GEOGRAPHICAL INSTITUTE "JOVAN CVIJIĆ" SASA **JOURNAL OF THE …**
Vol. 60 № 2 **YEAR 2010**

Original scientific paper 911.2:556.535(497.11)

ANALYSIS OF RIVER REGIME AND WATER BALANCE IN THE ĐETINJA RIVER BASIN

Dragana Milijašević[1] *, *Ana Milanović**
**Geographical institute "Jovan Cvijić" SASA, Belgrade*

Abstract: Water regime and water balance of the Đetinja River were analysed in this paper on the basis of a thirty-year data series on water level and discharge in the period from 1978 to 2008. The analysis of the Đetinja water level showed the mean annual water level of 53 cm in the mentioned period, whereas the lowest mean monthly water levels were in August, and the maximum mean monthly water levels in March and April. The average mean annual discharge of the Đetinja near Šengolj was 5.60 m^3/s of the observation period 1978-2008. The annual value of the average discharges was similar to the annual value of the mean monthly low and high waters. It has been concluded that the Đetinja River belongs to the moderate-continental variance of the pluvial-nival regime. The results of the research have shown that about 5.60 m^3/s of water is formed in the Đetinja Basin with specific runoff of 10.95 $l/s/km^2$. Even though precipitation is not so low and ranges around 875 mm per year, the amount of the river inflow is smaller due to high evaporation of over 60%. Considering that the Šengolj hydrological station has been situated at 8.2 km from the mouth, and the station Stapari stopped working in 2002, there is an opinion that it would be significant to put the hydrological station in the part of the river course, as well as on larger tributaries.

Key words: the Đetinja River, water regime, water balance, water level, discharge

Introduction

The regime and water balance of rivers in Serbia were studied by Ilešič (1947), Dukić (1955, 1970, 1994, 2002), Gavrilović (1994, 2002), Živković (1994, 2006). The work of Ilešič (1947) gave general conception of the types and variances of water regimes in Serbia. For the first time in our scientific literature, Dukić (1959) presented the water balance of major areas - pannonian and hilly-mountain ones.

The Đetinja drainage basin is situated in the west part of Serbia, between 44º08' and 43º42' N and between 19º27' and 20º06' E. Area of the drainage basin area is 1187.03 km^2. The main tributaries come from the left and form an asymmetrical drainage basin – the left bank covers 71.4% of the overall area of the drainage

[1] Correspondence to: d.milijasevic@gi.sanu.ac.rs

basin. The length of the Đetinja drainage basin is 49.6 km and the average width is 23.9 km (Milijašević, 2010 a). The Đetinja river is formed in the northern part of Kremna basin by the confluence of the rivers: Bratišina reka, Konjska reka, Užički potok and Tomića potok, at 712 m altitude. These tributaries arise on east and southeast slopes of Tara Mountain. At the lowest part of Požega Basin, it joins its tributary Skrapež, and downstream, with Golijska Moravica, it forms Zapadna Morava River, an important water flow of Serbia. Its length is 75.25 km (Milijašević, 2010 b).

Hydrological observations on the Đetinja River started in 1922 by founding a hydrological station (HS) Gorobilje. The station was in operation until 1976 when it was removed more upstream and the measuring has been carried out near Šengolj. The station is on the left bank of the Đetinja, 8.2 km away from the mouth. The hydrological station (HS) Stapari was founded in 1958, and the Republic Hydrometeorological Service of Serbia has carried out observations on it since 1961. It is located on the left bank of the Đetinja 36.6 km upstream from the mouth. The station stopped working in 2002, and the water level, discharge and water quality have been followed in the hydrological station Šengolj only.

Water Level

The mean annual water level of the Đetinja was 53 cm and the lowest mean monthly water levels were in August (38 cm), while the maximum mean monthly water levels were in March and April (57 cm) in the period 1978-2008.

