Columella - Journal of Agricultural and Environmental Sciences Vol. 5, No. 2 (2018)

Calculation nitrogen and sodium budget from lysimeter-grown short-rotation willow coppice experiment

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Abstract: Alternative water resources utilization should take priority over the conventional irrigation water resources (surface and subsurface waters) in the future in Hungary as well, similarly to the global trends because of the climate change impacts. However because of the environmental risks (e.g. nitrate leaching and soil salinization) the reuse of the wastewater require sustainable practices hence the farmers and researchers are responsible for development soil management practices and irrigation principles. Aim of our study was to determine the impact of a wastewater originated from an African intensive catfish farm on the nitrogen budget of the soil-water-plant system in order to evaluate the nitrogen substitution effect and the risk of the nitrate leaching. On the other hand, the aim of the study was to calculate also sodium budget to assess the risk of the sodicity regard to the high sodium concentration of the wastewater. The experiment was conducted at the National Agricultural Research and Innovation Centre (NAIK), Research Institute of Irrigation and Water Management (OVKI) in Szarvas, Hungary. The experiment was set up in the NAIK ÖVKI Lysimeter Station in 2014 with energy willow. During the study (between 03.07.2015 and 21.04.2017) irrigation water quality, rainwater quality, willow N and Na uptake by stems and N and Na leaching was measured. Nitrogen and sodium budget were calculated for two years (2015, 2016) from these data. According to our results the wastewater had high nitrogen content what was able to increase the nitrogen amount in the examined budget however without supplementary fertilizer it could not able to balance the budget only just at W60 treatment (irrigation with wastewater: N concentration 22,7 mg/l). The wastewater had high environmental risk as soil sodicity according to results of the sodium budget.

Keywords: nitrate leaching, salinization, wastewater, rainwater quality

Received 19 July 2018, Revised 12 December 2018, Accepted 28 December 2018

Introduction

Sustainable soil and water management and use of alternative water resources for agricultural production are one of the key elements of the fight against the consequences of the continuous increase in global population and effects of climate change (Singh 2015). The new water resources play determining role because of the water scarcity in addition to water and energy saving irrigation methods (Francés et al. 2017). The reuse of treated wastewater for irrigation is a suitable practice to close the water cycle in the agro-industrial sector (Vergine et al. 2017).

The climate change affects our country due to the basin character, the unfavourable distribution of rainfall is the consequence of the change of the regional climate patterns. Other example is the decreasing surface water quantity at summer time thereby there is a growing number of water bodies with water scarcity and regions with water stress. This water scarcity is occurred at summer time when the irrigation water demand is the highest (Hungarian River Basin Management Plan 2015). Alternative water resources utilization should take priority over the conventional irrigation water resources (surface and subsurface waters) in the future in Hungary as well, similarly to the global trends because of the global warming and water scarcity.

However, inappropriate management of irrigation with wastewater can cause substantial risks to public health and the surrounding environment (Elgallal et al. 2017). Understanding the processes of nitrate leaching and introduction of deeper-rooted trees or other crops can minimise the ground water contamination (Khajanchi Lal et al. 2015). On the other hand, wastewater usually has a higher concentration of total dissolved solids and major ions and a higher electrical conductivity than fresh water especially in regions with hot climates or it can originate from many sources such as detergents and washing material, the chemicals used during the treatment process and other sources (Elgallal et al. 2017). Removing salts from wastewater for irrigation purposes is prohibitively expensive.

DOI: 10.18380/SZIE.COLUM.2018.5.2.43

Therefore, there is a need for specific measures and management strategies to prevent and control the effects of salinity and sodicity during irrigation with wastewater (Elgallal et al. 2017).

The energy plantation may provide prosperous opportunity for the wastewater reuse in the future through irrigation (Vermes 2017). Energy willow and poplar have many favourable advantages compared to other plants: long growing season, high evapotranspiration rate, ability to take up nutrients and toxic elements with minimum leaching potential (Isebrands and Richards 2014). According to Ligetvári (2014) the use of sewage can make safer production of energy crops or forests or even not directly consumed agricultural products.

