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STATUS OF UNDERGROUND DRAINAGE IN EASTERN CROATIA AND DRAINED SOIL IMPROVEMENT BY AGROAMELIORATION

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Abstract

Croatia has about 2.3 million hectares of agricultural land, of which one third is state owned. About 167 thousand hectares of agricultural land in Croatia are covered by pipe drainage. Revitalization of pipe drainage and construction of new drainage systems are important potentials for improvement of agricultural production in Croatia. Intensification of drainage was carried out mainly from 1976 to 1990, mostly on agricultural land belonging to state owned farms. Eastern Croatia accounts for 30% of agricultural land at state level and pipe drainage is installed on 122,390.5 ha or 73% of total drained area in Croatia and 17% of agricultural land of the region. More than 20% of agricultural land is drained in three counties of the region (Vukovar and Srijem, Brod and Posavina, Virovitica and Podravina Counties). In general, maize and wheat yields in Eastern Croatia are by about 30% higher compared to the state average. In this regard, we presume that pipe drainage has given a considerable positive contribution, particularly under wet year conditions. Current status of pipe drainage functionality is mainly inadequate and reconstruction and regular servicing are needed. In spite of soil reclamation and pipe drainage management, yields of main field crops mainly in the southern lowland part of the region were accompanied with inadequate supplies of phosphorus and potassium. These problems were eliminated by adequate agroamelioration, for example, ameliorative fertilization. Nutritional problems could be also alleviated by selection of more tolerant field crop genotypes.

Keywords: underground drainage system, pipe drainage, current status, reconstruction

Introduction

Underground pipe drainage has been applied on 167,174 ha of agricultural land in Croatia since 1976. The largest part of this system - above 95% - was developed by open ameliorative canals of third and fourth orders during the period 1976-1990 (Marusic, 2003; Petosic et al., 2015; Sostaric et al., 2016). Current status of pipe drainage functionality is unsatisfactory because as much as about 63% at country level and about 53% in Eastern Croatia have the status of a low degree of functionality. Main reasons for the low drainage system status in Croatia are improvisation in construction, inadequate servicing and its devastation during the reconstruction of third and fourth order canals (Petosic, 2003; Petosic et al., 2015). Improvement of plant production on drained agricultural land will be achieved by revitalizing pipe drainage (Petosic et al., 2015), while some drained soils require correction of their chemical properties (Kovacevic and Basic, 1997; Kovacevic et al., 1988, 2005; Petosic et al.,

2003) due to very acid soil reaction and low levels of available nutrients, particularly potassium (K) and phosphorus (P). The aim of this study was to survey the current status of the pipe drainage system in Eastern Croatia and present the possibilities of improving plant production on drained soils.

Material and methods

Until the end of 1992, Eastern Croatia was territorially divided into 14 municipalities of a total area of 11,090 km^2 or 19.6% of the state territory (Vukovar, Beli Manastir, Osijek, Zupanja, Vinkovci, Djakovo, Slavonski Brod, Valpovo, Nasice, Slavonska Požega, Nova Gradiska, Donji Miholjac, Orahovica and Podravska Slatina). Since 1992, according to the new territorial division, Eastern Croatia includes five counties of a total area of 12,452 km^2 (22.0% of the state territory) as follows (Fig 1): Vukovar and Srijem County (15), Osijek and Baranja County (12), Slavonski Brod and Posavina County (14), Pozega and Slavonia County (10) and Virovitica and Podravina County (11). Control drainage units (Fig 1) were selected in each county of the region with the aim to test the status of the drainage system: Stara Sela (15),Trnava III (12), Veliki Crnac (14), Siljkovac (10) and Beljevina (11).
Publications of the State Bureau of Statistics (Statistical Yearbook of Croatia) were used as sources of maize and wheat growing area and yield data (Table 1).

