INFLUENCE OF PRECIPITATION UPON DRAINAGE DISCHARGE IN TWO DIFFERENT CLIMATIC REGIONS

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Abstract

The goal of three-year investigations was to determine the influence of precipitation upon the drainage discharge in two different climatic regions (Croatia and Lithuania) at two different pipe drainage spacing in each region (first region with 15 m and 20 m drainage spacing and second region with 12 m and 24 m drainage spacing), to calculate the soil water balance according Thornthwaite's method and compare the measured drainage discharge and the calculated surplus of water in soil. Investigations were carried out at the experimental amelioration sites in the central Sava River Valley (Croatia) on hydroameliorated Gleyic Podzoluvisol soil and in Middle part of Lithuania on hydroameliorated Hypogleyic Luvisol soil in the period 2009 - 2011. The research results showed that the drainage discharge and its duration depended on the amount and distribution of the precipitation during the study period. There isn't difference in the total drainage discharge between the tested drainpipe spacing in each investigation year, but there are differences in the duration of the drainage discharge both on an annual scale and depending on drainpipe spacing. In each year, the duration of drainage discharge was smaller at the 12-15 m drainpipe spacing than at the 18-20 m drainpipe spacing. The calculated surplus of water followed the monthly amounts of precipitation, but in all years was higher than the drainage discharge. The 12 to 15 m pipe spacing is more efficient for draining the surplus water from drained soils, since the surplus of water from soil is drained in a shorter period of time and better water-air relationships in soil are created faster, which is a prerequisite for timely application of agricultural management practices on hydroameliorated arable areas.

Keywords: experimental amelioration site, water balance, Thornthwaite's method, surplus soil water.

Introduction

The effects of climate change have become increasingly apparent over the past decades (Patt and Schröter, 2008). The average temperature was increased by 1.1-1.3 °C in 100 years in Central Europe (Kutilek, Nielsen, 2010). The climate change projections suggest a more variable climate with higher vulnerabilities in the lower income countries (Easterling et al., 2000). Global increase of precipitation is forecasted under changing climatic conditions; however, its extremes will also increase **(**Climate Change, 2007). The changes of climatic elements, influencing the discharge – temperature and precipitation - have already been recorded in Lithuania (Bukantis and Rimkus 2005). 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 discharge more intensely (Soussana, Luscher, 2006). The drainage discharge has the tendency to increase in winter and to decrease in spring in Lithuania (Miseckaite, 2010). Global climate change and the associated impacts on water resources are the most urgent challenges facing mankind today and will have enduring societal implications for generations to come. Potential impacts may include the changes in watershed hydrologic processes including timing and magnitude of surface discharge, stream discharge, evapotranspiration, and flood events, all of which would influence other environmental variables such as nutrient and

sediment flux on water sources (Simonovic and Li, 2004; Zhang et al., 2005). Agricultural production is very risky on such developed/undeveloped agricultural areas, especially when surplus and/or deficit of precipitation occurs before or during the growing season. Such conditions make production planning very difficult and/or almost impossible, because production, and there by yield, depends on the weather conditions, making yields of field crops and their quality highly variable. If soil water surplus persist during a longer period and is in the zone of plant roots in a part of the growing period, then the hydroamelioration measure of drainage should be applied. Drainage of surplus water is an ameliorative procedure that involves collection and removal of surplus water from soils intended for cropping or some other activity (Šimunić, 2016). The goal of three-year investigations was:
- determine the influence of precipitation upon drainage discharge in two different climatic regions at different pipe drainage spacing;
- calculate soil water balance according Thornthwaite's method;
- compare measured drainage discharge and calculated surplus of water in soil.

Material and methods
Investigations were conducted during three years (2009 - 2011) at the experimental amelioration site in the central Sava River Valley, Croatia (45°34’6 N, 16°37’17 E) on hydroameliorated Gleyic Podzoluvisol soil (Object No. 1) and the site under study is located in the Middle part of Lithuania (54°52’46 N, 23°51’30 E, Object No. 2 (Table 1).

