THE INFLUENCE OF COMBINED DRAINAGE ON THE STABILITY OF AGRICULTURAL PRODUCTION IN CONDITION OF CLIMATE CHANGE

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Abstract

Climate change and consequent appearance of natural hazards (floods, droughts, soil erosion, landslides) is major problem globally, and a subject of many scientific, expert and politics meetings and therefore solutions are being sought to mitigate its consequences. Because of climate change, agricultural production is very uncertain during unfavourable hydrological years, in which vegetation deficit or surplus precipitation appears, causing deficit or surplus moisture in rootzone with negative impact on growing and development of plants. To achieve safe agricultural production, hydrotechnical structures are often utilized: flood protection systems, ameliorative drainage systems, as well as irrigation systems. If hydro-ameliorative systems already exist, they often require reconstruction (adaptation) in addition to maintenance.

Keywords: combined drainage, agricultural production, climate change

I. Introduction

The amount of precipitation, its duration, intensity and frequency of occurrence are factors that directly affect agricultural activities, since surplus or deficit of precipitation restricts agricultural production and requires amelioration measures of drainage and/or irrigation [1]. The main consequence of climate change is the appearance of extreme weather events such as increasing occurrence of droughts and floods, which adversely affects the reduction of water supplies, reduced yields and biodiversity, occurrences of erosions and landslides, water pollution, i.e., changes in surface and groundwater quality [2]. Potential impacts of global climate changes may include the change in hydrologic processes and watershed response, including timing and magnitude of surface runoff, stream discharge, evapotranspiration, and flooding, all of which would influence other environmental variables [3]. More frequent and severe extreme weather events are anticipated to cause serious damage to ecosystems and agricultural systems [4, 5].

In the period from the 1970s to the 1990s, hydrotechnical structures and ameliorative drainage structures were intensively built in Croatia for the purpose of flood protection and drainage of excess soil water, with the largest interventions being carried out in the central part of the Sava River valley (Figure 1), aiming to increase of agricultural areas suitable for growing crops typically for this area, such as corn, wheat, soybeans, clover–grass mixtures. The middle course of the Sava River (pertaining to Lonjsko polje) is located at average altitude of 96 m a.s.l, which is characterized by low surface water runoff and low flow velocity in watercourses flowing through the basin into the Sava River. The area is dominated by hydromorphic soils heavier textures and very small permeability (Figure 1). In order to better monitor the functionality of the combined drainage system and the yields of cultivated crops in the area of Lonjsko polje, an hydroamelioration experimental field was set up in the early 1990s (Figures 2 and 3).

II. Materials and Methods

Investigations were conducted in the period 1996–2015 at the experimental hydroamelioration field (45°34'46'' N, 23° 51'30''E, Figure 1) at the altitude of 96 m a.s.l., on soil type defined as hydroameliorated Gleyic Podzoluvisol. The trial involved four different drainpipe spacing variants (15 m, 20 m, 25 m and 30 m), set up in four replications. All variants were combined with gravel as the contact material in the drainage ditch above the pipe up to plough layer. Drainpipes are 95 m in length, diameter 65 mm, slope 0.3% and average depth 1 m, which discharged directly into an open detailed canals. Water from details canals inflows into higher order canals and flows towards the pumping station which pumps the water into the river Lonja (recipient), Sava River's tributary. Variants covered areas of 1425 m^2, 1900 m^2, 2375 m^2 and 2850 m^2.

In order to obtain the better insight into climate conditions during the period 1996–2015 the official meteorological data from the main meteorological station Sisak were used. The mentioned station Sisak belongs to Meteorological Station Network of Croatian Meteorological and Hydrological Service located in the town of Sisak. The climate conditions are described by Lang's rain factor (R_f), which is conducted according Gračanin climate classification [6].

Maize, winter wheat, soybean and rapeseed were grown as the trial crops and the same standard agro–technical measures were applied in all variants for each crop in trial years. After the harvest of crops on each parcel of variant, the yield was determined and kernel samples were taken in order to determine water content in kernel. Real yield was calculated on content of moisture in kernel from 13 %.

Statistical analysis of the yield for both plant species was conducted by means of Duncan's multiple range test [7].

Figure 1: *Location of the experimental hydroamelioration (drainage) field*

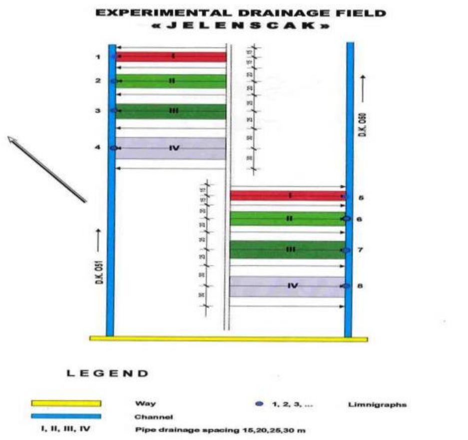

Figure 2: *Design of the experimental field*

Figure 3: *Drainage water collected from wider ameliorated area in the main canal and pump's wet well*

III. Results and discussion

2.1. Features of climate in central part of Sava River valley

All meteorological elements are important to growth and development of plants, but the success of agricultural production is mostly dependents on precipitation amount and air temperature.

