Taylor & Francis
Taylor & Francis Group

JOURNAL OF ENVIRONMENTAL ENGINEERING AND LANDSCAPE MANAGEMENT
ISSN 1648–6897 print/ISSN 1822-4199 online
2011 Volume 19(4): 326–334
http://dx.doi.org/10.3846/16486897.2011.634057

PATTERNS OF RIVER RUNOFF CHANGE CONSIDERING THE SIZE OF THE BASIN

Lina Bagdžiūnaitė-Litvinaitienė[1], **Andrius Litvinaitis**[2], **Valentinas Šaulys**[3]
Department of Hydraulics, Vilnius Gediminas Technical University,
Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
E-mails: [1]lina.litvinaitiene@vgtu.lt (corresponding author); [2]andrius.litvinaitis@vgtu.lt; [3]valentinas@vgtu.lt

Received 17 May 2010; accepted 01 Mar. 2011

Abstract. Climatic change and fluctuations of river runoff are among the most urgent topics nowadays. It is important to analyse and establish tendencies for forecasting.

The article deals with the reasons of runoff variation trends, i.e. river basins with different physical-geographical and meteorological conditions are analysed. In the research, statistical Mann-Kendall test and correlation coefficients were applied to assess the influence of precipitation amount variation on the variation of river discharges.

The achieved results showed that the correlation links between a major river outflow (Neris) and precipitation were established only during autumn and winter seasons, however, the links were very weak (correlation coefficient of 0.4). The correlation between major river runoff and precipitation is also weak but can be observed during summer season as well. The highest correlation coefficients were established in rivers of average size. This proves that the smaller the river, the stronger is the reaction to local climatic factors.

Keywords: runoff, climatic change, precipitation, Mann-Kendall test, correlation coefficient.

1. Introduction

As early as in the end of the 19th century, people started talking about possible global climatic change due to intensifying burning of organic fuel and increasing quantities of carbon dioxide released into the air. A famous Swedish chemist Arrhenius published his observations regarding the data of CO_2 concentration increase in the air in 1896. According to his theoretic calculations, if carbon dioxide concentration increases twice, the average air temperature increases by 5–6 degrees. This phenomenon was called the greenhouse effect.

The problem is that climatic fluctuations encompass all spheres of animate and inanimate nature. Climate changes that took place during several thousand of years had influence on the majority of animal and plant species; however, the current processes are much faster and have much more pronounced impact on nature.

Climate change has a significant influence on the water cycle. When discussing the changes of water regime, it is worthwhile mentioning that during several recent years, very significant and ill-timed floods as well as high waters occurred in many areas of the world; they were often related to the global change of the climatic system. Sure enough, climatic fluctuations are a natural phenomenon on earth; however, at present, the climatic change caused by human economic activity exceeds possibilities of maintaining a balance. River runoff is no other than a product of complex climatic formation, thus in a way it can be considered as an indicator of climatic change (Dayan, Lamb 2005; Povilaitis, Querner 2009). However, direct anthropogenic activity has also a special impact on runoff's regime, i.e. a) installation and operation of reservoirs, reformation of watercourse network, b) irrigated agriculture, c) direct take-out of water from basins and return in the form of sewage, d) reformation of basin surface changing the regime of outflow formation and evaporation, e) factors affecting meteorological conditions (Global Environmental Change 2007).

The results of researchers' works prove the increase of extreme floods and droughts; there are also no doubts that the distribution of runoff during a year will change (Bergstrom, Carlsson 2001; Schindler *et al.* 1996; Levine 1992; Huntington 2006).

The number of catastrophic floods has increased twice all over the world during the last 10 years (1996–2005) and there were 5 times greater economic losses suffered in comparison to the period from 1950 to 1980 (Kron, Bertz 2007). Floods are natural disasters during which 140 million people suffer every year (WDR 2003). E.g., around 70% of the country's territory was flooded in Bangladesh in 1998 (compared to mean value of 20–25%) (Mirza 2003; Clarke, King 2004).

On the 26 November 2007, Directive 2007/60/EC on the assessment and management of flood risks came into effect and its emergence shows a serious approach to the processes under way. The directive requires that all member states should assess flood risks, prepare flood risk maps and – finally – take appropriate coordinated measures to reduce risks.

In order to forecast chances of floods and droughts, it is important to investigate variation trends of long-term hydrological observation data. The Global Runoff Data Centre (GRDC) is mainly involved in the above men-

www.informaworld.com/teel

tioned investigations. According to the research results achieved by the GRDC, the conclusions regarding runoff variation in rivers of the world during recent decades were presented. When analyzing the mean daily values of runoff, it was discovered that out of 195 investigated rivers runoff increased in 27 cases, decreased in 31 cases, and no statistically significant trends were established in the remaining 137 cases. According to the authors, such results reflect an extremely varied runoff formation spectre in different continents and river basins (Kundzewicz, Graczyk 2005; Brázdil, Kundzewicz 2006; Radziejewski, Kundzewicz 2004; Kundzewicz, Robson 2004).

During recent decades, a lot of research works on water resources and the influence of climate's change have been conducted in the Northern European and Baltic countries (Frisk *et al.* 2002; Hisdal, Holmqvist 2003; Reihan 2002; Hisdal *et al.* 2004; Bagdžiūnaitė-Litvinaitienė 2005). However, river runoff variation was analyzed according to different methodologies in these works. Different statistical criteria were applied and unequal time-series were analysed, therefore, it is difficult to generalize the investigations made in different countries.