Table 1. Main technical characteristics of experimental amelioration sites

	Area of plots	Pipe spacings	Average depth	Average slope	Pipe length	Pipe diameter
Croatia (Object No. 1)	1425 m^2 1900 m^2	15 m, 20 m	1.0 m	3 $^0/_{00}$	95 m	65 mm
Lithuania (Object No. 2)	4400 m^2 4400 m^2	12 m, 18 m	1.1 m	8 $^0/_{00}$	75 m 80 m	65 mm

On Object No.1, in the drain ditch above the drainage pipes is installed hydraulic material gravel up to plough layer and drain directly into an open detailed canal. Climatic data used were provided by the weather station at Sisak, at 15 km distance from the experimental amelioration site. As per textural composition, hydroameliorated Gleyic Podzoluvisol soil is silty clay to 75 cm depth, silty clay loam at 75 cm to 115 cm depth, and silty clay from 115 cm to 130 cm. It belongs to the class of porous soils (average porosity 49 vol.%), on the borderline between medium and high water retention capacity (average water capacity 45 vol.%) and of very low air retention capacity (average air capacity 4 vol.%), as well as of very low water permeability (average water permeability 0.011 m/day). According to the MKCl (Molar potassium chloride) reaction to 75 cm depth, the soil has acid reaction; according to humus content to 35 cm depth, it is fairly humus-rich; according to the supply of available phosphorus and potassium (to 35 cm depth), it is in the poor availability class. Object No. 2. The test site soil sod podzolic (the experimental according to FAO: calcar - Hypogleyic Luvisol), texture - light loam, dripping down on medium loam. Topsoil layer thickness is 0.2 to 0.25 m. Arable layer (0-20-25 cm) of filtration rate - 1.0 to 2.0 m / day, the lower layers of soil - from 0.01 to 0.004 m / day. Drainage discharge in each pipe spacing variant was continuously measured with the aid of a limnigraph, installed at the pipe outlet to the canal. Soil water balance is calculated according Thornthwaite's method, software USGS Thornthwaite Water Balance Model, Version 1.1.0 - April 26, 2010 (USA). The Thornthwaite method is based on the fact that water infoltation into soil, water loss from soil and water storage in soil are dependent on soil characteristics (Šimunić, 2016). The following data was used to calculate soil water balance: monthly evapotranspiration potential (mm), monthly amount of precipitation (mm) and presumption that water storage in soil (root zone depth) is 100 mm at the beginning of the year (January). To facilitate interpretation of research results, site factors (soil) and climate (precipitation and temperature) were taken into consideration.

Results and discussion

According to its general climatic characteristics, the Sisak region (Object No. 1) belongs to the central-European temperate climate, warm climate zone, moderately rainy climate with expressly continental traits. In the twenty-year period 1986 - 2005, an average of 925 mm of precipitation fell in the Sisak region, which fluctuated from 614.8 mm to 1086.9 mm (Fig.1). The growing seasons had 523.4 mm or 56.6 %, which is a characteristic of the continental precipitation regime. Monthly precipitation maxima were recorded in late spring and late summer parts of the year (June and September). The multi-year average and distribution of precipitation over the year allow the conclusion that the precipitation regime is favourable for agricultural production. Based on the multi-year precipitation average, the Sisak region is on the borderline between semi-humid and humid climate (K_f = 81.9, K_f - Rain factor: the ratio between total annual rainfall (mm) and average annual air temperature (^oC)), pursuant to Lang's rain factor, whereas pursuant to the monthly heat index, the region belongs to moderately warm climate (t = 11.3^oC) (Šimunić et al, 2013). In the twenty-year period 1986 - 2016, an average of 646.3 mm of precipitation fell in the Kaunas region (object No. 2), which fluctuated from 437.2 mm to847.0 mm (Fig.1). The growing seasons had about 374.5 mm or 57.9 %, monthly precipitation maxima were recorded in June and August.

