DOI: 10.1515/jwld-2015-0009

JOURNAL OF WATER AND LAND DEVELOPMENT
2015, No. 25 (IV–VI): 23–30
PL ISSN 1429–7426
Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld

Received 01.07.2015
Reviewed 06.06.2015
Accepted 13.06.2015

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Impact of climate fluctuations on the spring runoff regime with regard to rivers in Lithuania

Lina BAGDŽIŪNAITĖ-LITVINAITIENĖ ABDEF**, Andrius LITVINAITIS** BCDEF

Vilnius Gediminas Technical University, Department of Water Engineering, Saulėtekio al. 11, 10223 Vilnius, Lithuania; e-mail: andrius.litvinaitis@vgtu.lt

For citation: Bagdžiūnaitė-Litvinaitienė L., Litvinaitis A. 2015. Impact of climate fluctuations on the spring runoff regime with regard to rivers in Lithuania. Journal of Water and Land Development. No. 25 p. 23–30

Abstract

The article describes the impact of fluctuations in climatic factors on hydrological processes. The analysis of climate and hydrology covers two periods, the first up to 1996 and the second from 1981 to 2012. Study object includes 22 river basins situated on the eastern coast of the Baltic Sea: 1000 km^2, up to 10 000 km^2 and bigger. The study involved Mann–Kendall, Spearman's and linear regression tests. Causal relationships, as criteria that may fundamentally change the runoff regime set up by climatic factors, were established by evaluating the size of the river basin and assessing the spread of sediments, lakes, swamps and forests in the river basin. The analysis of data from the last thirty years disclosed that, with reference to the previously obtained information, floods in lakes became substantially reduced. Nevertheless, within the winter period of recent years, temperatures prevented lakes from acting as water reservoirs. The paper examined and defined the impact of sediments on variations in the runoff regime. For the period of the last thirty years, cut-off dates, i.e. flood start, crest and end, have advanced.

Key words: *climate change, Mann-Kendall test, river, runoff regime, trend*

INTRODUCTION

Daily fluctuations in climate cause the major concern for the world population. In this particular case, Lithuania is not an exception. Currently, Lithuanian scientists have recorded a number of ongoing variations in trends for changes in climate. Global warming affects fluctuations in the hydrological regime and water resources, which may have a great impact on the distribution of annual runoff in rivers and cause more droughts and floods. Thus, an important point is monitoring variations in the flow and predicting possible alterations. Under the changing regime of the river flow, both water quality and the ecosystem as a whole are affected.

Recent decades have witnessed events that raised questions whether ongoing variations in the river runoff regime are related to climate fluctuations or it is only a regular hydrological cycle. However, we cannot rule out significant anthropogenic activity [MALMQVIST, RUNDLE 2002; SAHIN, HALL 1996]. Human beings have tried to protect their residential areas and improve everyday life [NILSSON *el. al.* 2005; NILSSON, MALM-RENÖFÄLT 2008]. Plenty of scientific works regarding the impact of climate fluctuations on the spring runoff regime have been done [ALCAMO *et al.* 2007; ARNELL 2004; ARNELL *et al.* 2011; GOTTCHALK KRASOVSKAIA 1997; IPCC 2013; KUNDZEWICZ *et al.* 2008; LINDSTROM, BERGSTROM 2004; MILLY *et al.* 2008; PAO-SHAN *et al.* 2002]. Close attention is paid to the analysis of extreme events in Europe, trends for floods in particular [DANKERS, FEYEN 2009; FREDERICK, MAJOR 1997]. Forecasts of fluctuations in climate and the impact of socio-economic factors have been made [LAIZE *et al.* 2010; 2014]. KAMGA [2001] maintains that climatic fluctuations leading to temporary and spatial changes in precipitation will have a major impact on human activities.

The impact of climate fluctuations on river runoff was identified in the northern and Baltic countries [BERGSTROM *et al.* 2001; HISDAL *et al.* 2001; KLAVINS, RODINOV 2008; REIHAN *et al.* 2001].

GOUDIE [2000] emphasizes clear evidence that recent decades have increasingly been getting warmer and precipitation is more intense in some parts of the United States of America, Canada, Australia, Japan, South Africa and Europe. Investigation into the reaction of runoff to fluctuations in climate revealed that the annual runoff is more sensitive to changes in precipitation than to evaporation, and such sensitivity is more expressed in arid than in wet areas.