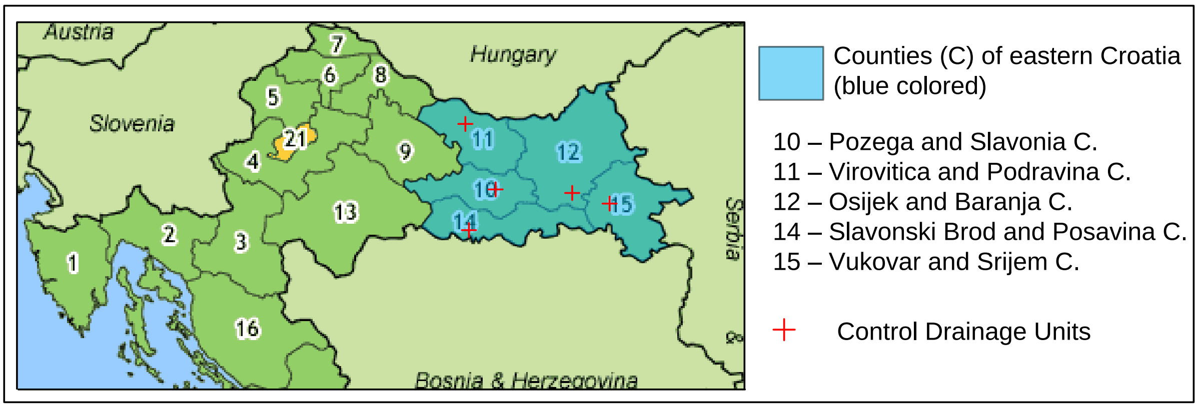

Fig 1. Location of the five counties of Eastern Croatia and control drainage units.

Results and discussion

Croatia has about 2.3 million hectares of agricultural land, of which one third is state owned. About 7% of agricultural land of the country is covered by the drainage system. Eastern Croatia accounts for 30% of agricultural land at state level and pipe drainage is installed on 122,390.5 ha or 73% of total drained area in Croatia and 17% of agricultural land of the region. More than 20% of agricultural land is drained in three counties of the region (15, 14 and 11) (Table 1). In general, maize and wheat yields in Eastern Croatia are by about 30% higher compared to the state average. In this regard, we presume that pipe drainage has given a considerable positive contribution, particularly under wet year conditions. However, alkalization of the soil surface layer is a negative soil property closely associated with drainage.
Higher yields in Eastern Croatia (maize 5.94 and 4.68 t ha^{-1}, 6.06 and 5.17 t ha^{-1}; wheat 5.02 and 3.87 t ha^{-1}, 4.51 and 3.92 t ha^{-1}; for 1980-1989 and 2000-2005, respectively) compared to the state averages can be partially attributed to systematic hydroamelioration (Table 1).
Basic elements of pipe drainage in Eastern Croatia were in the following ranges: depth from 0.9 to 1.1 m, pipe spacing from 15 to 40 m, diameter of drainage pipes from 50 to 65 mm and length of drainage pipes from 60 to 290 m (Table 2).

Basic parameters of open canals of third and fourth orders were from 2.0 to 2.7 m and from 1.5 to 2.2 m (depth), from 800 to 1000 m and from 175 to 320 m (spacing), from 9.2 to 11.4 m^2 and from 7.42 to 9.92 m^2 (cross-section), from 800 to 2000 m and from 350 to 850 m (length of canals), respectively (Table 2).

Table 1. Agricultural land of Eastern Croatia (SAGRA 2014; CRORED, 2015) and yields of maize and wheat (Statistical yearbooks of Croatia)

	*Eastern Croatia Counties					Total	
	VuSc (15)	OsBc (12)	BPc (14)	PSc (10)	ViPc (11)	Region	Croatia
Agricultural land area (ALA) in ha: total, state owned (SO) and drained area (DA)							
ALA	152 103	280 935	106 255	66 612	110 403	716 308	2 326 221
SO	34 557	86 321	40 286	32 972	46 770	240 906	833 233
DA	33 762 (22.2)*	41 096 (14.6)*	22 224 (20.9)*	1 497 (2.2)*	23 813 (21.6)*	122 392 (17.1)*	167 174 (7.2)*
Maize	1996-2000 (Kovacevic, 2005)					168 288	375 979
t ha^{-1}	6.57	6.18	5.58	5.75	5.73	6.06 t ha^{-1}	5.17 t ha^{-1}
Wheat	1996-2000 (Kovacevic and Josipovic, 2005)					117 421ha	211 253 ha
t ha^{-1}	4.59	4.66	4.12	4.57	4.20	4.51	3.92
Maize	1980-1989 (Kovacevic at al., 1994)					5.94 t ha^{-1} 207 576 ha	4.68 t ha^{-1} 506 575 ha
Wheat	1980-1989 (Kovacevic at al., 1995)					5.02 t ha^{-1} 139 700 ha	3.87 t ha^{-1} 311 300 ha
* Vukovar-Srijem (15), Osijek-Barannya (12), Brod-Posavina (14), Pozega-Slavonia (10) and Virovitica-Podravina (11); in brackets = share of DA in percent of ALA.							