Arable crops can be characterised by low species and breed number of crops with minimum crop rotation (Grónás et al. 2006). To improve the biodiversity and to break the monotony of the landscape, installation of energy plantation would be one feasible prosperous solution. Diversification of arable crops are would be beneficial to decrease the risk of the market and the cost of production (Grónás et al. 2006).

Aim of our lysimeter experiment was to determine the impact of a wastewater originated from an African intensive catfish farm on the nitrogen budget of the soil-water-plant system in order to evaluate the *nitrogen substitution effect* and *the risk of the nitrate leaching*. On the other hand, the aim of the study was to calculate also sodium budget to assess the *risk of the sodicity* regard to the high sodium concentration of the wastewater.

Materials and methods

Experiment site

The experiments were conducted at the National Agricultural Research and Innovation Centre (NAIK), Research Institute of Irrigation and Water Management (OVKI) in Szarvas, Hungary. The experiment was set up in the NAIK ÖVKI Lysimeter Station in 2014 in 64 pieces of 1 m^3 vessels with energy willow. The year 2015 was the second year of the plantation when the irrigation started. The willow clone (no. 77, 82) were selected by the NAIK Forest Research Institute of Püspökladány Experimental Station. Each treatment occurred in 8 replication/lysimeter. The 1 m^3 lysimeter vessels were filled with disturbed meadow topsoil. The soil was characterised by high clay content (~70-80%), low humus (~2%), lime content less than 0.5%, total soluble salt content less than 0.08%, and pH_{KCl} values between 5.88-6.97 (Kun et al. 2018).

Irrigation treatments

Three different irrigation waters were applied in the experiment. First one was originated from the Oxbow Lake of Körös River (K15, K30, K60 – numbers mean one-time irrigation doses in mm), while the second one was the wastewater (W15, W30, W60) from an intensive African catfish farm in Szarvas. The third irrigation water type (HG60) used for irrigation (only 60 mm doses) was treated wastewater, which was diluted (1:3) with Körös water than gypsum was added to it according to the following equation:

$$x = Sz_e \times E$$

where the x means the gypsum quantity (mg/l or g/cm^3), Sz_e= residual sodium carbonate index (RSC), E= equivalent weight of gypsum (86,1). There were one non-irrigated treatment (Control). The irrigation water quality was describe according to the 90/2008. (VII. 18.) Hungarian decree and FAO guideline as well (Kun 2018).

Sampling method and analyses

The irrigation water sampling occurred in the irrigation periods at every time between 15th April and 30th September according to Hungarian standard (MI-10-172/9-1990). Inorganic nitrogen (ammonium, nitrate, nitrite, total inorganic-N) and sodium was determined according to the Hungarian standards (MSZ EN ISO 11732:2005, MSZ EN ISO 13395:1999, MSZ EN ISO 13395:1999, MSZ 12750-20:1972, MSZ 1484-3:2006, respectively). In 2015 3 replication represents the Körös River and the wastewater quality, in 2016 the number of the replication was 7. In case of diluted and improved wastewater treatment (HG60) the irrigation quality was analysed based on 4 replications. The rainwater was collected at 4 rainfall events (14.06.2016, 20.09.2016, 19.04.2017, 29.06.2017) meaning 4 replications and the same parameters were

Table 1. The irrigation and the leachate water amounts (mm) in the experiment

	Irrigation water amounts (mm)		*Leachate water amounts (mm)*	
Treatments	***2015***	***2016***	***1st period***	***2nd period***
Körös 15 mm (K15)	195	90	383	23
Körös 30 mm (K30)	390	180	409	106
Körös 60 mm (K60)	780	360	621	532
Wastewater 15 mm (W15)	195	90	463	358
Wastewater 30 mm (W30)	390	180	470	145
Wastewater 60 mm (W60)	780	360	717	313
Diluted wastewater + gypsum (HG60)	720	360	674	676
Control (non-irrigated)	0	0	655	130

