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THE INFLUENCE OF CLIMATE CHANGE ON WATER REGIME IN DRAINAGE LAND

SUMMARY

The terrestrial water cycle and the impact of climate change have an important influence on water resources and on the potential for flood or drought and are, consequently, crucial to both agricultural and natural ecosystems. Soil properties and water regime can be improved in various ways, depending on soil texture and climatic conditions. Drainage hydrologic performance often depends on the quality of the installation, anthropogenic and climatic factors. It is important to assess the functioning of the drainage at different weather conditions. Under climate change the impacts of high temperatures, altered patterns of precipitation, increased water demand, and increased frequency of extreme events such as drought and floods. It is forecasted that air temperature will be subject to very high growth in Lithuania in the twenty first century. Especially significant changes are expected in winter. Climate conditions and physical geographic factors determine the fact that there are 3.4 million hectares of too wet lands in Lithuania, or approximately 86% of the total agricultural area, the intensive and productive usage of which is possible only after drainage. The analysis of four decades revealed a statistically significant trend of increase of annual temperature during spring season. A statistically significant trend of increase of annual drainage runoff was found during winter season, while there is no statistically significant trend for annual precipitation, the trend is very slightly increasing. The analysis of change trends of drainage runoff during different months revealed statistically significant changes in all winter months – there is a trend to increase.

Keywords: climate change, water regime, drainage

INTRODUCTION

Global increase of precipitation is forecasted under changing climatic conditions; however, its extremes will also increase **(**Climate Change, 2007). 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, Luscher, 2006). The principal impediment to sustainability of agricultural production is land

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degradation. Among the various land degradation processes, soil erosion is the greatest threat to the conservation of soil and water resources (Spalevic et al. 2012). The predicted climate change will exacerbate these concerns in many parts of the world by reducing precipitation and increasing evapotranspiration, both of which will reduce recharge and possibly increase groundwater withdrawal rates (Treidel et al., 2012). The predicted impacts of climate warming on groundwater include changes in the magnitude and timing of recharge (Hiscock et al., 2012) typically with a shift in seasonal mean and annual groundwater levels depending on changes in the distribution of rainfall (Liu, 2011) and snow melt (Jyrkama, Sykes, 2007). The effects of climate variability on groundwater have been less well explored than those on surface water (Green et al., 2011). 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 2009). Runoff and drainage are dependent on rainfall and when runoff is high, drainage tends to be low. (Wallace, Batchelor, 1997) suggest that combined runoff and drainage losses are often in the range 40–50 % of rainfall, broadly similar to the equivalent losses in irrigated agriculture. The changes of climatic elements, influencing the runoff - temperature and precipitation - have already been recorded in Lithuania (Bukantis, Rimkus, 2005; Stankūnavičius, 2009).

MATERIAL AND 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 Aleksandras Stulginskis University in Kazliškės was selected. Research object is located in Lithuania, in the southern part of Kaunas district (Fig. 1). Drain depth of 0.8, 1.10, 1.40 m, the drainage distance - 12, 18 m. 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 m.

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).

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.

Fig 1. Study area location

RESULTS AND DISCUSSION

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. 2). In the researched object the doughtiest year was 1992, the moistest – 1969 (1.31 times higher than standard).

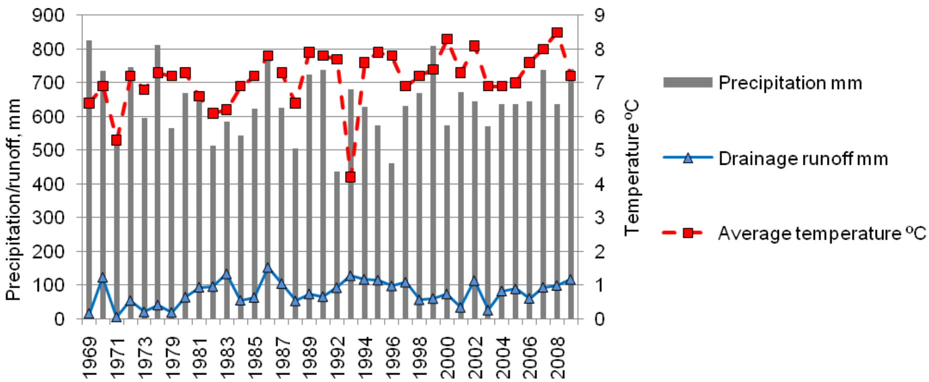

Fig 2. Variation of precipitation, drainage runoff and temperature

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. 3).