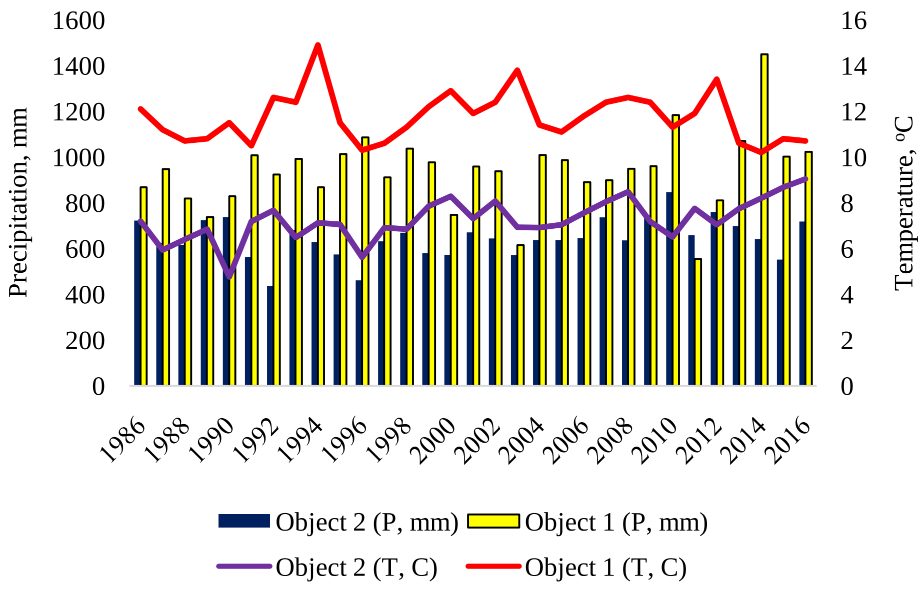


Figure. 1. Variation of the yearly precipitation (mm) and temperature (^oC) in the Objects

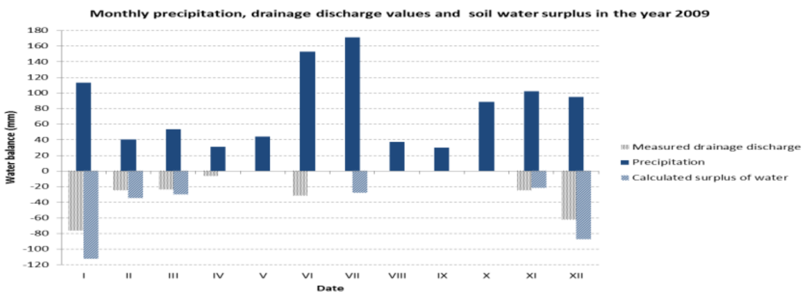
In the investigation period an average of 933.5 mm of precipitation fell, which fluctuated from 554.9 mm to 1285.3 mm in Object No. 1 and average of 749.4 mm of precipitation fell, which fluctuated from 657.0 mm to 847.2 mm in Object No. 2 (Table 2). In two years recorded extremes of precipitation, i.e. less and more precipitation than in the period 1986-2005. In the three investigation years, the average data of temperature was 11.9 ^oC (Object No. 1, Table 2) and temperature has increased with 0.6 ^oC in relation to the period 1986-2005. The average temperature was 7.4 ^oC in Object No. 2, and comparing with Climate Normals (CN, 1981-2010), has increased with 0.4^oC, the average annual precipitation quantity was about 749 mm, or 18% higher than the CN. Basing on the increase of these climatic elements, it is possible to speak about climatic changes, what was stated by other authors (Bukantis and Rimkus 2005; Kutilek, Nielsen, 2010).

The climatic and hydrological characteristics of the studied region are some of the indispensable indicators for the planning and designing of drainage systems, since multi-year precipitation, its monthly or seasonal distribution or maximum daily precipitation and its intensity define the key characteristic of climate and determine the type of agriculture and management on ameliorated areas. Precipitation amount, distribution and time of precipitation occurrence during the investigation period influenced the drainage discharge and its duration (Table 2), both at the annual and monthly levels, as well as the differences between the tested pipe spacing's.

Table 2. Total drainage discharge (mm), precipitation (%) and duration of drainage discharge (days) for different drainpipe spacing's (m)

Year	Average air temperature (t, °C)	Drainpipe spacing (m)	Total precipitation (P, mm)	Total drainage discharge (mm)	Precipitation (%)	Duration of drainage discharge (days)
2009	7.3	12	742.1	40.6	6.0	138
	12.4	15	960.2	253.0	26.3	88
	7.3	18	742.1	41.9	6.2	131
	12.4	20	960.2	250.0	26.0	96
2010	8.1	12	847.2	135.3	21.0	176
	11.3	15	1285.3	460.0	35.8	138
	8.1	18	847.2	128.4	6.0	179
	11.3	20	1285.3	462.0	35.9	148
2011	6.9	12	659.0	24.0	4.2	112
	11.9	15	554.9	21.0	3.8	8
	6.9	18	659.0	18.3	3.2	109
	11.9	20	554.9	21.0	3.8	10