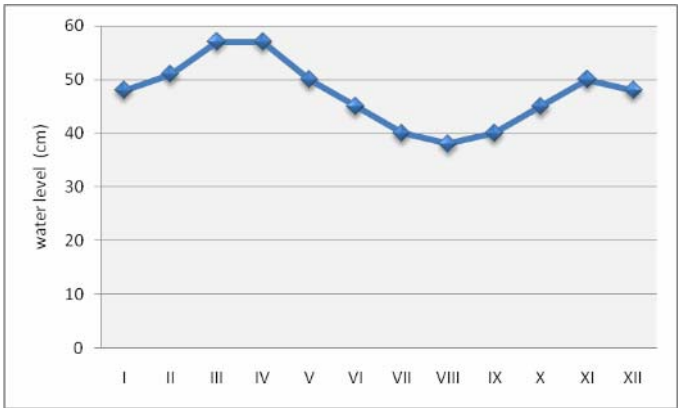

Figure 1. Level-curve of mean monthly water levels of the Đetinja near Šengolj (1978-2008)

Comparing the mean monthly precipitation (Figure 2) in the area of the basin and the mean monthly water levels (Figure 1), it can be noticed that the

maximum precipitation (in May and June) has been inconsistent with the mean monthly water level values.

Observing by seasons, the highest water level has been registered in spring due to increase in the air temperature and partial snow melting. The water level decreases from April up to September even above the maximum precipitation in June. The lowest water level is at the end of summer and the beginning of autumn (Figure 1). During summer, high water levels occur due to precipitation which mainly appears as downpours in the afternoon hours.

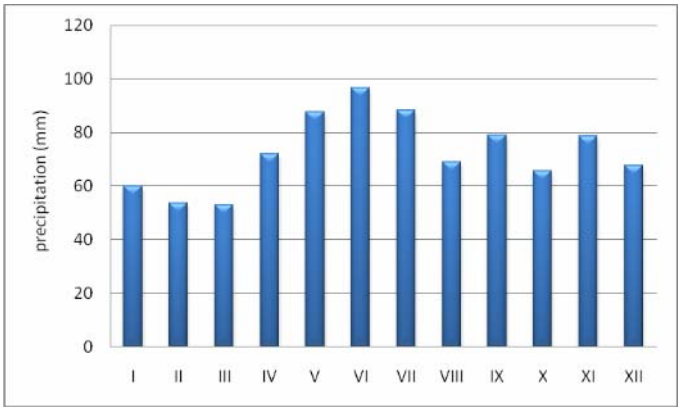

Figure 2. Mean monthly precipitation of the Đetinja River Basin (1961-1990)

The annual value of the mean low water level of the Đetinja was 37 cm and 71 cm of the mean high one in the period 1978-2008, so that the average amplitude was 34 cm. Based on data from the Table 1 it can be noticed that the lowest value of the mean low water level throughout the year has been 33 cm recorded at the end of summer and the beginning of autumn (in August and September), whereas the highest values of the mean high water level were in April (90 cm) and March (84 cm). Precipitation, air temperature and snow melting above all influenced such annual water level distribution.

Table 1. Mean low and high monthly water levels of the Đetinja near Šengolj in cm (1978-2008)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	annual
MLWL	39	40	44	43	40	36	34	33	33	34	38	38	37
MHWL	73	82	84	90	78	69	60	51	59	62	82	71	71

Extreme water levels represent the significant hydrological indicator for more detailed analysis of the water course regimes and prognosis of phenomena of high and low waters (Milanović, 2007).

The absolutely maximum water level of the Đetinja near Šengolj was 250 cm recorded on November 26th 1987 for the period 1978-2008, whereas the absolutely minimum water level of 21 cm was on June, 5th 1983 and August 19th 1985 (Table 2). The amplitude of extreme water levels was 229 cm in the mentioned period. The highest water level amplitude throughout a year was 227 cm recorded in 1987.

Table 2. Minimum and maximum annual water levels of the Đetinja near Šengolj in cm (1978-2008)

year	minimum	date	maximum	date
1978.	24	25.XI	169	30.I
1979.	22	20.IV	172	27.IV
1980.	22	3.IX	145	23.III
1981.	23	7.VIII	185	11.VI
1982.	23	19.IX	88	20.III
1983.	**21**	5.VI	121	12.II
1984.	22	10.VIII	144	11.V
1985.	**21**	19.VIII	156	18.IV
1986.	23	26.XII	193	19.II
1987.	23	10.I	**250**	26.XI
1988.	32	31.VII	98	17.III
1989.	32	2.II	153	28.VII
1990.	33	8.VII	96	11.XII
1991.	34	1.II	113	12.II
1992.	31	26.IX	131	26.VI
1993.	28	2.VIII	79	6.IV
1994.	30	17.IX	105	14.IV
1995.	34	6.X	126	4.IV
1996.	31	30.VII	144	18.IV
1997.	33	29.IX	82	22.I
1998.	32	10.VIII	108	7.XI
1999.	31	15.X	134	28.XII
2000.	29	18.X	106	3.II
2001.	33	21.I	117	24.IV
2002.	38	30.VI	145	18.IV
2003.	33	9.XII	90	15.III
2004.	38	23.VII	102	2.III
2005.	38	11.II	139	20.III
2006.	32	11.XII	151	24.III
2007.	39	5.VIII	127	26.XI
2008.	38	21.XI	98	5.XII