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.

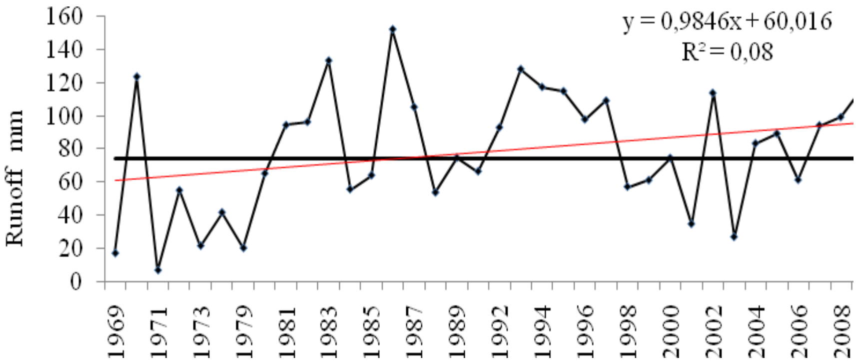

Fig 3. Chronological succession of drainage
run-off and their linear fluctuation trend

When relating the changes of runoff with periods of seasonal fluctuation (Fig. 4), 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.

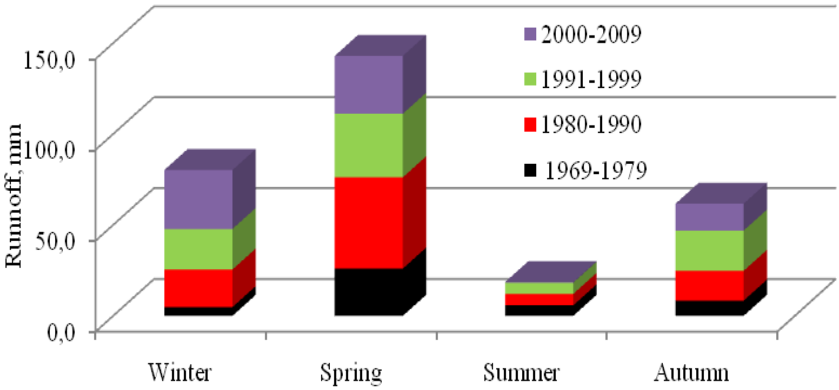

Fig 4. Variation of seasonal differences of runoff amount

Analyzing 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.

Table 1 presents the aggregate statistics of significant trends (5% significance level) of researched runoff characteristics. Mann-Kendall test for all research time of significant trends shows that runoff in winter increase.

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

The depth, duration and temperature of frozen ground of soil depends on winter duration and air temperature, thickness of snow layer, vegetation layer, thermal characteristics and humidity, texture of soil, depth of ground water. Since the middle of twentieth century the duration of frozen ground has shortened by approximately two weeks, moreover, the probability of its total thaw and repeated freezing has increased. An increased incidence of thaw of frozen ground demonstrates that water infiltration conditions of cold season must have changed. Water, present in thinner capillaries of clay and loam soil, freezes at lower temperature. On the other hand, wet soil freezes less, since during water freezing heat of water crystallization is released, which slows down the further drop of soil temperature.

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. It corresponds to global increase of precipitation, forecasted under changing climatic conditions. An important factor for runoff formation is precipitation intensity and duration, since intensive short rain forms a larger surface runoff, while the rain of lower intensity and longer duration better infiltrates into soil and evaporates from ground surface.

The analysis of runoff observation data revealed that seasonality, typical for run-off change, remains, however, the drainage runoff during winter season has increased significantly over the past four decades. Mann-Kendall test showed a significant increase of winter runoff during research period. It was also influenced by growth of multi-year temperatures of all seasons, except autumn: the frozen soil is characterized by low water permeability, irrespective of its content. Water, present in thinner capillaries of clay and loam soil, freezes at lower temperature. An increased incidence of thaw of frozen ground demonstrates that water infiltration conditions of cold season must have changed.

Significant decrease of drainage runoff is observed in July and August. It is related with redistribution of precipitation amount, which increased in winter and decreased in summer, and it corresponds to aridity, which is forecasted by other scientists to increase significantly in the second half of summer and in the beginning of autumn in Lithuania.

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