FORECAST FOR DRAINAGE RUNOFF AT DIFFERENT THICKNESS OF HUMUS SOIL LAYER

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ABSTRACT

Soil properties and water regime can be improved in various ways, depending on the soil texture and climatic conditions. Drainage hydrological performance often depends on the quality of the installation, anthropogenic and climatic factors. It is important to assess the functioning of drainage under different weather conditions. The article summarizes findings and presents the forecast of drainage flow dynamics bold (up to 40-50 cm) thick and natural (20-30 cm) layer of soils and the impact of meteorological conditions on drainage runoff.

Key words: drainage runoff, thick layer, forecast

INDRODUCTION

Climate change impact on flora is receiving increasing attention around the world (Fuhrer, 2003). Precipitation distribution in a territory and their change within a year has a great impact on the hydrological phenomena, soil formation and plant-growing seasons (Bukantis et al., 2009). Climate changes (temperature increase, precipitation decrease) may be related to environmental pollution. The most important is the size of drainage runoff (Bučienė, 2008). Climatic conditions and physical geographical factors determine the fact that in the territory of Lithuania there are 3.4 million hectares of overly wet land or about 86% of the total agricultural area, which may be used extensively and productively only after draining (Lukianas et al., 2009). The efficiency of land use also depends on the speed of removal of excess water. The changes of climate (temperature increase, precipitation decrease) can be linked to environmental pollution. The role of production agricultural systems as a non-point source of these nutrients in surface waters has come under increasing scrutiny in recent years (Grigg, 2003).

Subsequent transport of nitrate N to surface waters occurs through subsurface drainage (tile lines) or base flow (Randal et al., 2001). Compared to surface drainage alone (surface runoff), subsurface drainage increased loss of nitrate from these agricultural fields under both climate regimes, but particularly during drought (Grigg, 2004). At low temperatures and low moisture, the plants intake nutrients worse, therefore, they are eluted from the soil with drainage runoff more intensively (Soussana et al., 2006). Spatial variability of humus layer thicknesses can have important impacts upon soil water dynamics, nutrient storage and availability, as well as plant growth (Bens et al., 2006). The impact of humus on heavy-textured soil is multiple, since not only the moisture regime is related with its quantity (Maikštėnienė ir kt., 2007). The fertility and erosion of soil is determined by the content of organic materials in it. Humus accumulation depends on the soil texture and fertilization level, climatic conditions (Janušienė, 2002), grown plants (Jankauskas ir kt., 2005).

The thickness of humus layer influences not only elution of biogens, but also the speed of surface water drainage to deeper layers of soil. Land drainage is one of the most active areas of the anthropogenic activities which influence the runoff of the rivers (Ruminaite et al, 2011). River flow forecasting has always been one of the most important issues in hydrology (Nayak at al., 2005). Drainage network architecture in a basin is an expression of the surface water hydrological characteristics, and it is a function of the climate, geology and relief of the basin (Pakhmode et al., 2003).

Geomorphological characteristics can be treated as signatures of hydrological responses (Bhagwa et al., 2011). The size of water resources and the unevenness of distribution in time depend on the climatic and meteorological conditions of a specified territory and change every year – very watery and very dry periods occur (Meilutytė-Barauskienė et al. 2008). In most cases, the water table remains within the organic soil throughout the thaw period (Quinton et al., 1999). Soil moisture is an important variable as it affects the soil thermal properties, and therefore the amount of energy available to lower the frost table, which controls the hydraulic conductivity of the saturated layer, and ultimately the rate of subsurface drainage (Quinton et al., 2003).

The aim of research: to determine the influence of thickness of humus layer by using the data of research of 20 years and to make a runoff forecast under conditions of changing climate.

MATERIALS AND METHODS

The investigation was carried out in Lithuania. In the territory of investigations the soil was calcareus deeper gleyic leached soil, (the experiment according to FAO: calcar - HypogleyicLuvisol), according to mechanical composition – loam of medium-heaviness and light loam. Soil volume mass in the layer of 1 m varies from 1.3 to 1.7 g/cm^3, porosity - from 50.9 to 32.0 %, hygroscopic moisture – from 0.95 to 2.36 %, the filtration coefficient in arable layer – 0.31–0.94 m/day.
The scheme of the experiment: field I – 1.71 ha with thickened layer of 45–50 cm; field II – control, 1.72 ha with natural humus layer of 20–30 cm.
The results obtained were subjected to the statistical analysis program Statistica. The treatment effects were compared using the least significant difference test at the level of 95% (*p*-0.05) probability. Correlation relation is assessed, according to the value of correlation coefficient R.