Naturally, the greatest risks during floods are posed by major rivers, however, it must be remembered that minor tributaries are much more sensitive to changes and react faster to influencing factors. Accordingly, the objective of this article is to establish variation trends in the rivers of different size basins on the basis of long-time hydrological data series.

2. Research Object and Methodology

Lithuania is situated at the western border of the East European Plain and belongs to the Baltic Sea basin (Fig. 1). The boundaries of Lithuanian district coincide with a certain relief typological group. 11 districts are situated in plains and lowlands and cover about 48% of the country's territory, 5 – on plateaus (29%) and 6 – in uplands (23%). The lowlands stretch at 0–120 m, plains – 100–170 m, plateaus – 70–190 m, and uplands – 125–290 m of the absolute pitch. Thus, these distinguished territorial physical units express certain differences between different natural components regardless of the influence of the general zone climatic hypothermic background.

For the research, 10 Lithuanian rivers of different size were selected from different hydrological areas (Table 1).

This work analyses a hydrological parameter of Lithuanian rivers – discharge, its variation trends related to physical-geographical and climatic variations in a river during the period of 47 years.

Discharges and meteorological parameter (precipitation amount) are taken from the Lithuanian Hydrometeorological Service.

Runoff's cyclical nature consists of two watery phases of opposite sign. It happens that 1 or 2 interspersed watery values of opposite sign do not make a change in the sign of the longer phase. Such deviations of the opposite sign are eliminated in the chronological graph by using the compressed average method. According to this method, instead of all the data in the time-line, only the most recent data of the selected length interval are taken to make a forecast. Each new forecast displaces the earliest received actual value from the interval of the selected length and the implied forecast becomes the latest available value. This can be seen as a computing shift in the time-line.

$$F_{t+1} = A_t ,$$

where $A_t = (D_t + D_{t-1} + D_{t-2} + ... + D_{t-N+1})/N$; N – interval length; D_t – observation in the time-line.

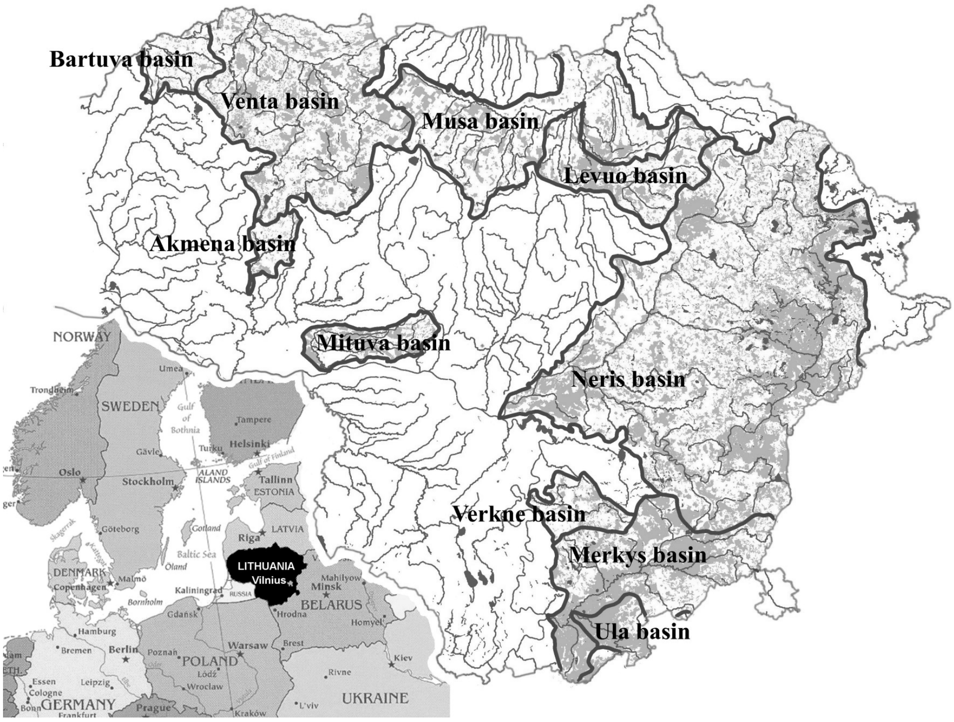

Fig. 1. Analysed river basins

Table 1. Characteristics of the river basins being analysed

River	Location of water sampling	Basin area, km^2	Lakes, %	Sand content, %	Swamps, %	Forests, %
Akmena	Paakmenis	308	0.8	1	11	5
Bartuva	Skuodas	612	0.2	3	5	3
Venta	Papilė	1570	0.6	10	7	27
Mūša	Ustukiai	2180	0.8	1	3	14
Lėvuo	Kupiškis	307	0.3	20	5	12
Mituva	Žindaičiai	403	0.2	8	1	20
Neris	Jonava	24600	2.4	–	10	28
Verknė	Verbyliškis	669	2.0	20	14	12
Merkys	Puvočiai	4220	0.9	67	10	46
Ūla	Zervynos	671	0.3	89	11	84

When increasing the length of the interval N, the compression and the stability of forecast increase; and vice versa: when decreasing N, the compression and the stability of forecast decrease. Moving average algorithms are characterized by the fact that when forecast is moving away from the average, that average increasingly attracts it toward itself, therefore, this method slowly reacts to changes. That is why interval of 3- and 5-year time-lines where examined.