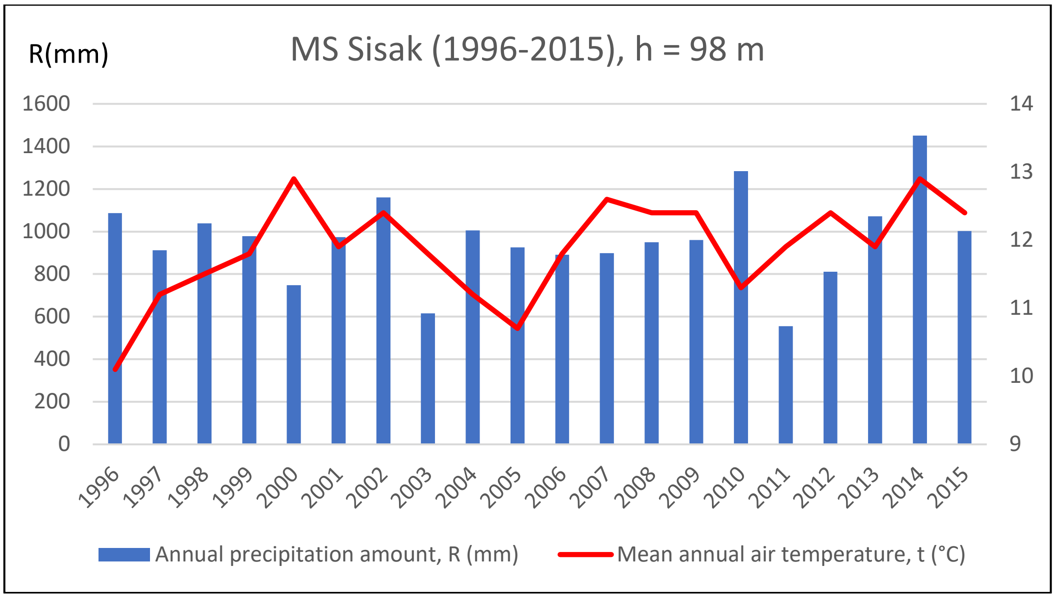

Figure 4: *Annual precipitation amount (mm) and mean annual air temperature (°C), MS Sisak*

As shown in Figure 4, annual precipitation amounts in the Sisak region ranged from 554.9 mm (2011) to 1,450.8 mm (2014), while multi–annual mean of annual precipitation amounts was 954.3 mm. In the twenty–year period (1996-2015) the difference between the maximum and the minimum value of annual precipitation amount was 895.9 mm. The precipitation regime is one of the most variable climate characteristics of some area, both spatially and temporally [8]. Monthly precipitation amounts can vary from year to year (Figure 5).

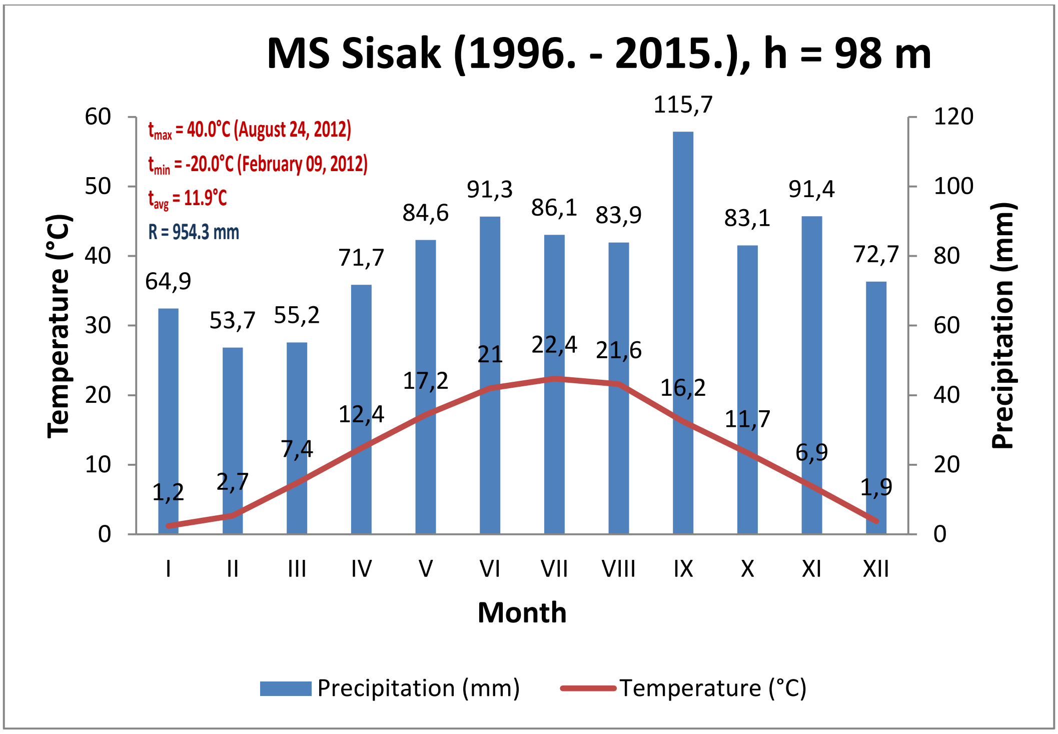

Figure 5: *The multi–annual mean of monthly precipitation amounts and multi–annual mean of monthly air temperatures (°C)*

