

## CHANGES OF DRAINAGE RUN-OFF HYDROLOGICAL REGIME IN GLACIAL LACUSTRINE CLAYS OF THE KARST ZONE

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**Abstract.** Long-term data (1976 to 1999 and 2009) on the hydrological regime change of the drainage situated in glacial lacustrine clay loam on clay in the North Lithuanian karst zone are presented in the article. Study data shows that the drainage run-off changed since 1988. Before 1988 the average drainage run-off was by 19 mm higher than 1988, the insignificant difference (Student's test  $t_{act}=0.58 < t_{0,05}=1.72$ ). However, seasonal distribution of drainage run-off changed significantly in the latter period. Due to changing climatic conditions the drainage run-off increased in winter (January-February), decreased in spring (March-May) and autumn (September-November). In the period of 1988-1999 the average air temperature and precipitation exceeded the corresponding data of 1976-1987 by 1.3 °C and 34 mm, respectively. Significant increase of the average air temperature (4.8 °C) was observed in January and February, that of precipitation – in February (16 mm). The influence of air temperature fluctuations on the drainage run-off was significant in January and February, that of precipitation – in March, September and October. According to Mann-Kendall test (MK), the drainage run-off significantly increased in January (MK= 2.28, significance level  $\alpha=0.05$ ) and in February (MK = 2.04,  $\alpha = 0.05$ ), and insignificantly decreased in March, April, September, October and November.

**Keywords:** drainage run-off, climate change, glacial lacustrine sandy loam and clay, karst zone.

### 1. Introduction

In process of the global climate change, alterations of natural environment were also noticed in Lithuania. Winter and spring seasons have particularly warmed, the temperature of summer and autumn seasons has risen 0.1 to 0.2 °C. The tendency to increased precipitation in cold season and decreased precipitation in warm season was identified. Changes in atmospheric circulation decided changes in seasonal duration (spring and autumn lengthen, and winter and summer shorten), decrease in differences between seasonal air temperature and precipitation, decrease in coat of snow rates (number of days with cover of snow and snow thickness) (Bukantis, 2007).

Climate change has a significant impact also on the water circulation cycle. As a result of climate change, the distribution of river flood in time is forecasted: more frequent high waters in all seasons, less spring floods and higher probability of minimum flow in summer. It will increase the biological contamination of surface waters in summer and decrease the general contamination in spring. With the rise in air and water temperature, eutrophication processes will speed up, the water quality will decline (Rimkus, 2007). The drain run-off has

increased in cold period (December to March) and spring (April and May) (Singh *et al.*; 2009). However, not only probable change in precipitation, temperature and water run-off should be taken into account, but also changes in the way of the farming (Soukup, 2006)

Since Lithuania is situated in the humidity excess zone, it is necessary to apply the means of wet soil draining. The area of drained land makes approx. 3 million ha in Lithuania, of them by drain – approx. 2.6 million ha (86 % drained land area) (Kisieliauskas, 1998).

The drain run-off is decided not only by precipitation, but also by its distribution within a year as well as many other factors, for example, soil moisture and snow supply in the drained area, conditions of water infiltration into the soil, and air temperature (Balčiūnas, 1998; Kudakas *et al.*; 1998). The drain run-off depends on the size of system. In large drainage systems, the run-off is formed under more complicated conditions than in small systems. In the case of moderate depth of freeze, in the beginning of snow melting, the drain run-off is formed earlier than the surface one. The main factor forming the drain run-off at that time is the surface water that gets into drains through various soil cracks (Sakalauskas, 1976). It was determined that the drain run-off was mostly influenced by the depth of freeze and the

relative humidity, and least by the temperature (Miseckaitė *et al.*; 2010). Subsurface drainage significantly influenced soil temperature for the soils (Jin *et al.*; 2008). This drain run-off depends on physical properties of the soil and the number of larger pores and cracks in soils. The effect of drain is highly improved by cracks formed in droughts. With the persistence of wet period, cracks fill up with water and, as the soil swells, close up (Balčiūnas, 1976).

Intensive draining changes the hydrographical net of the territory, conditions of surface and ground flow forming also change. The drain run-off (it may be considered interjacent between surface and groundwater) equals to 60-70% of annual run-off of small streams, the watersheds of which contain 80-100% of drained farming land (Juozapaitis, 1976). Most chemical substances contained in the soil are water-soluble; therefore, hydrological regime changes in the ecosystem are closely related to changes in nutritive load. By means of drain, much nitrogen and other elements contaminating the stream water are leached out. It was determined that N-NO<sub>3</sub> contents leached out by the drain water (determination coefficient 0.28 – 0.89) influence concentration fluctuations of the same compound in the stream (Rudzianskaitė and Šukys, 2000). Higher contents of nitrogen and phosphorus are leached out in winter and spring periods (Morkunas *et al.*; 2005).