The examination of the river basins of different sizes and varying physical-geographical conditions allows more accurately predicting the seasonal flow and warning about possible extreme events.

The article describes fluctuations in spring runoff in Lithuanian rivers for the last 30 years. The obtained data were compared with the previous long-term data.

RESEARCH OBJECT AND METHODS

We examined 22 rivers in Lithuania (including different stretches of the same rivers) (Tab. 1), of which 4 river basins are larger than 10 000 km^2. Thirteen river basins are larger than 1000 km^2 and 10 rivers have catchment areas less than 1000 km^2. The rivers represent different geographical and hydrological regions, and therefore their physical-geographical conditions vary (Fig. 1, 2). Data on river runoff, precipitation and temperatures were received from 10 weather stations under Lithuanian Hydrometeorological Service (LHMT 1981–2012).

Table 1. Physical-geographical conditions of river basins

No.	Rivers (location of sampling sites)	Area of river basin km^2	Laky areas %	Waterlogged areas %	Forested areas %	Sandy areas %
1	Nemunas (Kaunas)	46 300	1.3	21	19	–
2	Neris (Jonava)	24 600	2.4	10	28	41
	Neris (Grigiškės)	15 200	2.2	10	35	26
	Neris (Buivydžiai)	11 000	–	11	35	–
3	Šventoji (Anykščiai)	3 600	4.7	10	12	30
	Šventoji (Ukmergė)	5 440	3.8	9	12	30
4	Merkys (Puvočiai)	4 300	0.9	10	46	67
5	Žeimena (Pabradė)	2 580	7.0	10	37	76
6	Mūša (Ustukiai)	2 280	0.8	3	14	1
7	Šešuvis (Skirgailiai)	1 880	0.1	4	17	13
8	Jūra (Tauragė)	1 690	0.2	6	20	8
9	Venta (Leckava)	4 060	1.0	9	22	11
	Venta (Papilė)	1 570	0,6	7	27	10
10	Minija (Kartena)	1 230	1.4	8	20	12
11	Nevėžis (Panevėžys)	1 130	0.3	6	23	20
12	Lėvuo (Bernatonys)	1 130	0.5	9	15	12
13	Dubysa (Lyduvėnai)	1 070	0.7	13	14	20
14	Šalčia (Valkininkai)	746	0.1	5	34	70
15	Verknė (Verbyliškės)	694	2.0	14	12	20
16	Ūla (Zervynos)	679	0.3	11	84	89
17	Bartuva (Skuodas)	512	0.2	5	3	3
18	Mituva (Žindaičiai)	403	0.2	1	20	8
19	Akmena (Paakmenė)	314	0.8	11	5	1
20	Akmena (Kretinga)	293	0.0	1	27	1
21	Strėva (Semeliškės)	234	6.3	13	19	30
22	Skroblus (Dubininkai)	71	0.1	2	94	95

Source: own elaboration.

Ninety percent of hydrological series have distinct asymmetry in hydrology, which means that data do not obey the normal distribution law, i.e. nonparametric statistical tests were used [DUMBRAUSKAS 2008]. The paper analyses the regime of runoff fluctuations with the help of a few nonparametric statistical tests, i.e. Mann–Kendall, Spearmen‘s and linear regression [HELSEL, HIRSCH 2002].

Statistics S in the Mann–Kendall test is calculated according to the formula

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i-1} sign(x_i - x_j) \tag{1}$$

where

$$sign(x) = \begin{cases} 1, \text{if } x > 0 \\ 0, \text{if } x = 0 \\ -1, \text{if } x < 0 \end{cases}$$