The variability of monthly precipitation amounts is expressed by coefficient of variation and its maximum is in August (cv = 0.63) and minimum in November (cv = 0.41). A comparison of multiannual mean of monthly precipitation amounts reveals that maximum value occurred during the vegetation period. During the growing season (April-September) the Sisak area receives on average 533.3 mm of precipitation or 55.9%, what is characteristic of the continental precipitation regime. The annual course of monthly precipitation amounts in Croatia can be divided into two types, depending on the time of the year when the month with the lowest precipitation amount occur–the continental annual course of monthly precipitation amounts, with the lowest precipitation amount occurring during the cold half of the year [8].

During the analysed period, mean annual air temperatures ranged from 10.1°C (1996) to 12.9°C (2000 and 2014), while the multi–annual mean air temperature was 11.9°C (Figure 5). Based on multi–annual mean of precipitation amounts and multi–annual mean air temperature, the central part of Sava River valley is on the border between semi–humid and humid climate (Rf=80.2) and moderately warm climate (t=11.9°C). The values of multiannual mean of monthly precipitation amounts, precipitation regime as well as the multiannual mean of air temperature lead us to the conclusion that mentioned climate conditions are favourable for agricultural production. The negative impact on yields have extreme weather events such as a lack of precipitation (occurrence of drought) or surplus of precipitation due to heavy rain in a short period (flash floods, occurrence of the stagnant water on the surface of soil during a longer time period, etc.).

2.2. Yield of crops in central part of Sava River valley

As can be seen from Table 1, maize participate in the crop rotation in three years, winter wheat and soybean in two years and rapeseed only once.

Table 1: *Yield of crops in multi years period*

Drainpipe spacing (m)	Dry grain yield (t.ha^{-1})							
	Maize 1996	Maize 1999	Wheat 2000/2001	Maize 2002	Soybean 2008	Rapeseed 2009/2010	Soybean 2011	Wheat 2011/2012
15	5.82 a	6.23 a	5.70 a	6.62 a	3.23 a	3.30 a	2.32 a	6.70 a
20	5.34 b	6.16 a	5.74 a	6.44 a	3.14 a	3.03 b	2.40 a	6.64 a
25	4.92 c	5.77 b	5.75 a	6.12 b	2.90 b	2.69 c	2.39 a	6.52 b
30	4.35 d	5.62 b	5.35 b	5.87 b	2.76 b	2.38 d	2.29 a	6.51 b

Legend: Values marked by the same letter are not significantly different (p>0.05)

Yields of the same crops differed both in different trial years and between variants due to various factors, such as different precipitation amount during growing season (Figure 4), influence of different drain pipe spacing on drainage surplus of soil water, content of soil moisture, drilling time, harvest time, etc. The highest yields on all variants were achieved in years when precipitation amount was around average value and its favourable distribution. In the most humid years (1996, 2009/2010), the highest yields were achieved in drainpipe spacing variant of 15 m. In the less humid years (1999, 2002, 2008), the highest yields were achieved in drainpipe spacing variants of 15 m and 20 m, and the lowest always in drainpipe spacing of 30 m. According to the investigations conducted by [9,10,11,12], shorter pipe spacing is more efficient for drainage surplus water from drained soils, since larger water amounts are drained in a shorter period of time and better water–air ratio in soil are created faster, which is a prerequisite for timely application of agricultural management practices on hydro ameliorated areas. It is very important to remove the excess of water, which forms in the fields during summer season after abundant precipitation (13). In drought year (2011) yield of soybean was on all variants almost the same, but enough lower than in favourable year 2008. According [14] yields of crops in some region in Croatia can be reduced up to 90% due to the drought. Analysis of variance, done separately for each trial year, reveal significant differences (p >0.05) between yields of particular crops in dependence on drainpipe spacing in seven years, while in 2011 differences between yields, depending on the drainpipe spacing, were not significant.

Accordingly, satisfactory yields can be achieved in the agroecological conditions in central part of Sava River valley with the drainpipe spacing of 15 m and 20 m, but only if the drainage system is adequately maintained. In order to have the less risky agricultural production the build of irrigation system is of high importance.

IV. Conclusion

Based on twenty–year research results, one could conclude the following:

1. In the central part of the Sava River valley combined detailed drainage has influence on yield of growing crops, especially in more humidity years.
2. The highest yields are achieved for drain pipe spacing of 15 m and 20 m.
3. Reliable agricultural production requires construction of the irrigation system.

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