When carrying out discharge variation analysis in terms of time, it is very important to choose appropriate methods. One of the most popular options in analysing different phenomena is a linear regression method, which establishes increasing or decreasing trend of statistical values, when time is x and the value of analyzed phenomenon is y. It is attributed to parametric statistical tests. However, it should be noted that, when using this method, it is considered that the analysed data are subject to normal distribution (Grayson *et al.* 1996; Lukianas, Ruminaite 2009). However, in hydrology, almost 90% of hydrological series have expressed asymmetry, which means that the data are not subject to normal distribution. Therefore, non-parametric statistical tests are recommended here. Recently, the Mann-Kendall non-parametric test has become one of the most popular tests used in research of hydrological series

Firstly, data series are tested in regard to homogeneity (if an analyzed series is not affected by certain external, i.e., non-natural factors), if they agree with normal distribution, and if the data are independent. Only after these preliminary tests are carried out, a trend test of the analyzed hydrological series is carried out (whether hydrological series values have trend to decrease or increase). The calculated test statistics are compared with the critical values for individual significance levels and a conclusion regarding the presence or absence of increase/decrease trend is made.

Mann-Kendall test was chosen for statistical analysis. Mann-Kendall tests show whether there is a trend in the time-series data. It is a non-parametric test. The n time series values (X_1, X_2, X_3, ….., X_n) are replaced by their relative ranks (R_1, R_2, R_3,….., R_n) (starting at 1 for the lowest up to n).

The test statistic S is: $S = \sum_{i=1}^{n-1} \left[\sum_{j=i+1}^{n} \operatorname{sgn}\left(R_j - R_i\right) \right]$,

where sgn(x) = 1 for x > 0, sgn(x) = 0 for x = 0, sgn(x) = –1 for x < 0.

If the null hypothesis H_0 is true, then S is approximately normally distributed with:

$$\mu = 0,$$

$$\sigma = n(n-1)(2n+5)/18.$$

The z-statistic is therefore (critical test statistic values for various significance levels can be obtained from normal probability tables):

$$z = |S| / \sigma^{0.5}.$$

A positive value of S indicates that there is an increasing trend and vice versa.

3. Results

The discharge series variation of the analyzed rivers during 1960–2007 is adequate to the distribution of rivers with regard to hydrological areas, i.e., the mean discharge values in the Verknė river vary from 10 to 20%, the ones in Ūla, Merkys and Neris rivers vary only within the range of 5–10%. These rivers belong to the south-east hydrological area that is characterized by light soils. The variation coefficients of all discharge values in Mituva and Lėvuo rivers of the Middle Lithuanian hydrological area exceed the limit of 20%. Only the Mūša river was distinguished from others as here variation coefficients were distributed evenly during the entire investigation period. The same even distribution of variation coefficients was observed in the western Lithuania, in Bartuva and Venta rivers; and the mean discharge variation coefficient in the Akmena river exceeded 20%. Having calculated variation coefficients in respect of months during the whole analysed period, it turned out that the variation coefficients in Bartuva, Venta and Mūša rivers were more often between 5 and 10%, Lėvuo and Mituva exceeded 20% and the variation coefficients in all of the south-east rivers were established only within 5–10% range (Fig. 2).

For further analysis of hydrological data variation smoothing of data series was performed, which highlights a systemic component of time series and removes incidental fluctuations.

Though this method is also used when analyzing periodic fluctuations, it is more often applied to establish non-periodic cycles as after removing high frequency

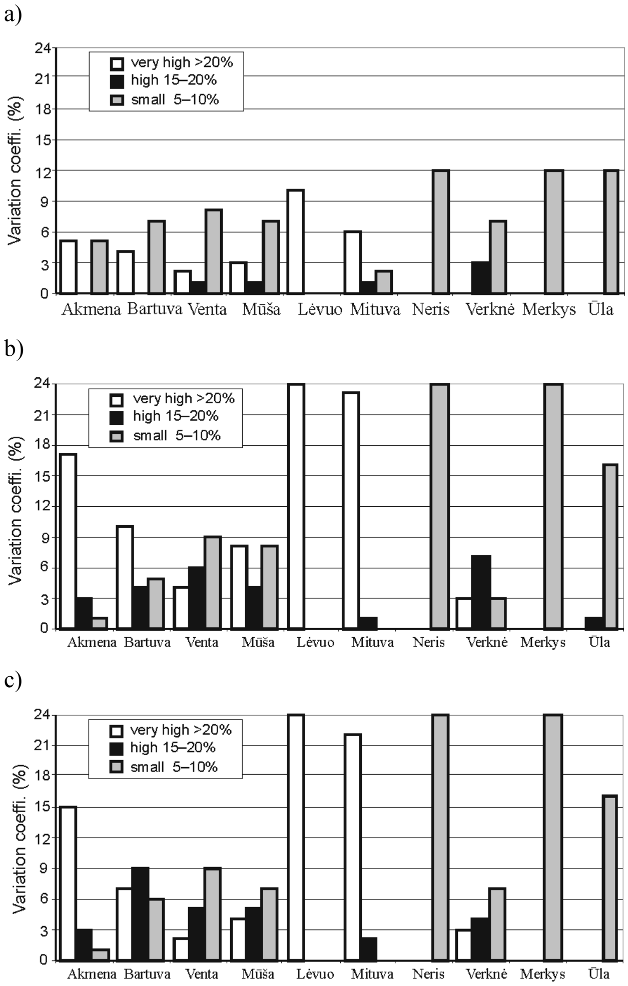

Fig. 2. Distribution of variation coefficients when analysing individual months during (a) 1960–2007, (b) 1960–1983, (c) 1984–2007 year period

fluctuation periods characterised by higher or lower mean indicator values are very well distinguished.

