakićević, 1972). The Jablanica is also the longest river that dries up in Serbia. It was the reason to examine in this study if there is a trend of discharge and a breaking point in data series on discharge on both rivers and when the breaking point occurs.

2. Methodology

Test methods have been used to test and to identify general trends in annual water discharge in Jablanica and Toplica rivers in Serbia. Such an analysis involved the following statistical tests: Pettitt's test, Standard normal homogenety test (SNHT), Buishand range test (BR), von Neumann test and Menn Kendall test. Under alternative hypothesis, SNHT, BR test, and Pettitt test assume the series consisted of break in the mean and considered as inhomogeneous (Radivojević et al., 2015). These tests are capable to detect the year where break occurs. Meanwhile von Neumann test is not able to give information on the year break because the test assumes the series is not randomly distributed under alternative hypothesis (Neumann, von, 1941). The results of the Pettitt, Buishard range, and a SNHT tests goal to annual discharge data series show that the change points were detected in Jablanica river 1987 and 1982.

The Pettitt's test is a non-parametric test, meaning that its application requires no assumption about the distribution of data. This test provides assessment of the null hypothesis H_0 implying that the data are homogeneous throughout the period of observation, i. e. that the data have been obtained from a single or several distributions with the same location parameter (average values). The alternative hypothesis, implies presence of a non-accidental component among data causing a shift of the location parameter at a particular moment. Aside from providing for a data homogeneity check, the Pettitt's test also determines if the alternative hypothesis happens to be accepted the change-point when a shift of the location parameter occurred (Pettitt, 1979).

The SNHT homogeneity test is a statistical test which also checks if the data originate from the same population with the same distribution or indicate presence of a significant difference in the location parameter between the data before and after a specific change-point tc bringing an increase or decrease of the value of the observed feature. The null hypothesis in this test H0 implies that the data are homogeneous, i. e. that they originate from the same population, while the alternative hypothesis H1 implies presence of a significant difference in the location parameter in the period before and after the moment tc. The SNHT test determines the moment of change of the location parameter (Radivojević et al., 2015).

The Buishand range test is also a non-parametric test checking presence of a change-point in the given data marking a change of the location parameter (average values) distribution. The null hypothesis implies data homogeneity in terms of the location parameter, i. e. absence of a change regarding the said parameter over time. The alternative hypothesis implies presence of a change-point involving an increase or decrease of the average value of the observed feature (Buishand, 1982).

The von Neumann test also tests the null hypothesis implying data homogeneity in terms of the location parameter and absence of its change over the period of observation, as opposed to the alternative hypothesis implying presence of the moment when the change of the location parameter occurs. If the alternative hypothesis is accepted, the von Neumann test cannot pinpoint the moment marking the change of the location parameter (Neumann von, 1941).

Mann-Kendall test is a nonparametric test which identifies the trend of the series on the basis of comparing relative magnitudes in data change (Stojković, 2015; Stojković et. al., 2015; Kendall, 1975). This test was used to determine the trend of the discharge of both rivers.

Program package "R" was used for the interpolation. Coefficients of interpolation polynome were calculated with the condition of maximization of the determination coefficient R2.

For the application of the mentioned tests, Microsoft Office Excel 2007 and its XLStat were used.

3. Results and discussion

On the basis of the observed sample, the following descriptive average annual indicators of the river Jablanica was obtained for the period 1950-2012 (Table 1); of the river Toplica for the period 1951-2012 (Table 2).

Table 1– Basic indicators of water discharge and the specific runoff of the river Jablanica on the hydrological station Pečenjevce

Period	**N**	**F [km^2]**	**Q_{max} [m^3/s]**	**Q_{min} [m^3/s]**	**Q_{avg} [m^3/s]**	**σ**	**c_v**	**q [l/s /km^2]**
1950-2012	63	891	200	0	4,39	8,59	1,96	4,92

The Jablanica discharge (Pečenjevce station) in the measuring period from 1950 to 2012 according to Mann-Kendall test shows a significant decreasing trend with significance threshold of α = 0.001 (Figure 3). Parameters of linear regression of median line of the trend of annual values are as follows: A = - 4,77×10^{-2}, B=5,*60* (Martić Bursać, 2015).