RESULTS AND DISCUSSION

Drainage runoff size and duration affect the humus layer thickness: in the field with an artificially thickened humus content (up to 50 cm) frequency curve is steeper, and shorter than outside with natural humus content (up to 30 cm) (Fig. 1).

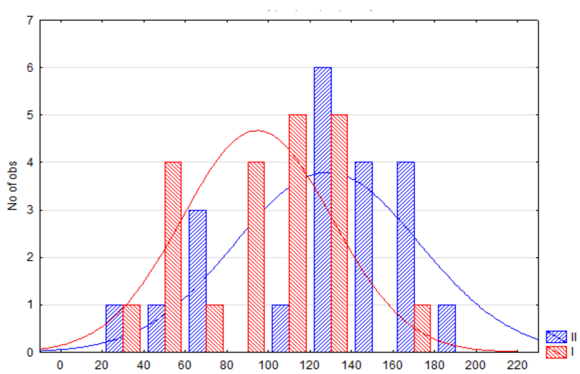

Figure 1. Runoff frequency curve

Analysing the drainage runoff during a twenty-year period between the annual values outside with the artificially thickened humus content (up to 50 cm) and in the control field, with natural humus content (up to 30 cm), a statistically significant difference (p <0.05) was defined (table 1).

Table 1

Analysis of Variance

SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	P
12001.25	1	12001.25	86715.01	40	2167.88	5.54	0.02

Fig. 2 presents annual runoff and its linear trend. As it can be seen, drainage runoff increases in both versions, however, the curve is sharper in the control field with natural humus layer.

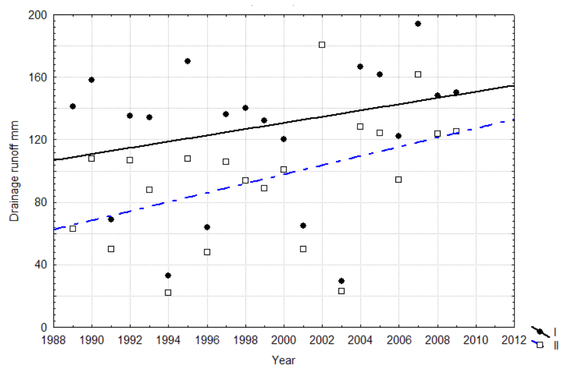

Figure 2. Annual runoff and the linear trend

While analysing the dependence of the size of annual drainage runoff on the annual amount of precipitation, annual temperature and evaporation individually, it was determined that the greatest impact on drainage runoff outside with thickened humus layer is by precipitation, as in the control field. Correlation relation is moderate (r=0.40 (I field), r=0.46 (II field)). By correlation analysis and the curve estimation of Statistica, the result showed that there were significant relationships (p<0.05) between the runoff and precipitation in I field. There was no significant relationship between the runoff and rainfall in I field, but the rainfall had an impact on the runoff. The results of statistical analysis are presented in Table 2.

Table 2

Results of statistical analysis

	Beta	Std. Err. of B	B	Std. Err. of B	t	p-level
I field						
Temperature	0.17	0.21	9.1	11.76	0.78	0.45
Precipitation	0.46	0.21	0.35	0.16	2.20	0.04
Evaporation	-0.06	0.21	-0.04	0 16	-0.28	0.79
II field						
Temperature	0.21	0.22	9.1	9.63	0.94	0.36
Precipitation	0.41	0.22	0.25	0.13	1.90	0.07
Evaporation	0.03	0.22	0.02	0.13	0.13	0.89

Following the method of group linear regression, the dependence of height of drainage runoff on precipitation, evaporation and temperature was analysed. While analysing field II (with thickened humus layer), the correlation coefficient r=0.49 was obtained. A similar correlation coefficient was obtained, when analysing the dependence of drainage runoff under natural humus (r=0.46).

The results of simple exponential smoothing method (initial data and smoothed data as well as forecast) are presented in Fig. 3. While forecasting by simple exponential smoothing (FSES) method, the best results are obtained as *a*=0.1.

Figure 3. Forecast by applying the forecasting model of simple exponential smoothing

By applying the forecasting model ARIMA (2.0), it was revealed that the size of drainage runoff with a natural or thickened humus layer will become equal or close to the drainage runoff outside with the natural layer (Fig.4). It is explained by the decay of the thickened humus layer through 30 years.