It is not possible to identify river size influence from the achieved results as only distribution of rivers in different hydrological areas determined the number of discharge fluctuations and their length. In rivers of south-eastern Lithuania there are 4 or even 6 fluctuations fixated and their length ranges from 4 to 7 years (Fig. 3), because river basins of this region are rich with sand (up to 89%) and swamps (up to 14%), which adjust runoff fluctuation rates, therefore their amplitude reaches only 1 m^3/s. In rivers of central and western Lithuania fluctuations of the flow ranged from 2 to 3 years, but their length was different, i.e. from 5 to 8 years in rivers of central Lithuania, and from 6 to 10 years in rivers of western Lithuania. However, the fluctuation amplitude ranged from 5–10 or even more m^3/s.

Having performed statistical analysis of hydrological parameters by the Mann-Kendall test, during which the goal was to establish the trends of river discharge variation, the investigations showed that the mean annual discharge series of all rivers were insignificant, i.e., test statistics did not exceed the calculated critical value (Table 2).

When analyzing discharge series in terms of individual seasons, it was observed that the winter season stood out most of all as the hydrological data series were significant in all analyzed rivers and variation trend was positive in all cases. That means that rivers yield more and more water during cold season of the year as due to warming climate precipitation is in the form of rain rather than snow. In the autumn season, the data series of all rivers were insignificant. The significance of the data series of the summer season was not high as well, as only the data series in the Ūla river was significant.

During the spring season, the data series of all analysed rivers had a negative variation trend, but in the Verknė, Mūša, Venta and Akmena rivers it was significant.

Precipitation is the main factor determining a basin's hydrological regime, therefore, the information regarding precipitation distribution in time a nd space provides

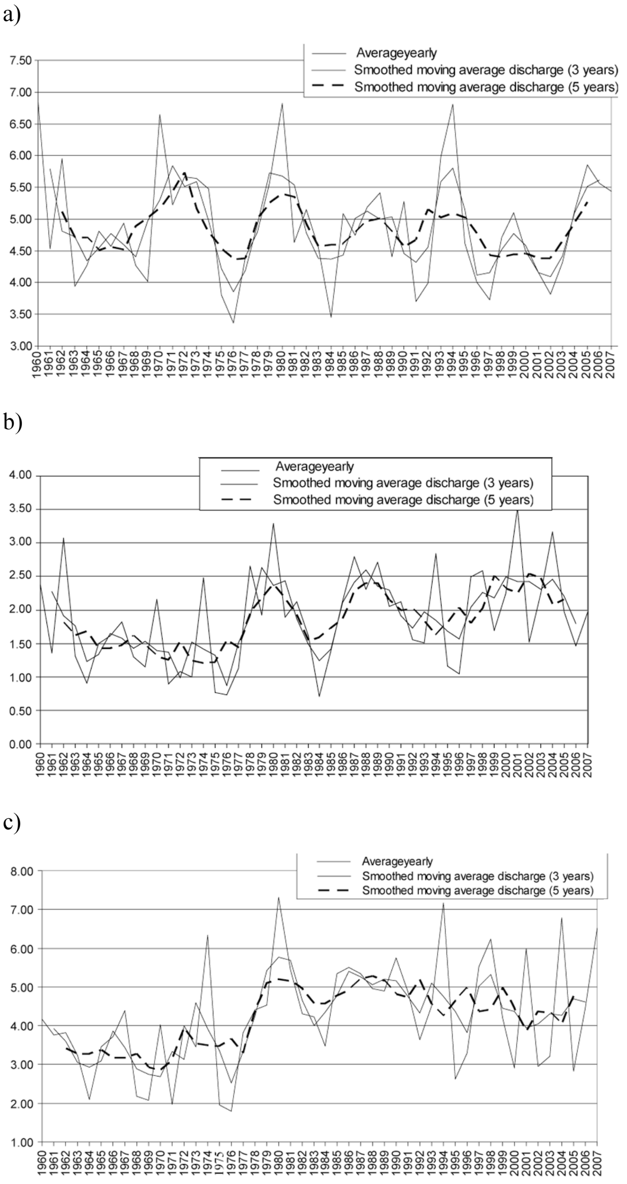

Fig. 3. Discharge fluctuations in Ūla at Zervynos (a), in Lėvuo at Kupiškis (b) and in Akmena at Paakmenis (c) during the analysed period