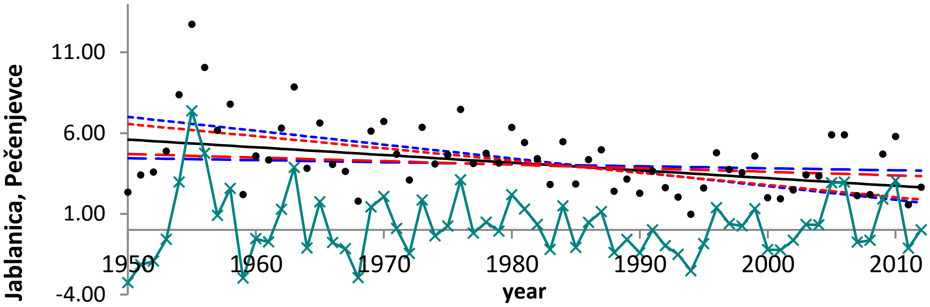

Figure 3- Trend of the annual water discharge of the river Jablanica (Pečenjevce) for the period 1950-2012 (Martić Bursać, 2015)

Table 2– Basic indicators of water discharge and specific runoff on the river Toplica on the hydrological station Pepeljevac

period	N	F [km^2]	Q_{max} [m^3/s]	Q_{min} [m^3/s]	Q_{avg} [m^3/s]	σ	c_v	q [l/s /km^2]
1951- 2012	62	986	275	0,09	7,07	10,38	1,47	7,17

Mann-Kendall test determined that there is no statistically significant trend of the Toplica discharge on the observed profile Pepeljevac in the given period (Martić Bursać, 2015).

Table 3. Pettitt's test results

	Jablanica	Toplica
K	590.0000	227.0000
t	1987	1963
p-value (Two-tailed)	0.0007	0.4930
alpha	0.05	0.05

Table 3 and Fig 4. show the results of the Pettitt's test. Regarding the data it can be concluded that there was a change-point when the annual water discharge decreased. This test indicates that the change point in average annual water discharge data occurred in 1987 for river Jablanica. On river Toplica is not established change-point in annual water discharge.

The results of the SNHT test are shown in table 4. The significance of the SNHT test leads to a conclusion that average annual water discharge in the observed period are homogeneous in terms of the location parameter. This test identifies 1982 as the year when a decrease in water discharge in Jablanica occurred. This can also be noticed in the following fig.5.

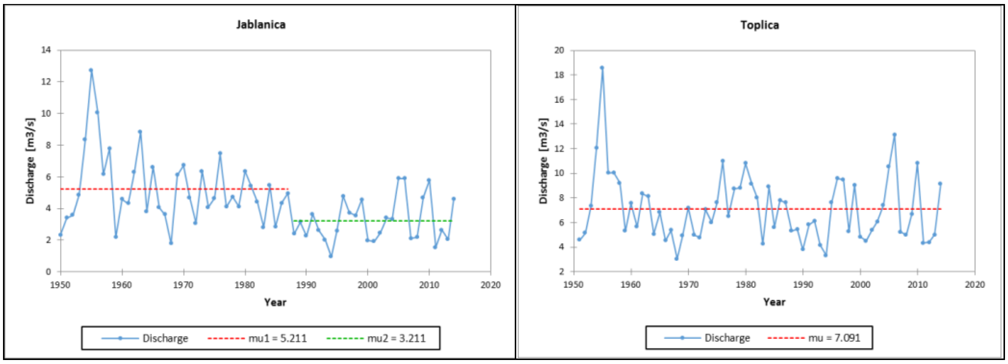

Figure 4. Pettit test for Jablanica (left side) and Toplica river (right side)

Table 4. Standard normal homogenity test (SNHT) for Jablanica and Toplica rivers

	Jablanica	Toplica
T0	14.3044	7.8726
t	1982	1958
p-value (Two-tailed)	0.0374	0.1086
alpha	0.05	0.05