Considering higher leakages taking place in cold period, these changes of drainage hydrological regime raise new questions in solution of environmental problems. The literature sources (Jansons *et al.*; 2009)

suggest that extreme weather conditions in summer and winter, due to the climate change in the future, might increase the nutrient concentration in agricultural run-off and role of diffuse pollution.

The researches aim was to determine the impact hydrological regime change of the drain in glacial lacustrine clay loam and clay of karst zone.

## 2. Materials and methods

The investigation area is located in karst zone of North Lithuania, in the watershed of the Bėrė stream, Biržai district, Kirdonys village; soil - glacial lacustrine loams on various clays (Fig 1).

The investigated drain was installed in 1975. The drain system area is 33.6 ha, drainage distances 10-14 m, and in some sinks between multiplex drains 5-7 m. Karst rocks in the drained area occur in the 8 m depth.

In the period of 1976–1999 run-off of the drainage was measured with V-notch weir and limnigraph. Momentary measurements were carried out in 2000-2008. Since 2009 daily measurements with automatic measurer e+WATER L (Level) have been continued.

In 1976 to 1996, data from the Hydrometric Annuals (Balčiūnas *et al.*; 1998) were applied to analyze the drain run-off.

Meteorological conditions were described using the data of the nearest Meteorological Office in Biržai.

The Student's and Mann-Kendall test and variation coefficient was applied for the research data analysis.



**Fig 1.** Scheme of investigated area: 1 – river and stream; 2 – road; 3 – drainage system; 4 – place of measurements; 5 – forest

### 3. Results of research

As a result of winter warming, the duration of seasonal freeze in 1981 to 2000, compared to 1955 to 1980, in karst region, has shortened from 110 to 96 days, and the average depth of frost has decreased from 42 to 30 cm. Frequent thaws and periodic unfreeze in winter were characteristic to winters of the two last decades in the 20 century (Taminskas and Mažeika, 2003).

In the period of 1988-1999 the average air temperature and precipitation exceeded the corresponding data of 1976-1987 by 1.3 °C and 34 mm, respectively. Significant increase of the average air temperature (4.8 °C) was observed in January and February, that of precipitation – in February (16 mm) (Fig 2).

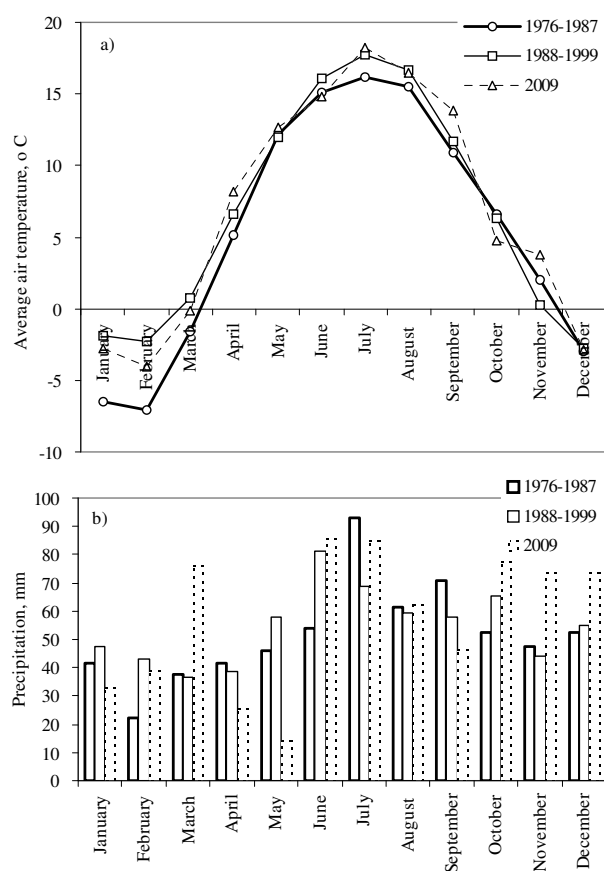


Fig 2. Average air temperature (a) and precipitation (b) in karst zone of Lithuania

The literature sources (Bendoravičius *et al.*; 2004) suggest that, in case of atmospheric soil feed the drain run-off volume and term depend on climatic conditions.

By analyzing long-term research data (1976 to 1999 and 2009), the drain run-off change since 1988 was observed. Before 1988 the average drainage run-off was by 19 mm higher than that 1988 (Table 1), the insignificant difference (Student's test  $t_{cal}=0,58 < 1,72=t_{0,05}$ ). Similar research results were determined also by other researchers (Bendoravičius *et al.*; 2004): the drain run-off was higher in 1967 to 1987 (177 mm) than in 1988 to 2003 (96 mm).