Table 2. Mann-Kendall test results

Rivers		Akmena	Bartuva	Venta	Mūša	Lėvuo	Mituva	Neris	Verknė	Merkys	Ūla
Annual mean	Test statistic	–1.075	–0.391	–0.693	–0.098	0.542	0.009	–1.307	–0.453	0.302	0.729
	Result	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spring season	Test statistic	–1.893	–1.475	–2.044	–1.44	–0.747	–1.093	–1.92	–0.667	–1.271	–0.862
	Result	S(0,1)	NS	S(0.05)	NS	NS	NS	S(0.1)	NS	NS	NS
Summer season	Test statistic	–1.093	1.04	0.827	1.529	0.382	0.453	–0.809	–1.031	0.356	2.124
	Result	NS	NS	NS	NS	NS	NS	NS	NS	NS	S(0.05)
Autumn season	Test statistic	–0.213	–0.187	0.693	0.951	1.058	0.293	–0.018	0.187	1.324	–0.133
	Result	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Winter season	Test statistic	**1.778**	**2.338**	**3.395**	**3.191**	**3.697**	**2.844**	**2.142**	**3.226**	**2.631**	**3.813**
	Result	**S(0.1)**	**S(0.05)**	**S(0.01)**	**S(0.01)**	**S(0.01)**	**S(0.01)**	**S(0.05)**	**S(0.01)**	**S(0.01)**	**S(0.01)**

ground to analyse runoff formation. Usually, the precipitation fallen on a water body's surface makes a relatively small part of runoff, as the water body itself makes a small part of the total basin area. Despite this fact, if a basin is abundant in lakes, direct precipitation can have greater influence. A certain portion of precipitation in the form of snow or rain can be retained on the surface of plants or buildings and return to the atmosphere through evaporation. Another portion of precipitation that reaches the ground infiltrates into the soil thus filling up soil pores.

Some part of precipitation turns into surface runoff, i.e., it flows into surface water bodies via the ground surface. The main reason for surface runoff formation is inability of water to infiltrate into the soil. Surface runoff reaches small streams very fast and is transported through them into larger rivers. The precipitation data analysed were taken from 8 stations, which are located on the basins of the analysed rivers (Fig. 4). The variation of precipitation amounts in all analysed rivers is individual in terms of a year as only in the western part of Lithuania general variation of meteorological parameters is observed – that is determined by the particularity of the maritime climate.

Varėna and Panevėžys meteorological stations recorded that the maximum precipitation amount falls in July and according to Vilnius station it happens in August. Raseiniai station records the maximum precipitation amount during 3 summer months – June, July and August (change amplitude of 10–15% of the total precipitation). However, a suddenly decreased amount of precipitation in September starts increasing again and the second maximum, though not that pronounced, is reached in November. Quite different variation is observed in western Lithuania. Though not to such pronounced extent, the amounts of precipitation recorded in Skuodas and Laukuva stations in March are higher compared with April and later precipitation amounts increase and reach the maximum in August. In September, precipitation decreases only from 5 to 10% of the total precipitation; however, in October and November, it reaches one more peak, which is very close to August in terms of precipitation amount.

In order to specify more accurately when precipitation amounts determining runoff variations changed, the analysed period was divided in two (1960–1983 and 1984–2007) and precipitation variation analysis for different periods was carried out as it was noticed that more pronounced variation of meteorological conditions had started in the sixties (Dumbrauskas 2008). The results proved that during the period of 1984–2007, the precipitation amounts in all analysed river basins increased during months of January and February. In March months, during the later analysed period, the amount of precipitation increased in Vilnius, Varėna and Raseiniai stations; and in April months, it decreased in all analysed meteorological stations during the latter period. Interesting is the fact that in September, during the period of 1960–1983, there was a lower amount of precipitation in all stations except for Skuodas. When analysing the dependence of discharge variation on the variation of precipitation amount, correlation coefficients and their reliability were calculated.

It can be seen from the achieved results (Table 3) that of reliable coefficients (reliability is less than 0.05) the highest correlation coefficients were observed in the Bartuva river during the autumn season (correlation coefficient 0.82) and the Mituva river in the winter season (correlation coefficient 0.74).

When summarizing the results, it can be said that during the spring season, the lowest correlation coefficients – both quantitative and qualitative – were established. The lowest precipitation falls and river runoff depend on melting of snow. However, the attention should be drawn to Akmena, Bartuva and Mituva rivers, where the correlation coefficients are determined to be between 0.47 and 0.59. As it can be seen from Table 1, these are small river basins with the lowest sand areas that lead to a closer connection because poor soil infiltration precipitation soon falls into a riverbed. During the remaining seasons, the dependence of precipitation and runoff are distributed according to hydrological regions. In rivers of south-east Lithuania, the correlation coefficients between precipitation and runoff are the weakest and range from 0.33 to 0.63.