Table 2. Basic elements of pipe drainage and ameliorative canals

	Eastern Croatia Counties and names of control drainage units				
County	VuSc (15)	OsBc (12)	BPc (14)	PSc (10)	ViPc (11)
Name	Stara Sela	Trnava III	V. Crnac	Siljkovac	Bjeljevine
	Basic elements of pipe drainage				
Area (ha)	235	150	600	199	480
Depth (m)	1.1	0.9 - 1.1	0.9 - 1.1	0.9 - 1.1	1.0 - 1.1
Spacing (m)	30 - 36	40	15 -20	30 - 35	30 - 35
Diameter (mm)	50	50	65	65	65
Length (m)	90 - 210	160 - 240	100 - 160	60 - 290	75 - 230
	Basic elements of ameliorative canals of the third order				
Depth (m)	2.5	2.5	2.0 – 2.5	2.7	2.6
Spacing (m)	800	800-1000	800 - 1000	800	800
Cross-section (m^2)	11.00	11.00	9.2 – 11.0	11.77	11.36
Length (m)	1220	800	1266	800- 2000	1900
	Basic elements of ameliorative canals of the fourth order				
Depth (m)	1.80	1.70	1.5 -1.8	2.2	1.8
Spacing (m)	220 - 290	180 -220	300	180 -320	175 -300
Cross-section (m^2)	8.48	8.12	7.4 – 9.2	9.92	8.50
Length (m)	580 -750	500 -600	800	400 - 640	350 -850

In Eastern Croatia, 3165 km or close to 48% of the existing ameliorative canals of third and fourth orders were fully reconstructed. Good pipe drainage functionality was found on 39,059 ha or close to 32%, on average on 14,390 ha or close to 12%, and poor on the remaining 68,940 ha or about 56% of the existing canals (Table 3).

Table 3. Status of waterway and ameliorative canals of third and fourth orders

	Eastern Croatia Counties					Total	
	VuSc (15)	OsBc (12)	BPc (14)	PSc (10)	ViPc (11)	Region	Croatia
Status of waterway and ameliorative canals (third and fourth orders) in km and % (R = reconstructed, NR =non-reconstructed)							
R (km)	816.7	1 562.1	341.5	78.1	366.9	3 165.3	5 157.1
R (%)	42.6	65.5	27.9	84.3	27.3	47.94	56.35
NR (km)	1 053.8	823.6	880.3	5.1	675.4	3 438.2	3 995.0
NR (%)	57.4	34.5	72.1	15.7	72.7	52.06	43.65
∑ (km)	1 870.5	2 385.7	1 211.8	83.2	1 042.3	6 603.2	9 152.1
Degree of drainage system functionality (ha)							
Good	13 305.3	10 909.7	7 025.5	302.6	7 516.2	39 059.3	43 229.7
Average	2 793.4	3 438.1	2 263.0	57.8	5 838.5	14 390.8	18 941.7
Inferior	17 662.9	26 747.7	12 935.4	1 136.2	10 458.1	68 940.3	105 002.8
∑ (km)	33 761.7	41 095.5	22 223.9	1 496.6	23 812.8	122 390.5	167 174.5

Table 4. Response of maize and soybean to ameliorative K fertilization on drained gleysol of the Vinkovci State Farm (Kovacevic and Vukadinovic 1992)

Fertili-zation	Maize					Soybean			
	Leaf (% in dry matter)			Yield	Lodging	Leaf (% in dry matter)			Yield
(kg K ha^{-1})	K	Mg	Ca	t ha^{-1}	(%)	K	Mg	Ca	t ha^{-1}
	First year of testing (growing season 1987)								
125	0.64	2.03	1.43	1.75	42	0.57	1.60	1.44	1.28
835	1.43	1.39	1.38	7.76	5	1.90	0.95	1.64	2.70
2220	1.86	1.14	1.33	8.88	2	2.28	0.78	1.49	2.55
LSD1%	0.14	0.21	0.17	0.87		0.27	0.27	0.31	0.36
	Third year of testing (growing season 1989)								
125	0.54	1.73	2.18	0.87	55	0.60	2.16	2.12	0.78
125	0.76	1.29	2.28	2.69	12	0.75	1.79	2.11	1.47
125	1.20	0.99	2.38	6.52	4	1.17	1.41	2.22	2.53
LSD1%	0.08	0.17	0.18	0.39		0.09	0.27	0.27	0.32