The highest amount of the drainage discharge and its duration (Tables 2) was in 2010 at the highest amount of precipitation and the smallest in 2011 at the smallest amount of precipitation. There is not difference in total drainage discharge between the tested drainpipe spacing in each investigation year. Data were approximately equal. Therefore, there are differences in the duration of the drainage discharge both at the annual and at the drainpipe spacing. In each year, the duration of drainage discharge was smaller at 15 m drainpipe spacing than at 20 m drainpipe spacing from. in Object No. 1, and the duration of drainage discharge was smaller at 12 m drainpipe spacing than at 24 m drainpipe spacing from each year in Object No. 2. Wallace and Batchelor (1997) suggest that combined discharge and drainage losses are often in the range 40–50 % of rainfall. In this study was found, that drainage discharge varied from 3.2 % to 35.9 % of total precipitation. Fig. 2 (a, b, c) shows flowchart monthly precipitation values, monthly drainage discharge values and calculated surplus of water, for 15 m drainpipe spacing (the same is valid for the 20 m drainpipe spacing) and Fig. 3 (a, b, c) for 12 m drainpipe spacing. Generally, in the winter/spring period and autumn/winter period, the monthly drainage discharge followed the monthly amounts of precipitation, that is, the higher the monthly amount of precipitation, the higher was the drainage discharge, and vice versa (especially in the first two years). The calculated surplus of water followed the monthly amounts of precipitation, but the data were higher in all years. In the late spring and summer months, due to intensified growth and development of plants, the amount of drainage discharge was not proportional to precipitation. Namely, evapotranspiration was increased at later plant development stages due to higher spring and summer air temperatures, so that lower drainage discharge was recorded in both pipe spacing variants. Autumn drainage discharge wasn't recorded in 2011 , neither surplus of water was calculated because soil water supply wasn't filled up with precipitation from the preceding months. As regards drainage discharge duration, Table 2 shows that the shorter duration was determined at the narrower pipe spacing (12, 15 m) than at wider pipe spacing (18, 20 m), which may be attributed to the drainage system efficiency. According to the investigations conducted by Petošić et al. (1998), Tomić et al. (2002) and Šimunić et al. (2011; 2013), narrower pipe spacing is more efficient for draining surplus water from drained soils, since larger amounts of water are drained in a shorter period of time and better water-air relationships in soil are created faster, which is a prerequisite for timely application of agricultural management practices on hydroameliorated arable areas. Surplus soil water calculated according Thornthwaite's method was in all years higher than measured drainage discharge in both objects. In Object No. 1, the difference was approximately 65 mm (first year), 190 mm (second year) and 12 mm (third year), while in the Object No. 2 the difference was about 93 mm in the first year, 133 mm in the second year, and 266 mm in the third year. This can be explained by the fact that this method includes only a climatic parameter (temperature) but on the water loss from soil can influenced other climatic parameters too, such as air humidity, wind speed, insolation, as well as different types of crops, etc. 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 Ruminaite, 2009). Pipe spacing from 12-15 m is more efficient for draining surplus water from drained soils, since surplus of water from soil is drained in a shorter period and better water/air relationships in soil are created faster.



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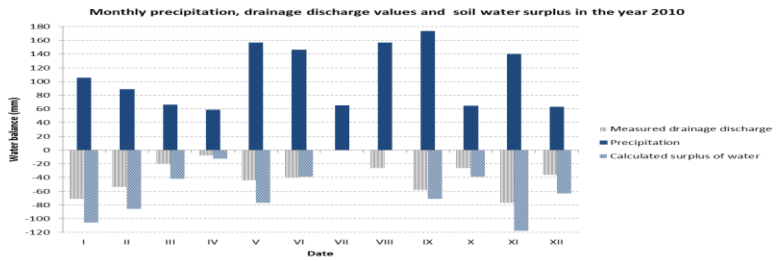