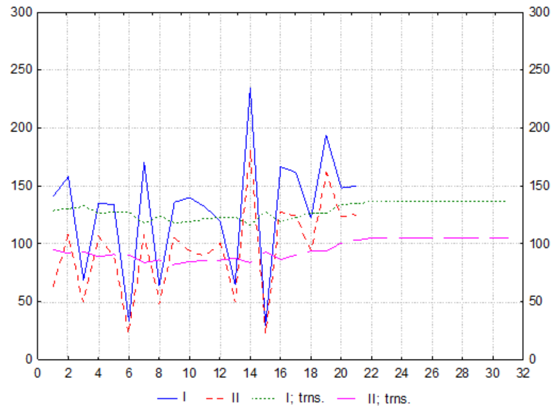

Figure 4. Forecast by applying the ARIMA (2.0) model

Thus, although the forecasts in both cases differ insignificantly, using the model ARIMA (2.0), lower error was obtained. The estimates of forecast accuracy are presented in Table 3.

Table 3

Forecast accuracy

Mean square	I	II
FSES	2714,10	1684,68
ARIMA	1808,7	1029,9

During the twentieth century the global air temperature increased by 0.6 °C, while in Europe – 0.95 °C. Moreover, due to a more intensive hydrological cycle and an increased atmospheric circulation in the middle and high latitudes, the warming is accompanied by an increased average amount of precipitation (Bukantis, 2005). In the 21st century air temperature is expected to rise by 2-5 °C in Lithuania (Rimkus, 2007).

In case the annual air temperature increases by 2°C and the annual amount of precipitation is the same, the forecasted increase of drainage runoff will be equal to 15% (I field) or 20% (II field), while in case the annual air temperature increases by 5 °C – 37% (I field), 52% (II field) (Fig.5).

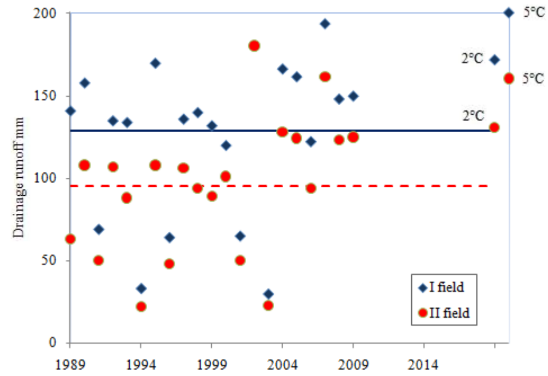

Figure 5. Predicted annual drainage runoff the temperature will increase to 2°C or to 5°C

In Fig. 6 the predicted runoff is presented, in case the temperature will increase to 2 °C or 5 °C, and the average annual rainfall increases 100mm: the forecasted increase of drainage runoff will be equal to 34% (I field), 37% (II field), while in case the annual air temperature increases by 5 °C – 56% (I field), 69% (II field).

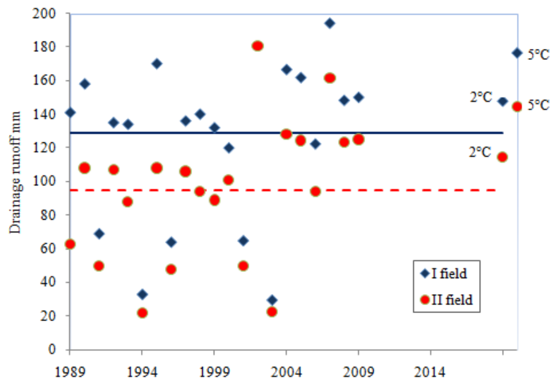

Figure 6. Predicted annual drainage runoff

CONCLUSIONS

Analysing the drainage runoff during a twenty-year period between the annual values outside with the artificially thickened humus content (up to 50 cm) and in the control field, with natural humus content (up to 30 cm), a statistically significant difference ($p < 0.05$) was defined.
The size of drainage runoff is mostly influenced by the amount of precipitation (r=0.46). In case of thickened humus layer, a statistically reliable result was obtained.
By expecting that the annual air temperature increases by 2 ^{0}C, the forecasted increase by drainage runoff will be 17.5%, while in case the annual air temperature increases by 5 ^{0}C, under the current average annual amount of precipitation, an increase of 44.5% is forecasted.
In case the annual air temperature increases by 2 °C and the annual amount of precipitation grows by 100 mm, the forecasted increase of drainage runoff will be equal to 35.5%, while in case the annual air temperature increases by 5 °C - 62.5%.

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