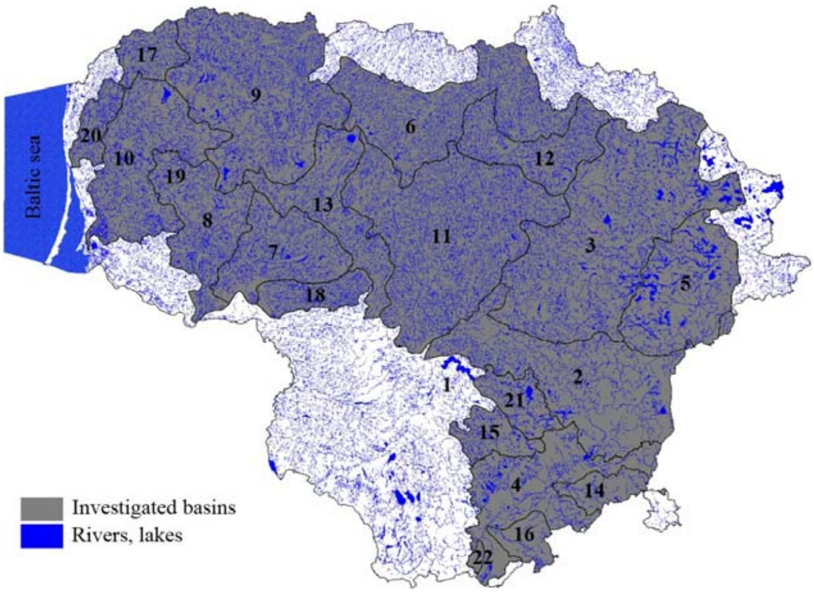

Fig. 1. Investigated river basins; source: own elaboration

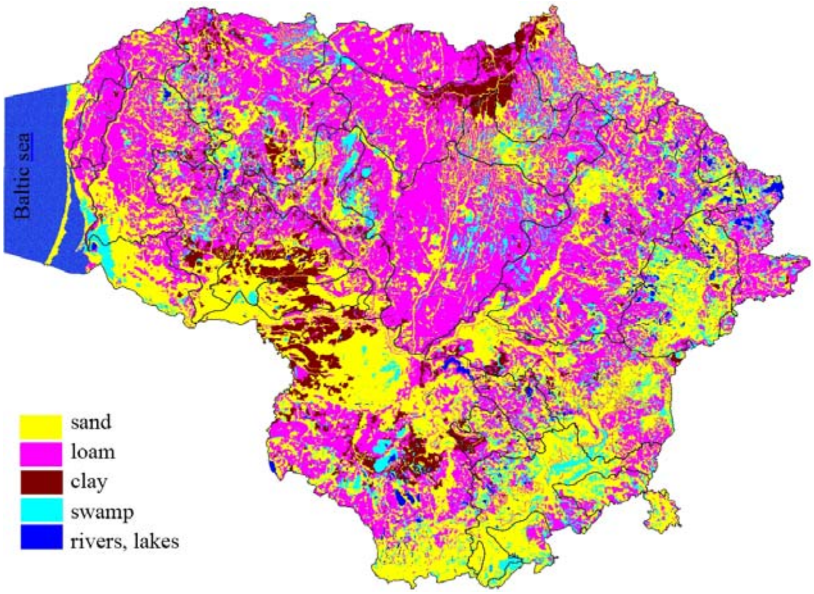

Fig. 2. Sediment dispersion on territory of Lithuania; source: own elaboration

If the null hypothesis H_o 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.

Spearman's Rho test confirms the findings obtained in the course of the Mann–Kendall test that indicates whether the correlation between two variables is significant. Test statistics q_s is the correlation coefficient that uses series and is obtained similarly to an ordinary correlation coefficient [CHIEW, SIRIWARDENA 2005]:

$$q_s = \frac{S_{xy}}{(S_x S_y)^{0.5}} \quad (2)$$

where

$$S_x = \sum_{i=1}^{n} (x_i - \bar{x})^2; \;\; S_y = \sum_{i=1}^{n} (y_i - \bar{y})^2;$$

$$S_{xy} = \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y});$$

and x_i (time), y_i (variable of interest), □x and □y refer to the ranks (□x, □y, S_x and S_y have the same value in a trend analysis).

Linear regression test is a parametric test that assumes normal distribution of the data. It tests whether there is a linear trend by examining the relationship between time *x* and the variable of interest *y*.

The Laboratory of Hydrology of Lithuanian Energy Institute investigated variations in the hydrological parameters of rivers in Lithuania. However, research was conducted up to 1996, and therefore data series cover the period from 20 to 100 years. The paper compares the results obtained within the period of the last 30 years to identify changes that occurred in national rivers, whether variations are significant enough and whether there are grounds for concern and for radical search for solutions to alterations [GAILIUŠIS *et al*. 2001].