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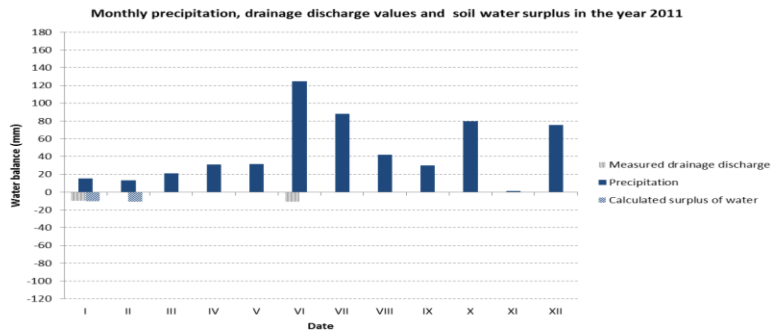
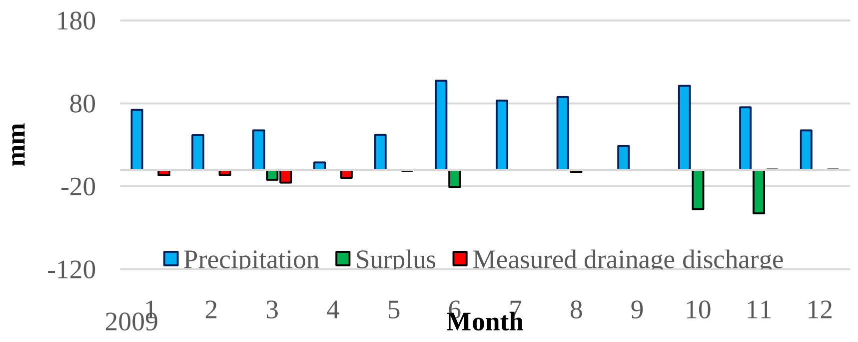


c)

Figure 2. Monthly precipitation values, monthly drainage discharge values and calculated surplus of water, for the drainpipe spacing of 15 m (a) – 2009, b) – 2010, c) – 2011)



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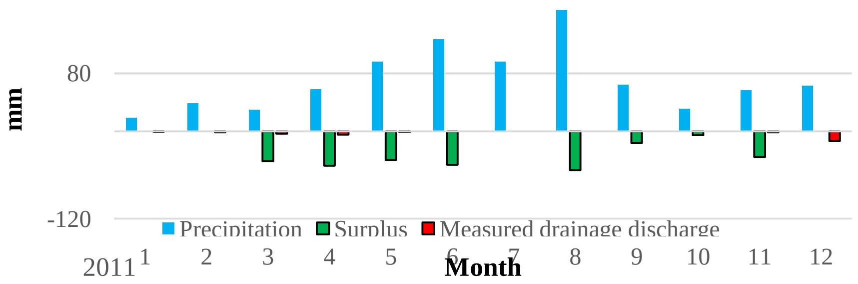

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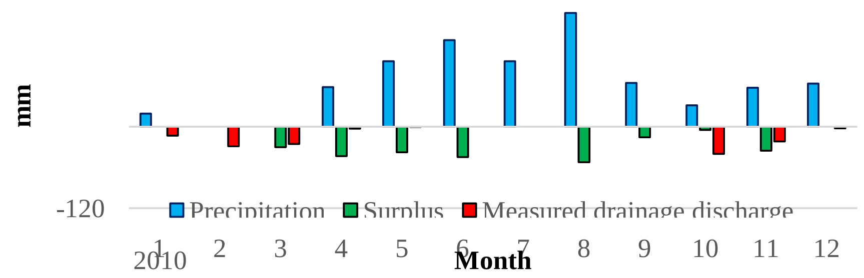

c)

Figure 3. Monthly precipitation values, monthly drainage discharge values and calculated surplus of water, for the drainpipe spacing of 12 m (a) – 2009, b) – 2010, c) – 2011)

Conclusions

Monthly drainage discharge followed the monthly amounts of precipitation in two different climatic regions, that is, the higher the monthly amount of precipitation was, the higher was the drainage discharge, and vice versa. There is no difference in the total drainage discharge between the tested drainpipe spacing in each investigation year. There are differences in duration of the drainage discharge both at the annual and at drainpipe spacing. In each year, the duration of the drainage discharge was smaller at drainpipe spacing from 12/15 m than at drainpipe spacing from 18/20 m. The calculated surplus of water followed the monthly amount of precipitation, but in all years the calculated data were higher than the drainage discharge. Pipe spacing from 12/15 m is more efficient for draining surplus water from drained soils, since the surplus of water from soil is drained in a shorter period of time and better water-air relationships in soil are created faster, which is a prerequisite for timely application of agricultural management practices on hydroameliorated arable areas.

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