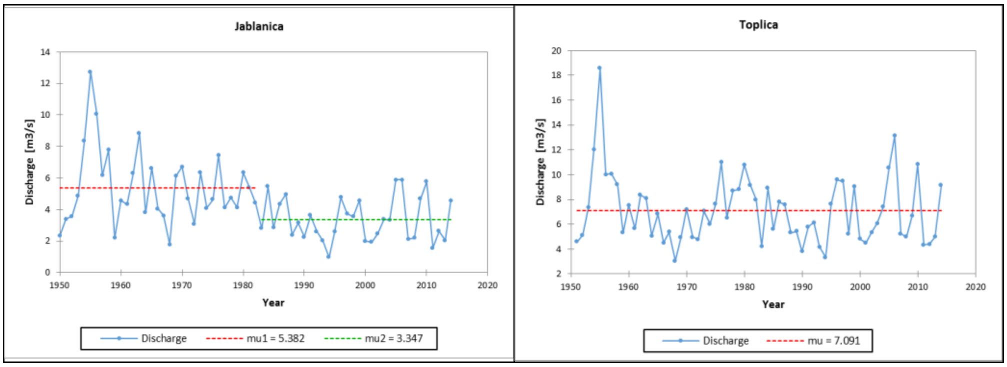

Figure 5. Standard normal homogenity test (SNHT) for Jablanica (left side) and Toplica river (right side)

Table 5. Buishand's test

	Jablanica	Toplica
Q	15.3630	7.4822
t	1982	1958
p-value (Two-tailed)	0.0003	0.2617
alpha	0.05	0.05

With regard to the test significance p <0.001 which is smaller than the significance level a =0.05, the alternative hypothesis is accepted, i. e. it can be concluded that there is a change-point marking occurrence of the change in average water discharge for river Jablanica. The Buishand test identifies 1982 as a moment when annual discharge decrease occurred in Jablanica river. Figure 6. shows this change in a graphical form.

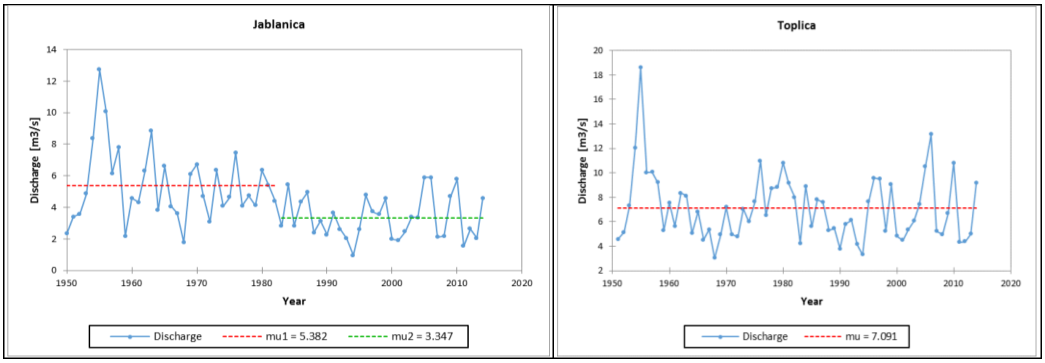

Figure 6. Buishand's test for Jablanica (left side) and Toplica river (right side)

Table 6. von Neumann's test for Jablanica and Toplica river

	Jablanica	**Toplica**
N	1.0676	1.2134
p-value (Two-tailed)	0.0001	0.0009
alpha	0.05	0.05

So, the results of the von Neumann test of homogenity, call for acceptance of the alternative hypothesis, i. e. lead to a conclusion that in the series of average annual water discharge there is a change-point regarding the location parameter in both rivers. The results are shown in table 6.

The analysis of annual water discharge recorded over 50-year period for the hydrological stations on rivers Jablanica and Toplica on the basis of used statistical tests, it can be concluded that there is a change-point marking occurrence of a decrease in average water discharge in Jablanica river. Neither trend of change, nor a change-point in the discharge data were determined for river Toplica.

The results obtained should be applied in the improving of the model for predicting river discharge, which is very important for water management and agriculture, but also for the society as a whole.

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