Remark: 1st period: between 15.06.2015 and 17.06.2016 2nd period: between 17.06.2016 and 21.04.2017

analysed as from the irrigation waters. The lysimeter is suitable to collect the leachate. The leachate water amounts were measured 33 times between 03.07.2015 and 21.04.2017 for 22 months in 62 lysimeter vessels. (In H15 and HG60 treatments there was 1-1 not-working lysimeter.) The leachate sampling occurred in winter time in both years (16.01.2016, 28.02.2016, 06.02.2017, 08.02.2017) and the analysed parameters were nitrate and sodium according to the methods above. The results represent 2 replications per treatments per the analysed periods.

The willow stem sampling occurred in 2015 at time of the willow harvest (02.12.2015). Harvested stems from each treatment (in 8 replication) were collect and analysed for dry mass, total Kjeldahl-nitrogen and sodium concentration according to Hungarian standards (MSZ-08-1783-1:1983, MSZ EN ISO 5983-2:2009, MSZ-08-1783-5:1983).

Nitrogen and sodium budget calculation and statistical analyses

Based on the leachate analyses results nitrogen and sodium budget was calculated for two periods. First period (2015) was between 15.06.2015 and 17.06.2016 and the second period (2016) was between 17.06.2016 and 21.04.2017. For the calculation the input quantities were: the nitrogen fertilizers, the nitrogen content of the irrigation waters and the rain and the output quantities were the nitrogen amount that was accumulated in the willow stems and the nitrogen losses by leaching. The applied fertiliser amount was 40 kg N/ha in the first period and there were no applied fertiliser in 2016. Input inorganic-N of the irrigation water were calculated by multiplying irrigation water amounts (Table 1). The input inorganic-N of the rainwater calculated by multiplying the precipitation volumes. The applied irrigation water amounts were different in 2015 and 2016 (Table 1), because the weather was different in the experiment years. In the first year the precipitation was 116.8 mm during the irrigation period but in the second year it was 220.6 mm. In 2015 the total precipitation was 400.6 mm and in 2016 it was 632.8 mm. Nitrate leaching loads were calculated by multiplying drainage volumes for each period (Table 1). The output nitrogen by the willow stem was calculated from the dry biomass data in 2015 and 2016 (not published data) and the Kjeldahl-nitrogen of the willow stems in 2015. The subtraction of the input and output N means the nitrogen budget (ΔN values). According to Arronson and Bergström (2001) the estimated ΔN values express the combined effect of mineralization, immobilization, build-up of the soil pool of nitrogen, and gaseous losses. Apart from the gaseous losses the others do increase or decrease the store of the soil nitrogen. So if ΔN has negative sign it means decreasing N-store in the soil and if ΔN is positive, the soil becomes richer in nitrogen. In our experiment the nitrogen content of the willow leaves were did not calculated in the nitrogen budget, due to the difficulty of estimate the leaf mass and partly because it can not be considered as real loss as leaves stay at the soil surface for the degradation processes, hence in our case the ΔN values also expresses some nitrogen in falling leaves at autumn. However, according to Szalai (1968) the leaves contain small amount of nitrogen. The sodium budget calculation was according to the same method above (without the fertilizer).

Table 2. Nitrogen budget of the willow lysimeter experiment in 2015 and 2016

	2015							
	W15	***W30***	***W60***	***HG60***	***K15***	***K30***	***K60***	***Control***
	Input							
Fertilizer (kg/ha)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
N content of the irrigation water (kg/ha)	43.3	86.7	173.3	76.3	1.3	2.6	5.2	0.0
N content of the rainwater (kg/ha)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.3
	Output							
N content of the willow stem (kg/ha)	90.4	122.8	171.2	101.8	58.0	80.1	95.6	35.7
N leaching (kg/ha)	6.1	5.6	15.9	0.6	1.5	0.6	0.3	56.9
Δ N (kg/ha)	-7.0^{abc}	4.5^{abc}	32.5^{c}	20.1^{bc}	-11.9^{abc}	-31.8^{ab}	-44.5^{a}	-46.3^{a}