RESULTS

The network of rivers and runoffs reflect climate, relief and sediment dispersion. The influence of all azonal factors can be best noticed in small river basins, as the big ones face the integration of the impact of several often differently acting factors. The flood process depends primarily on local climate conditions, and therefore is analysed accordingly to separate three hydrological areas that may be found in Lithuania and embrace south-eastern, central and western areas. Lithuania belongs to the Baltic Sea basin. The sea affects fluctuations in the meteorological elements of the country and the hydrological regime of rivers. Differences in the sizes of meteorological elements are obvious in various climatic regions, and their perennial averages vary from the west to the east according to terrain elevation.

River flooding is affected by the density of lakes, wetlands, forests and sand. Thus, we accepted these parameters as the most important criteria.

Theoretically, the annual distribution of the runoff of every river depends on factors in the local climate and floor surface. Climatic factors determine the total content of water per year and the dates of certain phases and time-span of the runoff regime that varies slightly in a relatively small territory of Lithuania. Factors in the floor surface, including the size of the river basin, lithological composition, the density of lakes, wetlands and forests in the river basin, can radically change the runoff regime formed by climatic factors. Lakes, as local factors, exert the major impact on the spring flood, regulate runoff and redistribute it from the flooding season to the dry one, i.e. they reduce maximum flow rate, tidal height and lengthen the duration of it [GAILIUŠIS *et al.* 2000; 2001; GAILIUŠIS, KRIAUČIŪNIENĖ 2009].

The analysis of data collected within the recent thirty years disclosed that, with reference to the figures of the previous years, lakes used to reduce floods; nevertheless, in the run of the recent winter seasons, temperatures prevented lakes from acting as water reservoirs. A comparison of two thirty-year periods points to substantial variations in air temperature (Tab. 2).

Table 2. A comparison of air temperature at different periods

Meteorological stations	Years 1950–1980						Years 1981–2012					
	XII	I	II	III	IV	annual mean	XII	I	II	III	IV	annual mean
Lazdijai	–2.7	–5.1	–4.7	–0.5	6.1	6.2	–1.8	–3.5	–3.4	0.6	7.2	6.9
Panevėžys	–2.9	–5.3	–4.7	–0.6	5.6	6.2	–1.8	–3.0	–3.9	0.4	7.0	6.7
Utena	–3.2	–6.0	–5.2	–1.2	5.5	5.8	–2.4	–3.5	–4.4	0.1	6.9	6.3
Raseiniai	–2.8	–5.4	–4.7	–1.0	5.3	5.9	–2.1	–3.6	–3.9	0.0	6.4	6.4

Source: own elaboration.

The study showed that, within the last thirty years air temperature in January increased from –5.5 to –3.4°C, i.e. by 2.1 degrees. The smallest variations were noticed in March and amounted only 0.5 degrees.

The impact of wetlands on flood is not that high, as before the start of the flood. The accumulation possibilities of wetlands are limited due to the fact that usually moisture reserves accumulated in autumn and frozen in winter remain unspent. At 20–30% density of wetlands, the flood layer is reduced on average by 5–15 mm [GAILIUŠIS *et al.* 2001]. Considering the examined rivers, only one has such a large wetland area that cover 21% of the total catchment area. However, an apparent effect was not recorded even in this basin in the course of spring runoff.

Large forests in the river basin also make changes in the course of flood. Forests extend the snowmelt process, their soils accumulate melt water and later return them to rivers thus reducing the maximum flow rate and prolonging flood duration. More than 84% of forests can be observed in two river basins of the investigated rivers. Ten rivers have forest density from 21 to 46% while the forests of 14 rivers cover from 3 to 20% of the basin area. The largest forest areas can be observed in the south-eastern part of Lithuania. Thus, we attempted to establish a correlation between spring run-off and the woodland of river basins both expressed in percentage (Fig. 3). The correlation was strong reaching 0.82. It appears that the larger are forest areas, the greater is their reducing impact on spring runoff.

