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THE TRENDS OF DRAINAGE RUNOFF CHANGE IN LOAM SOILS DURING A MULTI-YEAR PERIOD

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Abstract. The article presents the influence of fluctuation of the main climatic factors over time on drainage runoff, the analysis of drainage runoff distribution in the course of a year. For the preparation of the present paper the data of drainage runoff as well as monthly precipitation and average temperature data from the hydro-meteorological station have been used. The seasonal differences of annual temperature amplitude and precipitation quantity decrease. It has a significant impact on the seasonal distribution of drainage runoff. The change of drainage runoff and its distribution over a year as well as the patterns of runoff have been analyzed. The article analyses the nature of multi-year change of runoff during the last four decades – periodic fluctuations and change trends. Analysing the heights of the drainage runoff during winter period (1969-2009) by decades, the drainage runoff has increased, in spring, summer and autumn negative trends were defined, i.e. the decrease of runoff, whereas in winter time the runoff increased (29% in the last decade) and the change of total annual runoff was positive.

Keywords: drainage runoff, climatic conditions, hydrothermal coefficient.

1. Introduction

An intensive agriculture is impossible in Lithuania without soil drainage - approximately 90% of total agricultural production of the country is grown in drained areas (Šaulys and Lukianas 2003). The size of drainage runoff depends on meteorological conditions of the year, the most important of which are the precipitation quantity and air temperature, however, the interdependence of precipitation quantity and drainage runoff is quite complex. Drainage systems are especially important in spring, during the snow melting period, because the excess of water is removed quickly from the arable layer of the ground, therefore, the conditions to start spring field works for about two weeks earlier are guaranteed. It is also very important to remove the excess of water, which forms in the fields during summer season after abundant precipitation (Lukianas and Ruminaitė 2009).

Drainage of agricultural fields is not only a modern tool for removal of excess water, but also a great component of water balance of open water ponds. The study included watertable strategies subjecting the subsoil to various degrees of water status. The effects on drain outflow, nutrient losses, soil aeration, nitrogen flow and crop performance were measured (Wesstrom *et al.* 2001). The drainage systems should be improved, seeking not to remove more soil water, but to support and, partially, to purify water. Seeking to use water resources rationally (Ramoška and Morkūnas 2006). (Morkūnas and Ramoška 2001; Ramoška and Morkūnas 2006), recommends damming up the drainage: the detention of drainage runoff during the drought of spring – summer reduces the deficit of soil moisture, and during the year of normal moisture it is considered as the ecosystem protection mean. When analyzing the elution of biogenesis from soil through drainage, much research have been carried out (Šileika and Gužys 2003; McDowell and Sharpley 2001; David *et al.* 2008; Tan *et al.* 2008). Mališauskas and Kutra (2008) determined that the highest trend of increase of nitrates in drainage water is in May, and the concentration of nitrates in drainage water was characterized by the lowest increase in October. Climate changes (temperature increase, precipitation decrease) may be related with the environmental pollution. In case of low temperature and low moisture, assimilation of nutrients goes on much worse, therefore, they are leached from the soil with the drainage runoff more intensely (Soussana and Lüscher 2006). It is important to know, what is the major factor, which leads to the pollution diffused by biogenesis N and P through drainage runoff and how the pollution occurs under various natural and agricultural conditions. The most important is the size of drainage runoff (Bučienė 2008, Šaulys and Bastienė 2008).

Climate change causes the increasing concern for scientists from all over the world. When climate changes, various environmental phenomena also change, i.e.; more precipitation falls, air temperature increases. It affects the water circulation cycle as well. The size of water resources and the unevenness of distribution in time depend on the climatic and meteorological conditions of specified territory and change every year – very watery and very dry periods occur (Meilutytė-Barauskienė *et al.* 2008). The analysis of distribution and annual course of climate variables (temperature, precipitation, etc.; meteorological elements and phenomena) highlights the certain characteristics of its change (Galvonaitė and Valiukas 2005). The changes of climatic elements, influencing the runoff – temperature and precipitation - have already been recorded in Lithuania (Bukantis and Rimkus 2005; Stankūnavičius 2009). Thus, seeking to use water resources rationally, it is necessary to know the periodicity of drainage, the runoff, factors, which determine it, and it is also important to forecast its dynamics. Successful technological innovation in irrigation and drainage development depends on broad research programmes and on the number and quality of human resources involved (Schutz *et al.* 2002).

The objective of research – to evaluate the drainage runoff and its change during a multi-year period in loam soils, according to the long-term drainage data.

Methods. In order to carry out the analysis of drainage runoff fluctuations and the impact of climatic factors on this process, the test object of Lithuanian Agricultural University in Kazliškės was selected. This decision is based on one of the largest data row of drainage system runoff in Lithuania. The values of drainage runoff of the analyzed period were collected, using Hydrometric Yearbook and the data of Department of Land Reclamation of Lithuanian Agricultural University.