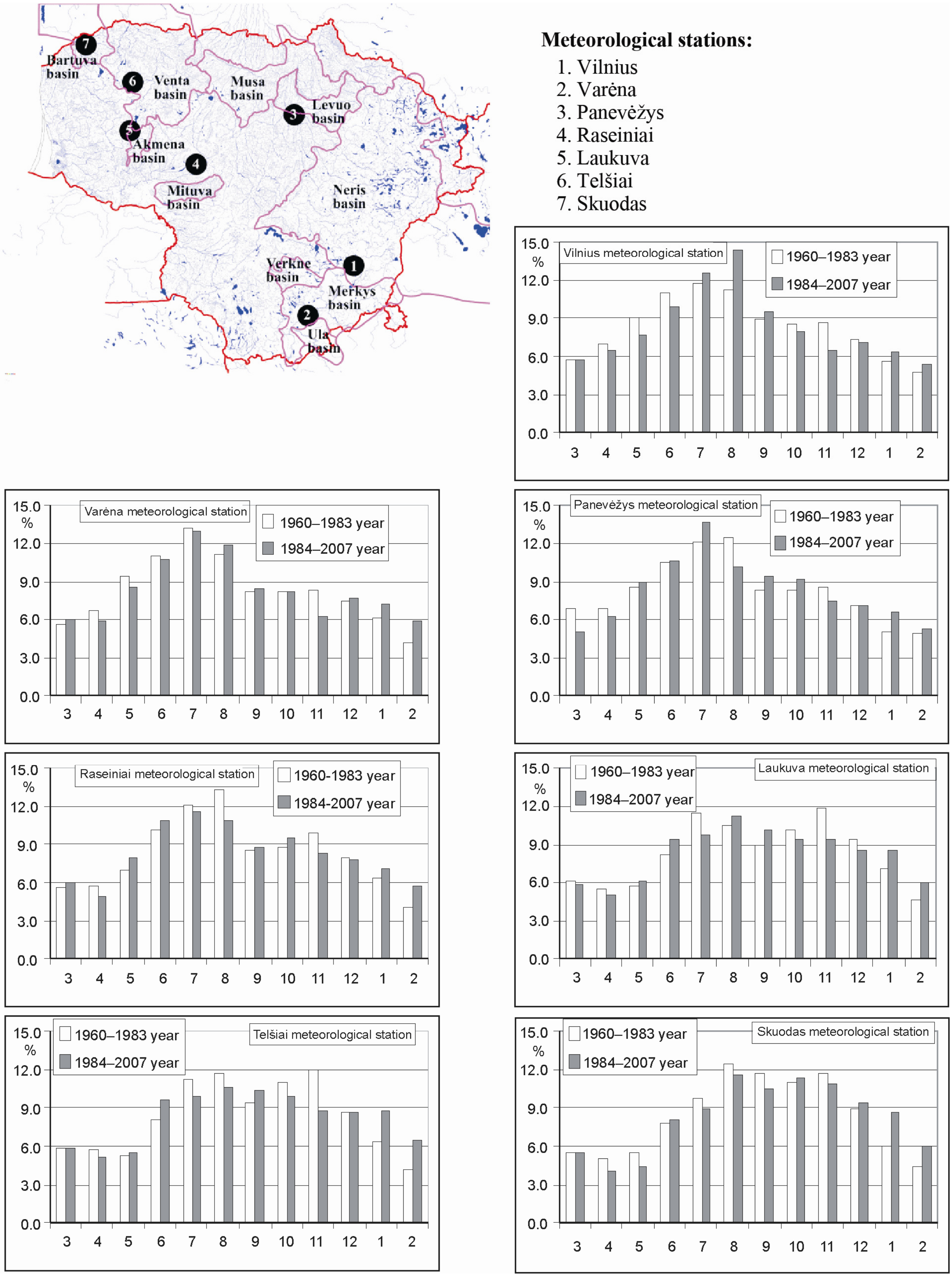

Fig. 4. Yearly change of precipitation during the analysed periods

Table 3. Correlation coefficients/reliability between precipitation amount and mean wateriness discharges

Rivers	Location of water sampling	Correlation coefficient and it's reliability, p	Mean year seasons			
			spring	summer	autumn	winter
Akmena	Paakmenis	correlation coefficient	0.57	0.57	0.68	0.70
		reliability	0.00	0.00	0.00	0.00
Bartuva	Skuodas	correlation coefficient	0.59	0.65	0.82	0.36
		reliability	0.00	0.00	0.00	0.01
Venta	Papilė	correlation coefficient	0.24	0.46	0.60	0.75
		reliability	0.11	0.00	0.00	0.00
Mūša	Ustukiai	correlation coefficient	0.16	0.42	0.63	0.47
		reliability	0.27	0.00	0.00	0.00
Lėvuo	Kupiškis	correlation coefficient	0.19	0.35	0.54	0.46
		reliability	0.20	0.00	0.00	0.00
Mituva	Žindaičiai	correlation coefficient	0.47	0.65	0.62	0.74
		reliability	0.00	0.00	0.00	0.00
Neris	Buivydžiai	correlation coefficient	0.32	0.33	0.4	0.4
		reliability	0.03	0.02	0.01	0.01
Verknė	Verbyliškis	correlation coefficient	0.24	0.43	0.49	0.47
		reliability	0.11	0.00	0.00	0.00
Merkys	Puvočiai	correlation coefficient	0.38	0.63	0.37	0.44
		reliability	0.01	0.00	0.01	0.00
Ūla	Zervynos	correlation coefficient	0.32	0.44	0.33	0.33
		reliability	0.03	0.00	0.02	0.02

Out of all rivers of central Lithuania, the distinctive effect of the precipitation to the runoff can be seen in the Mituva river. When comparing all three rivers in central Lithuania, the Mituva river distinguishes with its highest woodenness and lowest swampiness (Table 1). The latter is a water battery and this feature is supported by the fact that during the summer season, in the Mituva river, the dependence between runoff and precipitation is at its highest. The correlation coefficient rises up to 0.65.