Water Discharge

The discharge has been the most important element of water regime. It is in the closest connection with water level. Besides average values, the extreme values, that is, low and high waters will also be analysed in the paper.

The average discharges are statistically obtained values most frequently used in practice throughout the making of analysis and studies for the economic needs (Milanović, 2007). The average mean annual discharge is 3.52 m^3/s of the Đetinja near Stapar for the period of observation 1961-2002, whereas 5.60 m/s of the Đetinja near Šengolj for the period of observation 1979-2008.

The maximum mean monthly discharges have been recorded in March and April, and the minimum ones in August and September. High spring waters with the maximum in March and April were caused by snow melting in the higher parts of the Đetinja river basin and the increasing precipitation. Thereafter, the average discharge declining is recorded with low waters appearing at the end of summer and the beginning of autumn with the minimum in August and September due to smaller amount of precipitation and large evaporation. Thereupon, the average discharge has constantly been increasing until April. The annual value of average discharges, shown in the Figure 3, has been similar to the annual value of the mean monthly low and high waters.

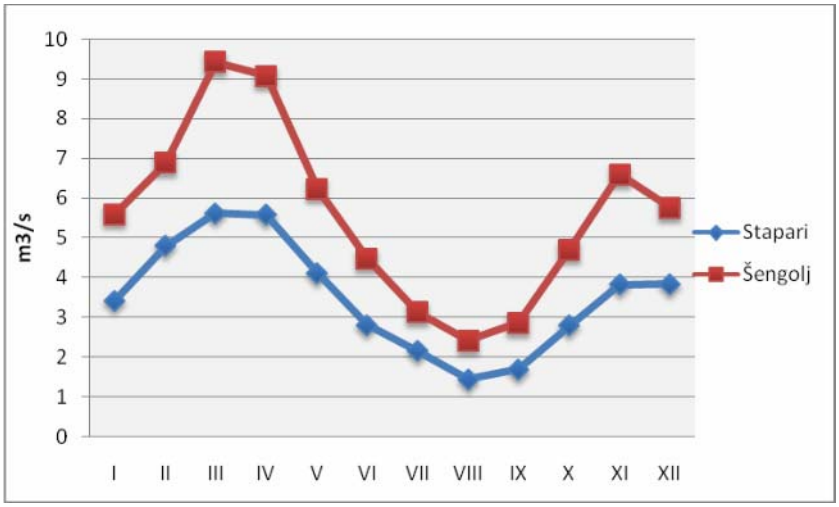

Figure 3. Hydrogram of the mean monthly discharges of the Đetinja

According to the water regime classification given by Ilešić (1947), it can be concluded that the Đetinja belongs to moderate-continental variance of the pluvial-nival regime with the highest water levels in March and April, and the lowest ones in September and August (Dukić, Gavrilović, 2006).

The minimum water discharge is analysed according to data of HS Šengolj in the period from 1979 to 2008. The value of 2.50 m^3/s has been the mean annual value of low waters. The regime of the Đetinja low waters has been characterised by the highest mean monthly values in March, 3.94 m^3/s and the lowest ones in August, 1.52 m^3/s (Table 3). The ratio between the highest and the lowest mean monthly low waters is presented as 1:1.9 which may give an impression that the Đetinja is flat course on the profile near Šengolj.

Table 3. Mean monthly low and high waters (m^3/s) of the Đetinja River near Šengolj (1978-2008)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	annual
Qmin	2.72	3.00	3.94	3.75	2.83	2.16	1.62	1.52	1.53	1.77	2.80	2.63	2.50
Qmax	16.3	23.2	25.0	28.8	20.7	16.9	10.9	6.41	9.90	11.4	25.9	16.3	17.9

The average values give more or less distorted picture of the discharge regime, and therefore it is significant to study the extreme values (Milanović, 2007). The absolutely minimum discharge of 0.30 m^3/s of the Đetinja near Šengolj was recorded on September, 19th 1982, while the absolutely highest value of low waters of 1.68 m^3/s was registered on November 25th 1978. The absolute amplitude of low waters was 1.38 m^3/s.