	2016							
	W15	***W30***	***W60***	***HG60***	***K15***	***K30***	***K60***	***Control***
	Input							
Fertilizer (kg/ha)	0	0	0	0	0	0	0	0
N content of the irrigation water (kg/ha)	20.8	41.6	83.1	38.2	0.6	1.2	2.3	0.0
N content of the rainwater (kg/ha)	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	Output							
N content of the willow stem (kg/ha)	72,8	92,4	95,6	53,2	46,6	46,6	41,6	28,5
N leaching (kg/ha)	0.4	5.5	12.3	1.1	0.9	0.4	0.3	8.1
Δ N (kg/ha)	$-46,1^{a}$	$-44,9^{a}$	$-6,5^{c}$	$-9,1^{bc}$	$-40,1^{ab}$	$-39,5^{ab}$	$-33,4^{abc}$	$-22,6^{abc}$

Remark: ANOVA was used to determine the significant difference between the treatments. The ^{a}, ^{b}, ^{c} indexes means the homogen subsets of the Tukey's post-hoc test. The negative ΔN values mean the soil (and the willow leaves) contribution to the nitrogen budget.

The statistical calculation was performed in SPSS 22.0 Statistics Software. ANOVA and Tukey's Test was used to determine significant difference between ΔN values and the homogenous subset means no significant difference between the treatments. To determine significant different between ΔNa values Non-parametric, Kruskal-Wallis test was used in both years.

Results

Nitrogen budget

To calculate the N budget three input factor were determined. The N content of the fertilizer, irrigation water and rainwater build up the all input N (Table 2).

The wastewater contained considerably more inorganic-N (2016: 23.1 mg/l, 2016: 22.2 mg/l) than the diluted and improved irrigation water type (2015, 2016: 10.6 mg/l) and the irrigation water from the River Körös (2015: 0.64 mg/l, 2016: 0.67 mg/l). In the wastewater the 99.8% of inorganic-N was in ammonium form. Nitrogen (N) and phosphorous (P) in metabolic waste produced by fish are the origin of most dissolved N and P waste resulting from intensive aquaculture operations (Lazarri and Baldisserotto 2008, Tóth et al. 2016). The ammonia production by fish is primarily dependent on the protein intake and metabolic efficiency of the fish, which is species-specific and is affected by waterborne ammonia levels (Dosdat et al. 2003). In case of the River Körös, the ammonium : nitrate : nitrite rate was 43:50:7. All of them was under the limit values of Decree No. 10 of 2010 (VIII. 18.) VM of the Ministry of Rural Development hence the oxbow lake can be consider as good quality surface water body. The input N content from the irrigation water was depended on the irrigation water amount (Table 1, Table 2).

The inorganic-N concentration of the rainwater was 1.25 mg/l. According to Gelencsér et al. (2012) the average total N concentration of the rainwater is 1.68 mg/l and the main nitrogen forms are inorganic forms. According to Csapák (2009) the ammonium concentration in the rainwater was 0.24 mg/l in NH_4-N, the nitrate was 0.21 mg/l in NO_3-N and there were no nitrite. The input N in the budget from the precipitation was 6.2 kg/ha in 2015 and 5.9 kg/ha in 2016 (Table 2).

Because of the different weather conditions of the experimental years the applied irrigation water amount was twice more in 2015 than in 2016. In 2016 fertilizer were not applied and less irrigation water was used hence the N input in the second year were lower than in 2015. In the treatments without waste water (K15, K30, K60 and Control) the fertilise-input was only 13-16%, but in waste and diluted water treatments the fertilise-input even was not more than 36-41% of the total input N in 2015.