Table 1. Drainage run-off (mm) in period

Statistics	1976-1987	1988-1999
Minimum	61	64
Maximum	328	319
Median	209	175
Average	205	186

The least drainage run-off was observed in 1976 (91 mm) and 1996 (64 mm), when precipitation fell respectively 449 mm (74 % perennial rate) and 462 mm (76 % perennial rate). Although during the research period the highest amount of precipitation 870 mm (143 % perennial rate) fell in 1998, the drain run-off was not the highest one. Of late years, the particularly great amount of precipitation 201 mm (261 % perennial rate) fell in July, when the average air temperature was 16.2 °C; therefore, as a result of intense evaporation and transpiration, less precipitation water got into drains. More significant annual variations of the drainage run-off (variation coefficient 45 %) were observed in the period from 1988 to 1999 than from 1976 to 1987 (variation coefficient 38 %). In the latter period, also less change in precipitation was observed (variation coefficient 14 %).

The influence of air temperature fluctuations on the drainage run-off was significant in January and February, that of precipitation – in March, September and October (Table 2).

Table 2. Dependence drainage run-off on precipitation and average air temperature

Month	Precipitation		Air temperature	
	<i>r</i>	<i>t<sub>cal.</sub></i>	<i>r</i>	<i>t<sub>cal.</sub></i>
January	0.30	1.5	<b>0.65</b>	<b>3.99</b>
February	<b>0.43</b>	<b>2.23</b>	<b>0.68</b>	<b>4.33</b>
March	<b>0.49</b>	<b>2.64</b>	<b>0.36</b>	<b>1.81</b>
April	0.07	0.33	0.17	0.82
May	0.03	0.15	0.09	0.42
June	0.30	1.48	0.14	0.67
July	0.24	1.19	0.11	0.52
August	0.31	1.54	0.31	1.53
September	<b>0.49</b>	<b>2.67</b>	0.26	1.29
October	<b>0.63</b>	<b>3.83</b>	0.24	1.19
November	0.27	1.34	0.17	0.82
December	<b>0.44</b>	<b>2.27</b>	0.33	1.65

Note. *r* – correlation coefficient, *t<sub>cal.</sub>* – calculated Student's test, *t<sub>95%</sub>* – theoretical Student's test of 95% probability, *r* reliable when Student's test  $t_{cal.} > t_{95\%}=1.717$  (in bold).

Seasonal distribution of the drain run-off has changed. In the period of 2009 and from 1988 to 1999, the drain run-off increased in winter (January to February) and made 32 % of annual drain run-off as well as in summer (June to August) and made 4 %, and decreased in spring (March to May) and made 48 % as well as in autumn (September to November) with 7 % of annual drain flow. In the period of 1976 to 1987, the drain outflow in spring made 67% of annual drain flow, in autumn 19 %, in winter 5 %, and in summer 2 % of

annual drain flow. It was determine changing climatic conditions. Similar results were obtained also by other researchers (Balčiūnas, 1998; Bendaravičius *et al.*; 2004).

According to Mann-Kendall test (MK), the run-off significantly increased in January (MK= 2.28, significance level  $\alpha= 0.05$ ) and in February (MK = 2.04,  $\alpha= 0.05$ ), and insignificantly decreased in March, April, September, October and November (Table 3). It demonstrates that changes in seasonal distribution of the drain run-off are related to the change in climatic conditions. Frequent thaws in winter decreased depth and absence of freeze establish favourable conditions for the drainage run-off to form.

**Table 3.** Significance of temporal changes in drainage run-off

Month	Mann –Kendall test
January	<b>2.28</b>
February	<b>2.04</b>
March	-0.30
April	-1.19
May	0.99
June	1.63
July	0
August	0.30
September	-0.84
October	-0.39
November	-0.30
December	0.17

Note. Results in bold type are statistically significant at the significance level  $\alpha= 0.05$

#### 4. Conclusions

In the period of 1988-1999 the average air temperature and precipitation exceeded the corresponding data of 1976-1987 by 1.3 ° C and 34 mm, respectively. Significant increase of the average air temperature (4.8 ° C) was observed in January and February, that of precipitation – in February (16 mm).

By analyzing the long-term research data (1976 to 1999 and 2009), the change in seasonal distribution of the drain run-off was observed since 1988. In the period from 1988 to 1999, the drain run-off increased in winter (January to February) 3.3 times and in summer (June to August) 2.1 times, and decreased in spring (March to May) 1.6 times as well as in autumn (September to November) 3 times as compared to the period from 1976 to 1987. It suggests that changes in seasonal distribution of the drain run-off are related to the change in climatic conditions.

According to Mann-Kendall test (MK), the discharge significantly increased in January (MK= 2.28, significance level  $\alpha= 0.05$ ) and in February (MK = 2.04,  $\alpha= 0.05$ ), and insignificantly decreased in March, April, September, October and November.

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