The average value of the mean annual high waters was 17.9 m^3/s for the period of observation 1978-2008 on the Đetinja near Šengolj (Table 3). The amplitude between the average low and high waters was 15.4 m^3/s, that is, their ratio was 1:7.16. Such ratio has indicated considerably uneven regime of the Đetinja discharge.

The regime of high waters differs a little from the regime of low waters. The highest mean monthly values appear in April (28.8 m^3/s), and the lowest ones in August (6.41 m^3/s). The ratio between the lowest and the highest high water is 1:4.49 which indicates that the variation of high waters is larger than the variation of low waters on the average. The absolutely maximum discharge of 187 m^3/s of the Đetinja near Šengolj for the period 1978-2008 was recorded on November 26th 1978, and the highest amplitude of high waters was 169 m^3/s.

Specific Runoff and Regime of Precipitation Runoff

The specific runoff has been the element of the water regime very suitable for hydrographical studying the rivers and determining the richness of basin in water (Dukić, Gavrilović, 2002). Numerous problems have appeared associated with the quantity, distribution in space and time and quality of water in the river basin area.

The mean annual specific runoff of Đetinja River for 1978-2008 period was 10.95 l/s/km^2. The specific runoff values have been ascertained to range from 4.73 to 18.43 l/s/km^2 during a year. Considerable increase in the specific runoff has been recorded at the beginning of March, while the maximum appears in April as the result of the increase in the precipitation amount, whereas simultaneously the air temperatures are still low and evaporation small. The constant specific runoff decreasing has been recorded from May to September due to increasing air temperature causing large evaporation. The trend of the specific runoff increase has again been noticed from September (Milijašević, 2010).

Besides mean monthly and mean annual values, it is also significant to analyse the mean minimum and maximum specific runoff values (Table 4).

Table 4. Mean maximum and minimum specific runoff values (l/s/km^2) of the Đetinja (1978-2008)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	annual
q_{min}	5.32	5.87	7.71	7.33	5.57	4.22	3.17	2.97	2.99	3.46	5.47	5.14	4.89
q_{max}	31.9	45.4	48.9	56.3	40.6	33.2	21.3	12.5	19.4	22.2	50.6	31.8	35.1

As with average values, the same annual value has also been noticed in the case of the mean minimum and maximum specific runoffs, with the maximum in April and the minimum in August. The ratio between the mean annual value of the minimum and maximum specific runoffs is 1:7.18 which indicates considerable oscillations.

Based on the specific runoff data, the height of the runoff in the river basin can be calculated, as well as the runoff coefficient.

Calculated by the method of arithmetical mean, the mean annual precipitation is 875 mm in the Đetinja River Basin, with the maximum in June and the minimum in March. Of the total amount, most precipitation is deposited

throughout summer, 254 mm, insignificantly less in autumn, 223 mm, then in spring, 212 mm, and the least in winter, 181 mm.

Table 5. Mean monthly and annual precipitation (mm) for period 1961-1990

N	Altitude	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	annual
1	840	68	62	66	77	100	104	96	78	81	68	87	74	961
2	455	52	49	50	56	96	97	85	66	59	49	65	60	780
3	530	56	52	55	62	92	99	90	69	58	48	64	61	806
4	810	64	59	59	75	105	112	93	83	70	61	73	71	926
5	920	75	59	61	94	118	122	96	77	77	73	78	84	1014
6	310	52	44	48	58	86	84	81	60	59	50	62	56	739
7	475	54	46	54	60	103	110	86	74	58	49	64	61	821
8	460	54	46	53	62	94	103	84	65	61	49	67	60	798
9	390	54	46	47	62	86	92	79	72	63	52	70	58	781
10	900	69	64	78	83	114	123	92	71	71	56	78	81	978
11	440	56	48	50	56	75	89	78	63	54	52	67	56	743
12	430	54	44	50	59	88	97	85	70	60	52	67	57	781