Summarize the five long-term drainage systems (No 21, area 0.44 ha, no. 22, area 0.45 ha, no. 23, area 0.44 ha, no. 24, area 0.44 ha, no. 25 area of 0.45 ha) of drainage studies, which began in 1967 and continuing up to now, the data (Fig 1). Drain depth of 0.8, 1.10, 1.40 m, the drainage distance - 12, 18 Average test object surface slope - 0.008. The test site soil sod podzolic (the experimental according to FAO: calcar - HypogleyicLuvisol), texture - light loam, dripping down on medium loam. Topsoil layer thickness is 0.2 to 0.25 Arable layer of filtration rate - 1.0 to 2.0 m / day, the lower layers of soil - from 0.01 to 0.004 m / day. Drainage collectors enter into individual wells to measure the leakage. Drainage runoff to 1994 was measured using the recorder devices 'Valdaj' with day clock movement and subsequently measured at the mouth of experimental systems, embedded control wells, positive displacement method. Drainage flow data to 1994 taken from the published edition (Hidrometrinis...; 1995) and subsequent years, data from the Lithuanian University of Agriculture, Department of Land Reclamation employee (B. Bendaravičius, A. Dirsė) since 2007 drainage runoff data collected in one of the authors (O. Miseckaitė).

Research object is located in the southern part of Kaunas district, in the territory of training farm of Lithuanian Agricultural University (Fig 1).

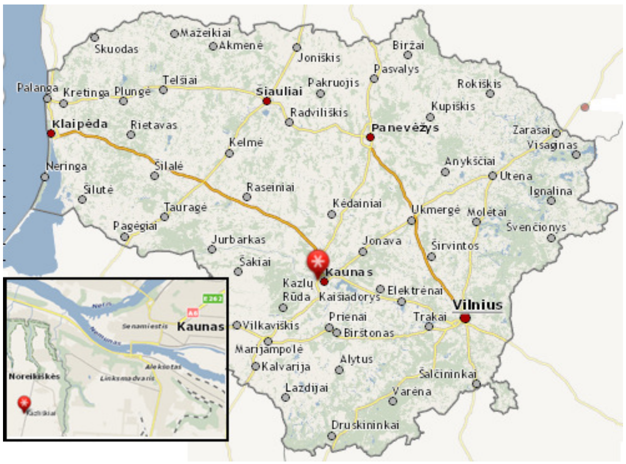

Fig 1. Study area location

Geomorphologically, the soil of the training farm is classified as the ground moraine of the last glacier. It is the continuation of the Middle Lithuania plain. From the hydro geological point of view, the test territory lies on the almost impermeable heavy loam or clay soils. Near the soil surface (0 – 0.20 m) the ground water, the regime of which depends on the atmosphere precipitation, location soils, the position of water-proof layer of soil and relief, is found. The moisture regime in almost all soils is conditioned by atmosphere feeding, therefore, their blotting is of temporary nature (five drainage systems are equipped there) (Hidrometrinis...; 1995).

The meteorological data of the analyzed period of 1969-2009 were collected from the Kaunas Meteorological Station, which is the nearest to the analyzed object (at the distance of 0.5 km). The relative hydrothermal coefficient (HTK_s) is usually used for assessment of meteorological conditions, since it allows assessment of moisture of not only the entire vegetative period, but also of individual months (Kudakas *et al.* 1998). It is calculated as follows:

$$HTK_s = \frac{K\sum p}{\sum T} \quad (1)$$

where K – climatic relative zero coefficient, the relative zero is equal to 1; Σp – the total of precipitation of the period under calculation, mm; ΣT – the total of air temperature values of the period under calculation oC.

According to HTK_s, the conditions of location moisture are grouped as follows: when $HTK_s \geq 1.2$ – moist period, when in the range of 0.8 – 1.2 – the period of average moisture, when $HTK_s \leq 0.8$ – droughty period (Kudakas *et al.* 1998). Following the research object data, the relations, which would allow determination of temperature and precipitation quantity on the quantity of drainage runoff and its seasonality, were sought during data systematization. Interdependence of the individual factors was analyzed, using binomial correlation method: the determined correlation and reliability of the data was checked by autocorrelation analysis. Descriptive statistics and correlation methods have been used for data analysis. For the analysis of runoff change the Mann-Kendall test, which determines positive and negative trends of analyzed characteristic and significant positive or negative trends (5% significance level) was used (Libiseller and Grimvall 2002).