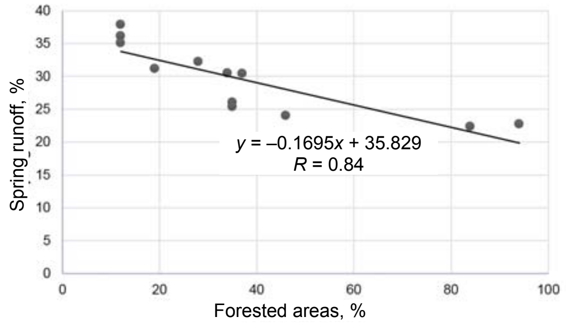

Fig. 3. The impact of forest area on runoff expressed in % of the spring runoff; source: own study

The assessment of fluctuation coefficients of flood runoff in spring demonstrated that river runoff in southeast Lithuania varied at minimum amplitude from 0.26 to 0.56 in spring. The highest amplitude of fluctuation coefficients indicates that runoff is uneven, almost directly depends on precipitation as that found in the middle part of Lithuania, where heavy sediments i.e. loam and clay are the dominating elements. The coefficients of fluctuations in spring runoff in the rivers of western Lithuania varied from 0.46 to 0.6.

Statistical analysis of annual runoff regularities for the period 1981–2012 revealed that, according to the Mann–Kendall test, the trend for flow rate fluctuations in all rivers was negative, i.e. water content in rivers decreased with the exception of those having sandy areas covering 40 to 89% of the river basin. The results of the Spearman's test showed that a positive trend regarding data can be observed in a number of rivers in southeast Lithuania. Similar findings were obtained with the help of the linear regression method. Thus, considering lithological parameters, river basins in southeast Lithuania fairly frequently contain sandy sediments characterized by high porosity and water permeability and quickly absorb rain water and snow melt. Water accumulated in thick layers is returned to rivers through underground feeding within runoff. Therefore, rivers in southeast Lithuania have the most balanced flow regime. Underground feeding amount 40–60% of the annual runoff there. A large number of lakes have a profound influence on smoothing the runoff in this part of Lithuania

Investigation into the regularities of fluctuations in the spring runoff demonstrated that the trend for variations in the Mann–Kendall test was negative in almost all rivers, except those whose basins were larger than 1000 km^2 and the content of sand exceeded 89% of the general catchment area. According to the Spearmen's test, a negative tendency in fluctuation can be observed in all rivers, except those in the south-eastern part of Lithuania where the forest cover exceeds 35% of the catchment area. Similar results were obtained after examining data with the linear regression method.

The change of meteorological situation in the last 30 years was followed by the nature of floods (Tab. 3).

Table 3. A comparison of precipitation at different periods

Meteorological stations	Years 1950–1980						Years 1981–2012					
	XII	I	II	III	IV	annual mean	XII	I	II	III	IV	annual mean
Telšiai	66	58	49	45	45	825	79	71	48	51	40	827
Panevėžys	44	41	41	38	44	666	46	40	31	34	39	617
Kybartai	55	55	45	43	43	736	42	43	33	34	32	604
Varėna	45	50	46	39	46	727	45	55	52	39	41	694

Source: own elaboration.

The assessment of variations in precipitation for the two different periods of thirty years demonstrated that April was the month of most significant differences, as, for the last thirty years, precipitation decreased by 15%, and the total annual precipitation was reduced by 7%.

Water produced by snowmelt theoretically causes river floods; however, spring precipitation adds to the extent of floods.

Fluctuations in spring runoff, under changing climate, were established to be an unavoidable phenomenon.

The inspection of regularities in flood changes and a comparison of temporal variations confirmed that, accordingly to the previous research, spring flood in the rivers of Lithuania most frequently starts in the second half of March and only in the laky rivers of eastern Lithuania – 5–10 days later. Spring flood duration in most medium-sized rivers varies from 15–25 to 70–80, in small rivers from 10–15 to 30–35 and only in those having laky basins, for example Žeimena, from 50–110 days (Fig. 4).

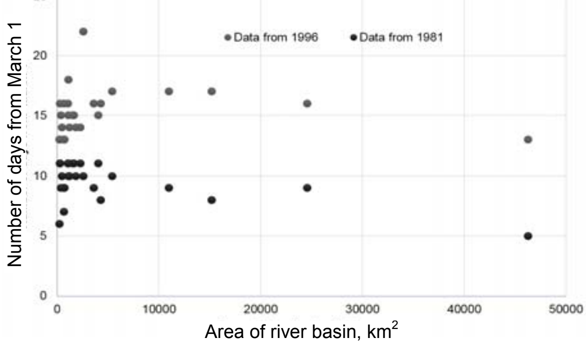

Fig. 4. Flood start in the previous and recent years; source: own study

The flood of the majority of medium-sized rivers ends in the end and that of small rivers – in the beginning and middle of April. The flood in the Nemunas River ends on average between May 12 and 15, and in the Neris River – on May 12 [GAILIUŠIS *et al.* 2001].