Despite soil reclamation and pipe drainage management, yields of main field crops, mainly on hydromorphic soils in the southern lowland part of the region, sporadically remained low due to inadequate P and K supplies (Petosic et al., 2003; Kovacevic, 2002; Kovacevic et al., 2005). Nutritional unbalance and maize and soybean yields were considerably improved by adequate ameliorative K fertilization (Table 4). Survey of K nutritional problems and responses of main field crops to K fertilization were elaborated by Kovacevic and Basic (1997).
Both inadequate P and K status were found in some drained gleysols of the Sava Valley area and ameliorative fertilization resulted in considerable maize yield increases of 87% (K effect)

and 41% (P effect) as well as in alleviation of nutritional unbalance due to lower P and particularly K uptake by plants (Table 5).

Table 5. Response of maize to P and K fertilization in the Crnac polje area on the former Nova Gradiska State Farm (Kovacevic et al., 1997)

Fertilization in spring 1990 (kg ha^{-1})			Maize yield (t ha^{-1})	Maize ear-leaf at silking (% in dry matter)			
N	P_2O_5	K_2O		P	K	Ca	Mg
200	150	150	3.81	0.28	0.70	1.51	1.46
200	150	2550	7.13	0.25	1.74	1.29	0.73
200	2550	150	5.36	0.48	1.15	1.33	1.06
	LSD	0.05	0.57	0.02	0.13	0.13	0.22

Table 6. Response of maize hybrids on drained K-fixing soil (Kovacevic and Vujevic, 1994)

Pedigree (♀ x ♂)	Yield (t/ha^{-1})	Stalk* (%)				Pedigree (♀ x ♂)	Yield (t/ha^{-1})	Stalk* (%)			
		SL	K	Mg	P			SL	K	Mg	P
Maize hybrids of Os1-48 inbred line (A group)						Maize hybrids of Os87-24 inbred line (B group)					
Os87-44 x A	5.23	8.8	0.30	0.48	0.11	Os87-61 x B	2.83	79.0	0.18	0.64	0.18
Os84-15 x A	6.30	4.8	0.30	0.55	0.07	Os88-15 x B	4.71	83.3	0.21	0.88	0.29
Os84-25 x A	5.56	4.1	0.18	0.52	0.14	Os86-92 x B	2.90	23.7	0.17	0.74	0.22
Os84-24 x A	5.89	4.6	0.17	0.48	0.08	Os87-56 x B	3.52	52.1	0.21	0.74	0.21
Os86-39 x A	4.45	7.5	0.18	0.71	0.16	Os84-24 x B	5.45	95.6	0.18	0.68	0.24
Os89-24 x A	7.20	4.1	0.30	0.45	0.07	Os 1-48 x B	5.40	5.3	0.18	0.69	0.19
Os87-24 x A	4.83	0.7	0.21	0.52	0.27	Os87-57 x B	4.28	74.1	0.19	0.68	0.22
Mean A	5.64	4.9	0.24	0.53	0.13	Mean B	4.16	59.1	0.19	0.72	0.22
LSD 5%	0.53		0.04	0.09	0.03	LSD 5%	0.53		0.04	0.09	0.03
LSD 1%	0.72		0.05	0.12	0.04	LSD 1%	0.72		0.05	0.12	0.04

* K. Mg and P in three developed lowest stalk nodes at maturity (% in dry matter); SL=stalk lodging

Nutritional problems can be alleviated also by selection of more tolerant genotypes (Kovacevic and Vujevic, 1994; Simic et al., 2003; Kovacevic et al., 2011). Fourteen maize hybrids were grown under the K deficiency and Mg oversupply conditions. Seven hybrids of the Os1-48 male parent (group A) were more tolerant to this type of soil stress conditions compared to the hybrids of the Os87-24 male parent (group B), particularly regarding stalk lodging resistance at maturity. The higher K and lower Mg and particularly P concentrations in the stalk base were associated with lower stalk lodging (Table 6).

Conclusion

Soil reclamation by pipe drainage and construction of appropriate ameliorative canals had a considerable effect on the yields of main field crops in Eastern Croatia, particularly under hydromorphic soil conditions. However, improvisation during construction and inadequate servicing of drainage systems during exploitation resulted in their mainly low functionality. For this reason, their urgent revitalization is required. Some soils of the region have less favorable chemical properties and appropriate agroamelioration is required to improve their productivity, for example, ameliorative potassium and phosphorus fertilization.

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