2. Results and discussion

The analysis of climatic conditions of forty years (1969-2009) shows that the air temperature and precipitation quantity was very different during the mentioned years. The relative hydrothermal coefficient of individual years was changing significantly: droughty period was in 1971, 1975, 1976, 1983, 1988, 1991, 1994, 1996, 1999, the period of average moisture – in 1969, 1970, 1972, 1973, 1977, 1979, 1981, 1984, 1985, 1989, 1995, 1997, 2002, moist period – in 1974, 1978, 1980, 1986, 1987, 1990, 1993, 1998, 2000, 2001, 2003, 2004, 2005, 2007, 2008, 2009 (Fig 2). Thus, on average, every fourth year is droughty, however, the period, which has started in 2000 lasts up to now (except 2006 – moist).

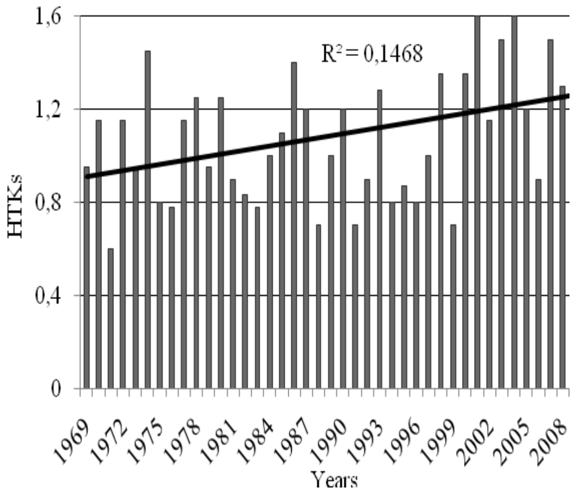

Fig 2. Relative hydrothermal coefficient (HTK_s) dynamics in the object at 1969-2009

One of the key factors in determining the size of runoff is precipitation. The analysis of average annual precipitation quantities shows that precipitation quantity was 639 mm, or 1.5% higher than the standard during the mentioned period (Fig 3). In the researched object the doughtiest year was 1992, the moistest – 1969 (1.31 times higher than standard).

Air temperature affects the nature of runoff and its distribution in two ways: directly and indirectly. Direct influence occurs during snow melting, and indirect - during evaporation. The freezing of water ponds, thickness of ice cover, its melting, as well as water flow conditions during the war period depend on the air temperature. While analyzing the annual air temperature for the period of 1969–2009, it is seen that the highest average temperature was in 2008 (8.5 ºC), and the lowest - in 1993 (4.2 ºC) (Fig 4).

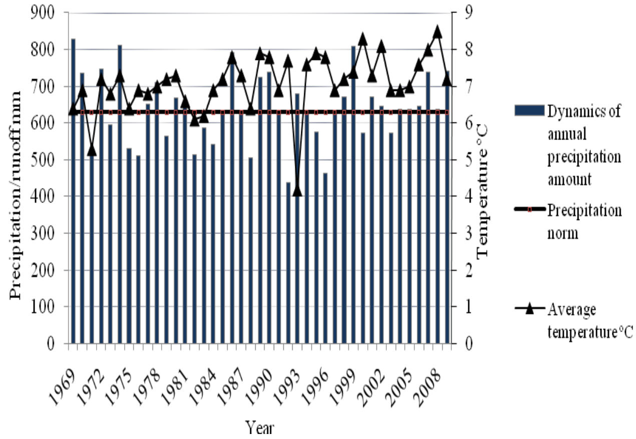

Fig 3. Variation of precipitation and temperature amount according to the data of Kaunas Meteorological Station

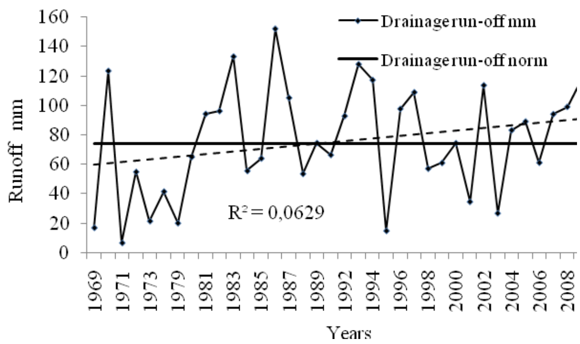

Fig 4. Chronological succession of drainage run-off and their linear fluctuation trend

The integral curves of average annual drainage height deviation from the average show the trends of runoff height change: the linear trend, defining the trend of chronological sequence change, is positive (Fig 4).

The analysis of runoff observations' data shows that the seasonality, typical for runoff change, remains: during spring – March and April – the average runoff is the highest, it is the lowest in summer season – July and August, while in May, June and August – almost the same (1.9 – 2.2 day/mm). Precipitation – the main feeding source of drainage runoff, therefore, this factor has a significant impact on runoff characteristics. The influence of precipitation on the runoff occurs directly and indirectly. When precipitation falls, a part the water infiltrates into deeper layers of ground, and a part flows through the surface (Fig 5).