A comparison of flood starting dates with data provided by the Laboratory of Hydrology revealed that floods advanced within the period from 1981–2012. Advanced flooding is observed from insignificant 2 to significant 12 days. In the previous years, floods used to start in the middle of March and even prolonged until the end of March. For the recent thirty years, advanced floods began in the beginning of March and lasted differently. With reference to data for the period 1981–2012, floods in the river basins larger than 1000 km^2 last approximately 27 days while, in the previous period, it took up to 38 days. Floods became shorter by 29%, i.e. from 44 to 31 days, in the river basins larger than 1000 km^2 but smaller than 10 000 km^2 while flooding time was reduced from 55 to 42 days in big catchment areas. The obtained results show that runoff was temporally redistributed. A decrease in the amount of precipitation during the winter season ended up in the situation when large river water flows are not recorded in spring (Fig. 5). However, meteorologists have frequent fears about more common summer and autumn floods [GALVONAITĖ 2007].

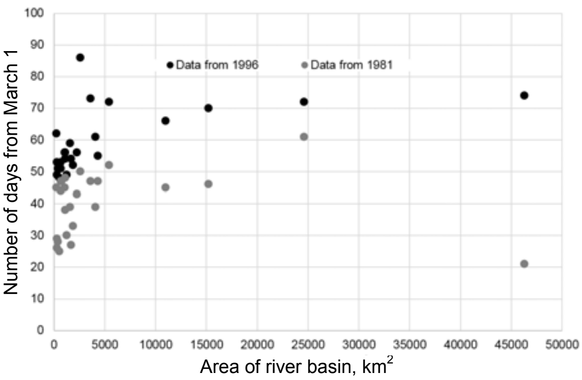

Fig. 5. Flood end in the previous and recent years; source: own study

Flood crest naturally advances. According to the previous long-term data, flood crest could be observed at the end of March. Nevertheless, according to the recent records, dates of flooding advanced from 6 to 23 days. Thus, the findings showed that flood water flows over a shorter period of time. With reference to data on the last decades, the flood, on average, takes 5 days longer and rises to the maximum, but the overall flood period shortened by an average of 15 days, i.e. 34%.

CONCLUSIONS

Basic factors including the size of the river basin, lithological composition and the density of lakes, wetlands and forests in the catchment area can radically change the runoff regime formed by climatic factors. However, this is a rather complex process, and specific impact cannot be unambiguously proved when examining any of the azonal factors. Nonetheless, according to data on the previous years, lakes obviously reduced floods due to the fact that winter temperatures of recent years have prevented lakes from acting as water reservoirs.

For the period of the last three decades, the total annual precipitation fell by 7.0%. April was distinct in the spring season with its decrease of precipitation by 15 %. The recent period of thirty years faced a rise in air temperature. This was especially visible in January when temperature increased from –5.5 to –3.4°C, i.e. by 2.1 degrees. The smallest variations of only 0.5 degrees was observed in March.

Mann–Kendall, Spearman's and linear regression statistical tests confirmed trends for fluctuations in spring runoff in the decreasing direction. However, the encountered regularity cannot be attributed to rivers whose runoffs are levelled because of light sediments.

The cut-off dates for floods were found to be more advanced in the last thirty years. Floods start within the period from 2 to 12 days, flood crest lasts 6 to 23 days and the full span of the flood decreased by 34%.

REFERENCES

ALCAMO J., FLORKE M., M□ARKER M. 2007. Future long-term changes in global water resources driven by socio-economic and climate changes. Hydrological Sciences Journal. Vol. 52 p. 247–275.

ARNELL N.W. 2004. Climate change and global water resources: SRES emissions and socio-economic scenarios. Global Environmental Change. 14 p. 31–52.

ARNELL N.W., VAN VUUREN D.P., ISAAC M. 2011. The implications of climate policy for the impacts of climate change on global water resources. Global Environmental Change. Vol. 21 p. 592–603.