In western Lithuania, the relationship between river runoff and precipitation is even through all the seasons of the year. The correlation coefficient varies from 0.36 to 0.82. The highest correlation coefficients were observed in rivers of average size and that proves the fact that the smaller the river, the more climate factors, precipitation in this case, determine its runoff; precipitation passing into rivers is also determined by the river basin lithology.

4. Conclusions

1. Having calculated variation coefficients in respect of months during the entire analysed period, it turned out that the variation coefficients in Bartuva, Venta and Mūša rivers were more often between 5 and 10%, Lėvuo and Mituva exceeded 20% and the variation coefficients in all rivers of south-east were established only within 5–10% range.

2. After having done the compression of data lines, it was defined that the runoff of rivers of south-eastern Lithuania has been regulated by lithological elements, such as sand (89%) and swamps (14%), therefore, hydrological fluctuations are frequent, but have low amplitudes. The runoff of central and western Lithuanian rivers changes in an infrequent cycle, but it has high-level amplitude.

3. Having performed the Mann-Kendall test in terms of individual seasons, it was observed that in the winter season, the hydrological data series were significant in all analysed rivers and variation trend was positive in all cases. That means that rivers yield more and more water during the cold season of the year as due to warming climate, precipitation is in the form of rain rather than snow.

4. On the subject of river sizes and the influence of precipitation on them, it was observed that the correlation links between the runoff and precipitation in a major river (Neris) were established only during autumn and winter seasons; however, links were weak (correlation coefficient of 0.4). The correlation between the runoff and precipitation in large rivers is also weak but it can be observed in the summer season as well. The highest correlation coefficients were observed in the rivers of average size and that proves the fact that the smaller the river, the more pronounced is its reaction towards the local climate factors.

References

Bagdžiūnaitė-Litvinaitienė, L. 2005. Fluctuations of mineral nitrogen and phosphate in river water during periods of various wetness, *Journal of Environmental Engineering and Landscape Management* 13(3): 132–141. doi:10.1080/16486897.2005.9636861

Bergström, S.; Carlsson, B.; Gardelin, M.; Lindström, G.; Pettersson, A.; Rummukainen, M. 2001. Climate change impacts on runoff in Sweden-assessments by global climate models, dynamical downscaling and hydrological modelling, *Climate Res* 16: 101–112. doi:10.3354/cr016101

Brázdil, R.; Kundzewicz, Z. W.; Benito, G. 2006. Historical hydrology for studying flood risk in Europe, *Hydrological Sciences Journal* 51(5): 739–764. doi:10.1623/hysj.51.5.739

Clarke, R.; King, J. 2004. *The Atlas of Water*. Earthscan, London. 128 p.

Dayan, U.; Lamb, D. 2005. Global and synoptic-scale weather patterns controlling wet atmospheric deposition over Central Europe, *Atmospheric Environment* 39: 521–533.

Dumbrauskas, A.; Bagdžiūnaitė-Litvinaitienė, L.; Vyčienė, G. 2008. Trend detection in hydrological series of main Lithuanian privers, in *The 7th International Conference "Environmental Engineering": selected papers, May 22–23, Vilnius, Lithuania* 2: 508–514.

Frisk, T.; Klavins, M.; Radionov, V.; Kokorite, I.; Briede, A. 2002. Long-term changes of hydrologic regime and aquatic chemistry in inland waters of Latvia, *J. the Finish Environment* 586: 11–19.

Grayson, R. B.; Argent, R. M.; Nathan, R. J.; McMahon, T. A.; Mein, R. 1996. *Hydrological Recipes: Estimation Techniques in Australian Hydrology.* Cooperative Research Centre for Catchment Hydrology, Australia. 125 p.

Hisdal, H.; Holmqvist, E. E.; Hyvärinen, V.; Jónsson, P.; Kuusisto, E.; Larsen, S. E.; Lindström, G.; Ovesen, N. B.; Roald, A. L. 2003. *Long time series – a review of Nordic studies, Climate, Water and Energy project*. Report No. 2. Reykjavik, Iceland.

Hisdal, H.; Holmqvist, E.; Kuusisto, E.; Lindström, G.; Roald, A. L. 2004. Has streamflow changed in the Nordic countries, in *XXIII Nordic Hydrological Conference.* Tartu, 2: 633–643.

Huntington, T. G. 2006. Evidence for intensification of the global water cycle: Review and synthesis, *Journal of Hydrology* 319: 83–95. doi:10.1016/j.jhydrol.2005.07.003

Kron, W.; Berz, G. 2007. Flood disasters and climate change: trends and options a(re-)insurer's view, *Global Change: Enough Water for All?* Eds., Hamburg, 268–273.

Kundzewicz, Z. W.; Graczyk, D.; Maurer, T.; Pińskwar, I.; Radziejewski, M.; SveNson, C.; Szwed, M. 2005. Trend detection in river flow series: 1. Annual maximum flow, *Hydrological Sciences Journal* 50(5): 797–810. doi:10.1623/hysj.2005.50.5.797

Kundzewicz, Z. W.; Robson, A. J. 2004. Change detection in hydrological records – a review of the methodology, *Hydrological Sciences Journal* 49(1): 39–51. doi:10.1623/hysj.49.1.7.53993

Levine, J. 1992. Global climate change, in Firth, P.; Fisher, S. G. (Eds.). *Global Climate Change and Freshwater Ecosystems*. New York: Springer-Verlag, 1–25. doi:10.1007/978-1-4612-2814-1_1

Lukianas, A.; Ruminaitė, R. 2009. Impact of land drainage on the rivers runoff, *Journal of Environmental Engineering and Landscape Management* 17(4): 226–235. doi:10.3846/1648-6897.2009.17.226-235

Mirza, M. M. Q. 2003. Climate change and extreme weather events: can developing countries adapt?, *Climate Policy* 3: 233–248.