Two output factor was used to determine the nitrogen budget: the N content of the willow stem and the N content of the leaching water. The mean N content of the willow stem was 0.51 m/m%, the range was 0.2-0.87 m/m%. According to our results the lowest accumulated nitrogen values of the willow stem was 29 kg N/ha and the highest was 171 kg N/ha (Table 2). According to Dimitriou and Aronsson (2004) the N-uptake of the willow was 110-115 kg N/ha in clay soil and 36-44 kg N/ha in sandy soil. Four willow clones were compared by Curneen and Gill (2014), according to their results the smallest N-uptake was 82 kg N/ha (in case of *Torhild* clone, irrigated with freshwater) and the highest was 262 kg N/ha (in case of *Sven* clone, irrigated with secondary treated wastewater). According to Galbally et al. (2013) the willow N-uptake after treatment with biosolid was 107 kg N/ha and after irrigation with distillery effluent water it was 231 kg N/ha. So our data can show the same order of magnitude then other researchers'.

According to our results the mean nitrogen losses caused by nitrate leaching was 10.9 kg N/ha in 2015 and it was 3.6 kg N/ha in 2016 (Table 2). According to willow lysimeter experiment belongs to Aronsson and Bergström (2001) the highest N leaching was measured in the first year of the willow plantations (clay and sandy soil: 341-140 kg N/ha). After the starting year in the second (43-17 kg N/ha, respectively) and in the third year (3-1 kg N/ha, respectively) the N leaching was negligible. According to Mortensen et al. (1998) also in the first year of the plantation was the highest nitrogen leaching (130-142 kg N/ha) and it was decreased in the second (9-61 kg N/ha) and in the third (0-4 kg N/ha) years.

The subtraction of the input and the output N amount was the result of the nitrogen budget (ΔN). In 2015 in the wastewater treatments were calculated the most favourable ΔN values, in three cases (W30, W60, HG60) it was positive. The lowest values were in case of irrigation with River Körös water and in the Control treatment (mean of the ΔN values for this 4 treatment was -34 kg N/ha). In 2016 the most favourable ΔN values were also in the W60 and the HG60 treatments. All the other treatments had lower values then W60 and HG60 (Table 2).

Sodium budget

To calculate the Na budget two input factor was determined. The Na content of the irrigation water and rainwater build up the all input Na. The wastewater had considerably higher Na concentration (2015: 278 mg/l, 2016: 274 mg/l) than the diluted and improved irrigation water

Table 3. Sodium budget of the willow lysimeter experiment in 2015 and 2016

					2015			
	W15	***W30***	***W60***	***HG60***	***K15***	***K30***	***K60***	***Control***
					Input			
Na content of the irrigation water (kg/ha)	542.6	1085.2	2170.4	945.0	81.5	162.9	325.9	0.0
Na content of the rainwater (kg/ha)	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.2
					Output			
Na content of the willow stem (kg/ha)	1.0	1.5	1.4	1.2	0.5	0.7	0.9	0.3
Na leaching (kg/ha)	28.4	29.6	65.7	88.4	23.3	33.6	48.7	37.8
Δ Na (kg/ha)	*527.3*	*1068.2*	*2117.4*	*869.5*	*71.8*	*142.7*	*290.4*	*-23.9*

					2016			
	W15	***W30***	***W60***	***HG60***	***K15***	***K30***	***K60***	***Control***
					Input			
Na content of the irrigation water (kg/ha)	247.0	494.0	987.9	472.5	26.0	52.0	104.0	0.0
Na content of the rainwater (kg/ha)	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
					Output			
Na content of the willow stem (kg/ha)	0,8	1,1	1,0	0,6	0,4	0,5	0,4	0,3
Na leaching (kg/ha)	1.6	11.1	68.1	61.5	5.7	14.3	29.9	6.0
Δ Na (kg/ha)	258,0	495,2	932,3	423,8	33,4	50,7	87,1	7,2

type (2015, 2016: 131 mg/l) and the irrigation water from the River Körös (2015: 42 mg/l, 2016: 29 mg/l). The high sodium content of the wastewater was originated from the fishfarm water source because thermal water is used to provide the high water amount for intensive technology (Tóth et al. 2016). Because of the wastewater quality the input sodium from the irrigation water was very high (200-2200 kg/ha/year), (Table 3).