BERGSTROM S., CARLSSON B., GADELIN M., LINDSTROM G., PETTERSON A., RUMMUKAINEN M. 2001. Climate change impacts on runoff in Sweden assessments by global climate models, dynamical downscalling and hydrological modelling. Climate Research. Vol. 16 p. 101–112.

CHIEW F.H.S., SIRIWARDENA L. 2005. TREND – trend/change detection software [online]. CRC for Catchment Hydrology. [Access 01.06.2015]. Available at: http://www.toolkit.net.au/Tools/DownloadDocumentation.aspx?id=1000134

DANKERS R., FEYEN L. 2009. Flood hazard in Europe in an ensemble of regional climate scenarios [online]. Journal of Geophysical Research-Atmospheres. Vol. 114. Doi: 10.1029/2008JD011523. [Access 01.06.2015]. Available at: http://publications.jrc.ec.europa.eu/repository/handle/JRC49983

DUMBRAUSKAS A., BAGDŽIŪNAITĖ-LITVINAITIENĖ L., VYCIENĖ G. 2008. Trend detection in hydrological series of main Lithuanian rivers. In: Environmental engineering. Vol. 2. 7th International conference, May 22–23, 2008 Vilnius, Lithuania. Vilnius. Technika p. 508–514.

FREDERICK K. D., MAJOR D. C., 1997. Climate change and water resources. Climatic Change. Vol. 37 p. 7–23.

GAILIUŠIS B., JABLONSKIS J., KOVALENKOVIENĖ M. 2001. Lietuvos upės: Hidrografija ir nuotėkis [Lithuanian rivers: Hydrography and runoff] Kaunas. Lithuanian Energy Institute.

GAILIUŠIS B., KOVALENKOVIENĖ M., RIMAVIČIŪTĖ E. 2000. Tvenkinių poveikis Lietuvos upių nuotėkio režimui [Reservoir impact on hydrological regime of Lithuanian rivers]. Geografijos metraštis. Vol. 33 p. 97–107.

GAILUŠIS B., KRIAUČIŪNIENĖ J. 2009. Runoff changes in the Lithuanian rivers due to construction of water reservoirs. In: Rural development 2009. Proceedings of the International Scientific Conference. Vol. 4. Iss. 2. 15–17 October, 2009. Akademija, Kaunas region, Lithuania. Vilnius. Lithuanian University of Agriculture p. 24–28.

GALVONAITĖ A., MISIŪNIENĖ M., VALIUKAS D. 2007. Lietuvos klimatas [Lithuanian climate]. Vilnius. Lithuanian Hydrometeorological Service.

GOTTCHALK L., KRASOVSKAIA I. 1997. Climate change and river runoff in Scandinavia, approaches and challenges. Boreal Environment Research. Vol. 2. Iss. 2 p. 145–162.

GOUDIE A. 2000. The human impact on the natural environment. 5th ed. Cambridge, Massachusetts. The MIT Press. ISBN 0-262-57138-2 pp. 511

HELSEL D.R., HIRSCH R.M. 2002. Statistical methods in water resources. Techniques of water resources investigations [online]. B. 4. Ch. A3. U.S. Geological Survey pp. 522. [Access 01.06.2015] Available at: http://pubs.usgs.gov/twri/twri4a3/pdf/twri4a3-new.pdf

HISDAL H., STAHL K., TALLAKSEN L. M., DEMUTH S. 2001. Have streamflow droughts in Europe become more severe or frequent? International Journal of Climatology. Vol. 21 p. 317–333.

IPCC 2013. Climate change 2013: The Physical Science Basis Working Group I contribution to the IPCC Fifth Assessment Report Climate Change 2013. The Physical Science Basis. New York. Cambridge University Press. ISBN 978-1-107-05799-1 pp. 1535.

KAMGA F.M. 2001. Impact of greenhouse gas induced climate change on the runoff of the Upper Benue River (Cameroon). Journal of Hydrology. Vol. 252 p. 145–156.

KLAVINS M., RODINOV V. 2008. Long-term changes of river discharge regime in Latvia. Hydrology Research. Vol. 39. Iss. 2 p. 133–141.

KUNDZEWICZ Z.W., MATA L.J., ARNELL N.W., DOLL P., JIMENEZ B., MILLER K., OKI T., SEN Z., SHIKLOMANOV I. 2008. The implications of projected climate change for freshwater resources and their management. Hydrological Sciences. Vol. 53. Iss. 1 p. 3–10.