Source: Ducić V., Radovanović M., 2005
1- Čajetina, 2 – Bjeloperice, 3 - Gornja Dobrinja, 4 – Gostinica, 5 – Kremna, 6 – Požega, 7 – Ražana, 8 - Seča Reka, 9 – Sevojno, 10 – Taor, 11 – Užice, 12 - Kosjerić

Out of the total precipitation amount deposited on the surface of the basin, 336 mm is runoff, i.e. 39%. The coefficient of the precipitation runoff has the highest value in March (0.89), and the lowest in July, August and September (0.18) (Table 6). The precipitation runoff is caused by climate conditions (precipitation, air temperature, evaporation), hilly-mountain terrains in the basin, as well as anthropogenic influence.

Table 6. Mean monthly and annual precipitation (X, mm), runoff height (Y, mm) and runoff coefficients (C) for the Đetinja (1978-2005)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	annual
X	60.0	53.5	52.9	71.9	87.5	96.7	88.2	69.0	79.0	65.6	78.7	67.6	875
Y	28.4	33.4	47.1	45.6	32.5	22.8	16.7	12.7	14.5	24.1	32.2	29.1	336
C	0.47	0.62	0.89	0.63	0.37	0.23	0.18	0.18	0.18	0.36	0.40	0.43	0.39

Water Balance

Water balance represents available quantity of atmospheric, surface and underground water on certain area, whether some river or sea basin, an area or state territory about. Its understanding has great significance for water management and planning the water resource use (Dukić, Gavrilović, 1994).

The water balance of the Đetinja has been represented by the ratio between precipitation on the one side and runoff and evaporation on the other side. The water balance of the Đetinja is represented on the basis of data for the hydrological station Šengolj, excluding the basin area of the Skrapež River from the calculation. Precipitation and runoff are determined on the basis of measuring data in the basin, and evaporation by difference between precipitation and runoff.

Observing the Đetinja river basin to the HS Šengolj, with the area of the basin of 511 km^2, the average of 875 mm of precipitation is noticed to have been disposed in its basin for the 1979-2005 period, where of 336 mm or 38% runs off, and 539 mm or 62% evaporates. The largest precipitation amount runs off during the spring period because air temperatures are still low and the evaporation is small. On the contrary, July, August and September represent the months with the least precipitation runoff throughout the year.

The results of the research have shown that about 5.51 m^3/s of water is formed in the Đetinja River Basin with the specific runoff of 10.66 $l/s/km^2$. Even though precipitation is not so small and ranges about 875 mm per year, the amount getting to the river is less due to large evaporation of over 62% (Milijašević, 2010).

Conclusion

The water level analyses for the Đetinja River in the period 1978-2008 have shown that the maximum values are registered in March and April as the result of snow melting and frequent rainfalls, and the minimum in August due to high evapotranspiration and less precipitation. The average water level amplitude is 34 cm near Šengolj in the period 1978-2008. According to the classification of river regimes given by Ilešič (1947), it can be concluded that the Đetinja River belongs to moderate-continental variance of pluvial-nival regime.

The average mean annual discharge is 3.52 m^3/s of the Đetinja near Stapar for the period of observation 1961-2002 and 5.60 m^3/s of the Đetinja near Šengolj

for the period of observation 1979-2008. The maximum mean monthly discharges are recorded in March and April, and the minimum ones in August and September. High spring waters with the maximum in March and April are caused by snow melting in higher parts of the Đetinja River Basin and increasing precipitation. The amplitude between average low and high waters is 15.5 m^3/s, i.e. their ratio is 1:7.18. Such ratio indicates the considerably uneven discharge regime of the Đetinja.

The values of the specific runoff for the Đetinja are low, caused by climate conditions and anthropogenic influence. The largest quantity of precipitation runs off throughout the spring period because the air temperatures and evaporation are still low. On the contrary, July, August and September represent months with the least precipitation runoff during the year.

The water balance components of the Đetinja river basin to the hydrological station Šengolj have been determined in the paper. The mean annual precipitation for the whole basin of the Đetinja is about 875 mm, where of 38.5% runs off, and 61.5% evaporates. The ratio between the water balance components in the basin is not much favourable, so certain measures are necessary to be taken to its improvement (forestation, hydro-technical measures).

Acknowledgements:
This paper is the result of a project funded by the Ministry of Science and Technological Development of the Republic of Serbia.