Climatic factors make the general model of runoff distribution for a period of one year. Climatic factors are seasonal in nature, and this creates the seasonal runoff. Drainage runoff distribution of each season of the year (spring, summer, autumn, winter) is usually calculated. A long series of observations of the drainage runoff provides a possibility to assess the seasonal fluctuations of runoff.

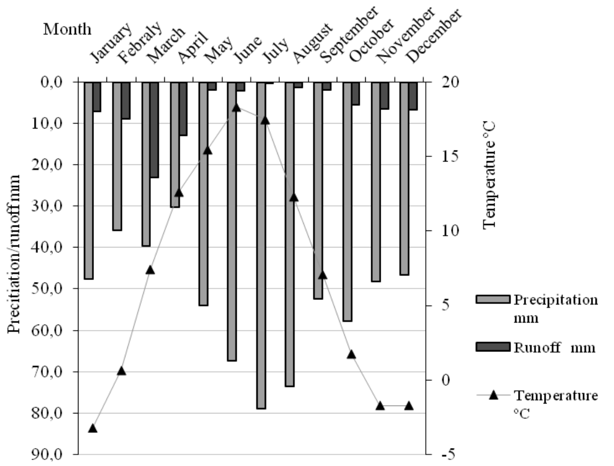

Fig 5. Variation of precipitation, temperature and runoff amount by month

When relating the changes of runoff with periods of seasonal fluctuation (Fig 6), it becomes obvious that the drainage runoff has significantly increased during the winter season over the last four decades. It is likely that the maximum runoff values, which were under very different meteorological conditions, are determined by the conditions of global climate change - warmer winters, and thus earlier snow melting, smaller water supplies in snow cover, etc.

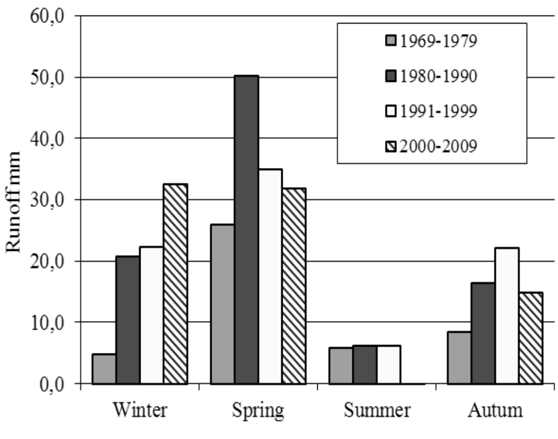

Fig 6. Variation of seasonal differences of runoff amount

Analysing the heights of the drainage runoff during winter period (1969-2009) by decades, it is possible to see that the drainage runoff has increased (Fig 6). It is seen that in spring, summer and autumn (1969-2009) negative trends were defined, i.e. the decrease of runoff, whereas in winter time the runoff increased (29% in the last decade) and the change of total annual runoff was positive.

Looking for the relationship between the runoff and meteorological parameters (monthly precipitation, temperature) the following correlation coefficients were defined: runoff/precipitation – 0.70; runoff/temperature – 0.64, runoff/evaporation – 0.50. The above results confirm the fact that the main source of the runoff formation is precipitation, to be more exact – the relation of the precipitation with the temperature regime of the locality. The hydrothermal coefficient evaluates this process best of all.

After determining the nature of drainage runoff fluctuations, the question, what the trends of change shall be (upward or downward) arises. To this end Mann-Kendall test was employed. Runoff characteristics divide the analyzed research time (1969–2009, there are no data the period of 1975-1978, 1994-1999 and data 1984, 1991). Table 1 presents the aggregate statistics of significant trends (5% significance level) of researched runoff characteristics.

Table 1. Mann-Kendall test for all research time (1969–2009)

Month	Sum of year	MK-Stat	p-value
1	29	**2.89**	**0.01**
2	29	**3.59**	**0.01**
3	29	**2.66**	**0.01**
4	29	-0.36	0.72
5	29	0.21	0.84
6	29	-1.53	0.13
7	29	-1.13	0.26
8	29	-0.06	0.95
9	29	1.39	0.17
10	29	1.10	0.27
11	29	1.18	0.24
12	29	**2.17**	**0.03**

3. Conclusions

After performing the analysis of annual drainage runoff change during the period of 1969-2009, the significant one-trend change was not determined, however, the insignificant statistical linear trend is noticed.

The negative trends were defined in spring, summer and autumn (1969-2009 decrease of runoff, whereas in winter time the runoff increased (29%).

Mann-Kendall test showed that the significant increase in winter run-off period, during the analysis period. Significant positive trends are observed in December-March.

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