LAIZE C.L.R., ACREMAN M.C., DUNBAR M.J., HOUGHTON-CARR H., FLORKE M., SCHNEIDER C. 2010. Monthly hydrological indicators to assess impact of change on river ecosystems at the pan-European scale: preliminary results. [British Hydrological Society Third International Symposium Role of Hydrology in Managing Consequences of a Changing Global Environment]. [19–23 July 2010. Newcastle].

LAIZE C.L.R., ACREMAN M.C., SCHNEIDER C., DUNBAR M.J., HOUGHTON-CARR H., FLORKE M., HANNAH D.M. 2014. Projected flow alteration and ecological risk for pan-European rivers. River Research and Applications. Vol. 30 p. 99–314.

LINDSTROM G., BERGSTROM S. 2004. Runoff trends in Sweden 1807–2002. Hydrological Sciences Journal. Vol. 49. Iss. 1 p. 69–83.

MALMQVIST B., RUNDLE S. 2002. Threats to the running water ecosystem of the world. Environmental Conservation. Vol. 29 p. 134–153.

MILLY P.C.D., BETANCOURT J., FALKENMARK M., HIRSCH R.M., KUNDZEWICZ Z.W., LETTENMAIER D.P., STOUFFER R.J. 2008. Stationarity is dead: whither water management? Science. Vol. 319. No. 5863 p. 573–574.

NILSSON C., REIDY C.A., DYNESIUS M., REVENGA C. 2005. Fragmentation and flow regulation of the world's large river systems. Science. Vol. 308. No. 5720 p. 405–408.

NILSSON C., MALM-RENÖFÄLT B. 2008. Linking flow regime and water quality in rivers: a challenge to adaptive catchment management. Ecology and Society. Vol. 13. Iss. 2 p. 18–24.

PAO-SHAN Y., TAO-CHANG Y., CHIH-KANG W. 2002. Impact of climate change on water resources in Southern Taiwan. Journal of Hydrology. Vol. 206. Iss. 4 p. 161–175.

REIHAN A., KOLTSOVA T., KRIAUČIŪNIENĖ J., LIZUMA L., MEILUTYTĖ-BARAUSKIENĖ D. 2007. Changes in water discharges of the Baltic states rivers in the 20th century and its relation to climate change. Nordic Hydrology. Vol. 38. Iss. 4/5 p. 401–412.

SAHIN V., HALL M.J. 1996. The effects of afforestation and deforestation on water yields. Journal of Hydrology. Vol. 178 p. 293–309.

Lina BAGDŽIŪNAITĖ-LITVINAITIENĖ, Andrius LITVINAITIS

Wpływ zmian klimatycznych na reżim wiosennego odpływu na przykładzie rzek Litwy

STRESZCZENIE

Przedmiotem artykułu jest wpływ czynników klimatycznych na zmianę procesów hydrologicznych. Dokonano analizy klimatycznej i hydrologicznej dwóch okresów: do roku 1996 i od roku 1981 do 2012. Obiektem badań były zlewnie 22 rzek we wschodniej części wybrzeża Morza Bałtyckiego: do 1000 km^2, do 10 000 km^2 i większe. W badaniach stosowano testy statystyczne Manna–Kendalla, Spearmana i regresji liniowej przeznaczone do ustalenia związku przyczynowego w ocenie wielkości zlewni rzeki, osadów, jezior, bagien, zalesienia w zlewni rzeki jako kryteria, które w zasadniczy sposób mogą zmienić reżim odpływu ukształtowany przez czynniki klimatyczne. Analiza danych pochodzących z ostatnich trzydziestu lat wykazała, że według wcześniejszych danych jeziora w większym stopniu ograniczały występowanie powodzi, jednak w ostatnich latach temperatura w sezonie zimowym nie pozwala jeziorom pełnić funkcji akumulatorów wodnych. Zanalizowano i określono wpływ osadów na zmiany reżimu przepływu. Stwierdzono, że w ciągu ostatnich trzydziestu lat graniczne daty powodzi – początek, szczyt i koniec – notowane są wcześniej.

Słowa kluczowe: *reżim przepływu, rzeka, test Manna–Kendalla, trend, zmiany klimatyczne*