Manuscript submitted on 23 April 2010; accepted on 19 November 2010.

References

Ducić, V. & Radovanović, M. (2005). *Climate of Serbia.* Belgrade: Serbian State Company of Textbooks (Дуцић, В. & Радовановић, М. 2005. *Клима Србије*. Београд: Завод за уџбенике и наставна средства).

Dukić, D. (1970). Graphic method of analysis of river regime. *Journal of the Geographical institute „Jovan Cvijić" SASA, 17*, 24-35 (Дукић, Д. 1970. Метод графичке анализе речних режима. *Зборник радова Географског института „Јован Цвијић" САНУ, 17*, 24-35*).*

Dukić, D. (1954). Contribution to the knowledge of regional river regime in Yugoslavia. *Bulletin of the Serbian geographical society, 34,* 119 - 138. (Дукић, Д. 1954. Прилог регионалном познавању речних режима у Југославији. *Гласник Српског географског друштва*, *34*, 119- 138).

Dukić, D. (1959). Water balance FNR Yugoslavia. *Bulletin of the Serbian geographical society, 39,* 15 – 36. (Дукић, Д. 1959. Водни биланс ФНРЈ Југославије. *Гласник Српског географског друштва, 39,* 15 – 36).

Dukić, D & Gavrilović, Lj. (1994). Water balance in Yugoslavia. *Bulletin of the Serbian geographical society, 74 (1),* 47- 65. (Дукић, Д. & Гавриловић, Љ. 1994. Водни биланс СР Југославије. *Гласник Српског географског друштва, 74* (1), 47- 65).

Dukić, D & Gavrilović, Lj. (2002). *Hydrology*. Belgrade: Serbian State Company of Textbooks (Дукић, Д. & Гавриловић, Љ. 2002. *Хидрологија*. Београд: Завод за уџбенике и наставна средства).

Ilešič, S. (1947). The river regimes in Yugoslavia. *Geografski vestnik, 19*, 71 – 110 (Ilešič, S. 1947. Rečni režimi v Jugoslavij. *Geografski vestnik, 19*, 71 – 110).

Milanović, A. (2007). Analysis of river regime and water balance in the Lepenica River basin. *Journal of the Geographical institute „Jovan Cvijić" SASA, 56,* 36 – 49. (Миланoвић, А. 2007. Анализа речног режима и водног биланса у сливу Лепенице. *Зборник радова Географског института „Јован Цвијић" САНУ*, *56*, 36 – 49).

Milijašević, D. (2010 a). *Hidrogeographic study of the Đetinja River.* Special issues, N^0 76. Belgrade: Geographical institute „Jovan Cvijić" SASA. (Милијашевић, Д. 2010. *Хидрогеографска студија реке Ђетиње.* Београд: Геогафски институт „Јован Цвијић", САНУ).

Milijašević, D. (2010 b). Flood frequency analysis of the Đetinja River. *Bulletin of the Serbian geographical society,* 90 (2), 15-28. (Милијашевић, Д. 2010. Вероватноћа појаве великих вода на реци Ђетињи. *Гласник Српског географског друштва, 90* (2), 15-28).

Republic Hydrometeorological Service of Serbia. (1961–2007). *Hydrological Yearbooks*. Belgrade: Republic Hydrometeorological Service of Serbia. (Републички хидрометеоролошки завод Србије, 1961-2007. *Hidrološki godišnjaci.* Београд: Републички хидрометеоролошки завод Србије)

Republic Hydrometeorological Service of Serbia. (1961–2006). *Climate Annuals*. Belgrade: Republic Hydrometeorological Service of Serbia. (Републички хидрометеоролошки завод Србије, 1961-2006. *Klimatski godišnjaci.* Београд: Републички хидрометеоролошки завод Србије)

Živković, N. (1994). Contribution to the study of the water balance the Nišava River. *Bulletin of the Serbian geographical society, 84 (1),* 65-72. (Живковић, Н. 1994. Прилог проучавању водног биланса слива Нишаве. *Гласник Српског географског друштва, 84* (1), 65-72).

Živković, N. (2006). Contribution to the study of water regimes of rivers in Serbia. *Collection of papers Geographical faculty, 54*, 47 – 58. (Живковић, Н. 2006. Прилог изучавања водних режима река у Србији. *Зборник радова Географског факултета, 54*, 47 – 58).