Povilaitis, A.; Querner, E. P. 2008. Possibilities to restore natural water regime in the Žuvintas lake and surrounding wetlands – modelling analysis approach, *Journal of Environmental Engineering and Landscape Management* 16(3): 105–112. doi:10.3846/1648-6897.2008.16.105-112

Radziejewski, M.; Kundzewicz, Z. W. 2004. Detectability of changes in hydrological records, *Hydrological Sciences Journal* 49(1): 39–51. doi:10.1623/hysj.49.1.39.54002

Reihan, A. 2002. Long-term water discharge analysis in Estonia, in *XXII Nordic Hydrological Conference*. Röros, 2: 597–602.

Schindler, D.; Baylery, S.; Parker, B.; Beaty, K.; Cruikshank, D.; Fee, E.; Schindler, E.; Stainton, M. 1996. The effects of climatic warming on the properties of boreal lakes and streams at the Experimental Lakes Area, northwestern Ontario, *Limnology and Oceanography* 41: 1004–1017. doi:10.4319/lo.1996.41.5.1004

WDR, 2003. *World Disaster Report: Focus on Ethics in Aid.* International Federation of Red Cross and Red Crescent Societies, Geneva, 240.

ĮVAIRAUS BASEINO DYDŽIO LIETUVOS UPIŲ NUOTĖKIO KAITA

L. Bagdžiūnaitė-Litvinaitienė, A. Litvinaitis, V. Šaulys

Santrauka

Klimato kaita ir upių nuotėkio svyravimai – viena iš aktualiausių nūdienos temų. Aptariama nuotėkio kaitos tendencijų priežastys, t. y. analizuojama upių baseinai, kurių skirtingos fizinės-geografinės bei meteorologinės sąlygos. Tyrimams taikyti statistikos *Mann-Kendall* testas bei koreliacijos koeficientai. Jais buvo įvertinta kritulių kiekio kaitos įtaka upių debitų kaitai. Gauti rezultatai parodė, kad labai didelės upės nuotėkio ir kritulių koreliacijos ryšiai nustatyti tik rudens ir žiemos sezonais, bet tai yra labai silpni ryšiai. Didelių upių nuotėkio ir kritulių tarpusavio sąsaja taip pat yra silpna, bet jau pastebima ir vasaros sezoną. Didžiausi koreliacijos koeficientai buvo vidutinio dydžio upių, ir tai įrodo, kad kuo mažesnė upė, tuo ryškesnė reakcija į lokalius klimato veiksnius.

Reikšminiai žodžiai: debitas, klimato kaita, *Mann-Kendall* testas, koreliacijos koeficientas.

ИЗМЕНЕНИЕ СТОКА РЕК ЛИТВЫ РАЗНОЙ КРУПНОСТИ

Л. Багджюнайте-Литвинайтене, А. Литвинайтис, В. Шаулис

Резюме

Изменение климата и колебания стока рек являются одним из наиболее актуальных вопросов сегодняшнего дня. В статье рассматриваются причины изменения стока, анализируются бассейны рек с разными физико-географическими и метеорологическими условиями. При исследованиях использовался статистический тест Манна-Кендалла и коэффициенты корреляции для учета влияния количества осадков на оценку изменения стока рек. Полученные результаты показали, что для очень крупных рек (Нерис) корреляционные связи стока и количества осадков установлены лишь в осенне-зимний период, однако эта связь очень слаба (коэффициент корреляции 0,4). Связь стока и количества осадков для меньших рек является слабой, однако она наблюдается и в летний период. Наибольший коэффициент корреляции зафиксирован для рек средней величины. Таким образом, установлено, что чем меньше река, тем резче реакция ее стока на локальные климатические действия.

Ключевые слова: сток, изменение климата, осадки, тест Манна-Кендалла, коэффициент корреляции.

Lina BAGDŽIŪNAITĖ-LITVINAITIENĖ. Doctor of Technological Sciences, Department of Hydraulics, Vilnius Gediminas Technical University (VGTU).
Master of Science (environmental engineering), VGTU, 2001. Bachelor of Science (ecology), VPU, 1999. Publications: author of 15 scientific publications.

Andrius LITVINAITIS. PhD student of Technological Sciences, Department of Hydraulics, Vilnius Gediminas Technical University (VGTU). Master of Science (geography), VPU, 2001. Bachelor of Science (geography), VPU, 1998.

Valentinas ŠAULYS. Prof. Dr, Head of Department of Hydraulics, Vilnius Gediminas Technical University (VGTU), Faculty of Environmental Engineering. The council member for water problems of Lithuanian science Academy. Publications: author of five books including educational and more than 190 research papers. Research interests: environmental engineering and landscape management, drainage system reliability and maintenance efficiency, processes of surface water seepage, water quality, water management policy.