Two output factor was used to determine the Na budget: the Na content of the willow stem and the Na content of the leaching water. The mean Na content of the willow stem was 53.6 mg/kg, the range was 23.8-161 mg/kg. It means 0.3-1.5 kg/ha/year which is negligible compared to the leaching. According to Jama-Rodzenská et al. (2016) most of sodium (~300 mg/kg) was found in the willow shoots during the first year of the study which decreased in the second year (~200 mg/kg). According to Stolarski et al. (2017) the average Na concentrations of the analysed willow clones were between 80-180 mg/kg. Due to the low ion uptake of the willow the output mean Na values were very low in both years varied between 0.3 and 1.5 kg Na/ha (Table 3).

According to our results the mean Na losses caused by leaching was 44.0 kg Na/ha in 2015 and it was 24.5 kg Na/ha in 2016 (Table 3). According to Stefanovits (1963) the average sodium losses by leaching on clay soil is 9-42 kg/ha/year, in our lysimeter experiment the sodium losses varied between 1 and 125 kg/ha/year. According to Sorrenti and Toselli (2016) in 18-month-lysimeter experiment with 1-year old nectarine the sodium losses by leaching was 224 kg/ha in sandy soil.

The subtraction of the input and output Na amount was the result of the sodium budget (ΔN). In 2015 in the wastewater treatments were calculated the most unfavourable ΔNa values between 527-2117 kg/ha. The prosperous sodium budget was calculated in both years in the treatments with irrigated with River Körös. The lowest ΔNa value were in case of non-irrigated treatment, in the Control treatment in both years (Table 3).

Discussion

The ΔN value of the W60 treatment in 2015 was significantly higher than the other treatments (Table 2). In this case there were the highest N input owing to the nitrogen content of the wastewater. According to our results the wastewater not only does not pose the threat to groundwater nitrate pollution but it could be useful in the irrigation management and foster the sustainable soil management practices also. However according to the European regulation the maximum permissible amount of fertilizer per hectare is 170 kg N. Therefore, the concentration of nitrogen in the wastewater should be taken into account during the application on nitrate sensitive areas (Council Directive 91/676/EEC). There were no significant differences between the ΔN values of the W15, W30, K15 treatments. In these cases the input nitrogen was approximately enough for the plants hence neither the soil nitrogen loading nor the soil exhaustion did not occur. The ΔN value of the K30, K60 and Control was the lowest. In the treatments with Körös River water (K30, K60) the input N was not enough for the soil-water-plant system because the irrigation water did not contain enough inorganic-N hence the ΔN values were negative and it means the soil exhaustion. According to Kenessey (1931) the irrigation should always coexist with nutrient supply, because the water explore the soil nutrient stock and the plants become rich in nutrients but the soil exhaustion can occur. Otherwise in case of the Control treatment the adverse nitrogen budget was caused by high nitrogen losses by leaching. According to Szalókiné and Szalóki (2003) in the soil of non-irrigated treatment, there is more nitrogen (because of the less plant N-uptake) which, during the winter period, results in higher nitrate concentration in leachate waters.

In 2016 (the third year of the plantation) the lowest value was in the treatment W15 and W30, but they were in the same homogenous subset as the K15, K30, K60 and Control (Table 2). Nitrogen balance could be realized only in W60 and HG60 treatment, where the input N and the output N was approximately equal. In 2016 the

DOI: 10.18380/SZIE.COLUM.2018.5.2.43

Table 4. Subset of the ΔNa values in the different treatments

2015								
	H15	***H30***	***H60***	***HG60***	***K15***	***K30***	***K60***	***Kontroll***
H15	-	-541	-1590	-342	456	385	237	551*
H30		-	-1049	199	996**	925*	778	1092***
H60			-	1248	2046***	1975**	1827*	2141***
HG60				-	798*	727	579	893**
K15					-	-71	-219	96
K30						-	-148	167
K60							-	314
Kontroll								-

2016								
	H15	***H30***	***H60***	***HG60***	***K15***	***K30***	***K60***	***Kontroll***
H15	-	-236	-671	-160	225	208	171	251
H30		-	-435	76	461**	444	407	487***
H60			-	511	896***	878**	842	922***
HG60				-	386	368	331	411**
K15					-	-18	-55	26
K30						-	-37	43
K60							-	80
Kontroll								-

Remark: Results of the Non-parametric, Kurskal-Wallis test. Values (i-j) mean the subset of the columns (i) and the rows (j). (*:p<0.05 **: p<0.01 ***: p<0.001).

higher ΔN values in the control occurred than in the previous year because of the less nitrogen loss by leaching. The lower ΔN values in the W15 and W30 was the results of the lack of nitrogen fertilizer, because the output by the willow stems and the leaching was less than in 2015. According to Arronsson and Bergström (2001) in the third year of the willow plantation the ΔN value was -39 kg N/ha (low N input and irrigation water) and it was -237 kg N/ha (high N input and irrigation water) on clay soil.

For all irrigated treatments the sodium budget was unfavourable but in case of the River Körös the values were significantly lower (Table 3, Table 4). The Na concentration of the River Körös is very low in both years and it makes it suitable for irrigation purposes. According to Ayers and Westcot (1989) above the limit of sodium (3 meq/l) in the irrigation water ion toxicity can occur and the sodium sensitive plant developing can decline. According to the recommendation of the FAO for irrigation water quality under the limit there is no harmful impact of the sodium content in case of sprinkler irrigation (Ayers and Wastcot 1989). According to our results the wastewater and the diluted and improved water did not meet the recommended limit (~12 meq/l and 5.7 meq/l, respectively) but the River Körös (1.8 meq/l) is under the limit. In all irrigated treatments with wastewater the ΔNa values were the highest which means that harmful sodium stay at the system (Table 3).

In both years neither the sodium contain of the stems nor the sodium leaching were not able to increase the output Na amount making the sodium budget more favourable. In the treatments irrigated with wastewater the sodium outputs were higher than in the treatments with River Körös however it was not enough high to reduce the sodium loading during the irrigation period owing to the wastewater quality. According to Nouri et al. (2017) green remediation is the use of vegetation to remove or contain environmental contaminants such as heavy metals, trace elements, organic compounds and radioactive compounds in soil or water and it is suggested to use for treat the soil salinity. In our case the willow did not uptake and accumulate so many sodium ion to balance the sodium budget.

In case of the HG60 treatment the wastewater was diluted and improved by gypsum hence the sodium budget were better than in the W60 (Table 3). However in the HG60 the sodium budget was not auspicious and also truly high hence the soil monitoring is exceptionally important for the sustainable, long-term irrigation. In both year, the ΔN value were significantly higher than in the K60 because the N input was higher (from the diluted wastewater origin), (Table 2). According to our results the wastewater treatment was sufficient to reduce the sodium loading of the soil-water-plant system compared to the wastewater irrigation in both years and it was able to increase the nitrogen budget.

Summary

Aim of our study was to evaluate the impact of the wastewater irrigation on the nitrogen budget of soil-water-plant system and to assess the environmental risk of the sodium accumulation. The wastewater is originated an intensive fish farm hence it had high nitrogen content what it was able to increase the nitrogen amount in the examined system however without supplementary fertilizer it could not able to balance the budget only just at W60 treatment. The wastewater had high environmental risk as soil sodicity according to results of the sodium budget. Even the treated wastewater require soil monitoring to ignore the sodium accumulation, however the dilution and added gypsum was able to reduce the rate of the sodium accumulation of the wastewater.

Acknowledgements

This research was supported by the Hungarian Ministry of Agriculture.

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