

THE INFLUENCE OF GRASS SPECIES COMPOSITION ON FISHPOND DIKES ON SOIL INFILTRATION

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Abstract

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Infiltration of water into the soil was monitored from 2012 to 2015 in two fishpond dikes of three different variants of grass species composition: variant 1 – grass mix for extensively dry conditions, variant 2 – heavy duty grass mix, variant 3 – grass mix for intensively moist areas. The monitored grass vegetation was mowed twice a year. The Rohatec pond is situated in Jindřichův Hradec district, in terms of texture its dike is made of sandy soil. The Horní Šatlava pond in Hodonín district and its dike consists of sandy to sandy-loam soils. Unsaturated hydraulic conductivity was measured with a Mini Disk Infiltrometer. On Rohatec dike the heavy duty mix proved the most suitable option for soil infiltration, while the best variant on Horní Šatlava dike was the mix for extensive drought. The lowest average unsaturated hydraulic conductivity was found in the extensive moisture variant which was statistically confirmed in the Horní Šatlava location.

Keywords: soil, unsaturated hydraulic conductivity, infiltration, grass mix

INTRODUCTION

Vegetation cover is an important aspect in protecting the soil structure of dikes during floods. Grass provides the dike body with the same protection as paint on metal structures or plaster on a wall. Grass cover on soil, especially a good quality grass, is the only protective element of soil dikes known so far. Its dynamic bioenergetic potential plays a significant role in reducing the infiltration of organic matter and eutrophying nutrients into the water course. It provides effective anti-erosion protection for flood defences along water courses, as well as optical monitoring of leakage on open slopes. It also helps improve the environment (Suchoň, 2003).

Thanks to an increasing interest in sustaining and improving the environment the use of vegetation is often recommended to regulate erosion caused by water flow and roadside slopes. It has been confirmed that with adequate maintenance, vegetation cover can be very successfully applied to protect roadside slopes and flood defences of water reservoirs. It can also be used to mitigate erosion on

river-basin slopes, both in construction work and timber harvesting (Matic, 2010).

The type and density of vegetation significantly influence soil infiltration and effective hydraulic conductivity (Zhang *et al.* 1995). Grass turf provides erosion protection and reduces moisture seepage. Cantré *et al.* (2013) tested dikes made of various fine-grain materials sown with grass mixes for dikes and mixes with added legumes. After the first mowing, fine grasses, such as common meadow grass species, red fescue (*Festuca rubra*) and legumes, were partly suppressed by highly competitive rye-grass (*Lolium perenne*). After the second mowing, due to more favourable light conditions, legumes developed better. Sowing the mix with legumes proved right in practice; well established grass and its high root density provided significant anti-erosion protection. Pohl and Vavrina (2008) also state that the resistance of dikes to hydrodynamic forces during rains is based on the functional interaction of a sandy core, cohesive layer and grass cover. According to Zhan *et al.* (2007) grassed slopes, in comparison to bare slopes, show significantly

higher infiltration and, at the same time, surface runoff is reduced.

Unsaturated hydraulic conductivity $K_{(h)}$ is a key soil Parameter governing water and solute transportation processes. Most of the natural processes involving soil-water-atmosphere-plant interaction occur under unsaturated conditions in the soil. Hydraulic conductivity is a property describing the ease with which water can move through the soil profile. The rate at which the water moves through the porous system of the soil profile can be characterised by the hydraulic conductivity as a function of volumetric water content $K(\theta)$, or pressure head $K_{(h)}$ (Matula *et al.*, 2015).

The course of this function depends on many factors: e. g. structure and texture of soil (Johnson 1963), on the geometry of the pores (Matula *et al.*, 2015) and on saturation of soil profile (Kutilek 1978). There are a number of chemical-physical conditions of the soil profile which vary over time such as the specific surface of the porous system, distribution of soil water content, chemical and physical nature of the water, biological activity, temperature, percentage of entrapped air in the soil and atmospheric pressure. In addition, the measured value of hydraulic conductivity is affected by the length of application time and the type of equipment or methods used. Temporal changes are caused by crop seasonality or seasonal variability, irrigation practices, erosion processes and the effects of traffic-induced compaction of the soil. Another factor influencing the value of the measured unsaturated soil hydraulic conductivity is the initial water content of the soil (Matula *et al.*, 2015).

The aim of project was to improve dike embankment by means of different grass mixes.

MATERIALS AND METHODS

The evaluation was carried out between 2012 and 2015 on two locations: Rohatec – Soboňky near Hodonín and Stálkov near Slavonice – Horní Šatlava. Both locations are characterized by ruderalized vegetation on the banks of ponds which are not effectively managed or used.

Characteristics of the monitored pond areas:

Horní Šatlava – the pond lies in the area of Hercynian mesophyticum in a colder Part of the Českomoravská vrchovina uplands, on the edge of the area known as “Czech Canada”, moderately moist, 616m altitude, Jindřichův Hradec district. The pond is surrounded by mixed forests and crop fields. In terms of texture the soil in the dike is sandy to sandy-loam. Sealing layer of the dam is clay layer.

Rohatec – the pond is situated in the Pannonian thermophyticum in the warm climatic area of the Dolnomoravský úval lowlands, moderately dry, 187 m altitude, Hodonín district. The pond is surrounded by non-original pine forest planted to reinforce drift sands occurring in this area. In terms

of texture the soil in the dike is sandy. Sealing layer of the dam is clay layer.

Evaluated variants with different grass mixes:

Variant 1 – grass mix for extensively dry conditions: 20 % *Lolium perenne* “Ahoj”, 40 % *Festuca rubra* “Reverent”, 23 % *Festuca ovina* “Ridu”, 15 % *Poa pratensis* “Balin”, 2 % *Trifolium repens* “Klement”

Variant 2 –heavy duty grass mix: 38 % *Lolium perenne* “Ahoj”, 40 % *Festuca arundinacea* “Asterix”, 20 % *Poa pratensis* “Balin”, 2 % *Trifolium repens* “Klement”

Variant 3 – grass mix for intensively moist areas: 32 % inter-genus hybrid of *Festuca*, type “Fojtan”,

20 % *Lolium perenne* “Jonas”, 25 % *Phleum pratense* “Alma”, 10 % *Poa pratensis* “Balin”, 10 % *Trifolium pratense* “Suez”, 3 % *Trifolium repens* “Jura”

The monitored grass cover was mowed twice a year.

Unsaturated hydraulic conductivity $K_{(h)}$ was measured with a Mini Disk Infiltrometer. For $K_{(h)}$ calculation was used the method recommended by Zhang (1997) based on an equation by Philip (1957). The data measured was processed in Excel program – calculation of $K_{(h)}$ of the soil. The method is based on the measurement of cumulative infiltration of water into the soil over the course of time, using the function:

$$I = C_1 t + C_2 \sqrt{t},$$

where C_1 [m.s^{-1}] and C_2 [$\text{m.s}^{-1/2}$] are the function Parameters. C_1 is a function Parameter relating to hydraulic conductivity while function Parameter C_2 relates to soil sorption. Hydraulic conductivity of soil $K_{(h)}$ is calculated using the function:

$$K_{(h)} = C_1 / A,$$

where C_1 is the value of the course of the curve of cumulative infiltration of water into the soil depending on the square root of the time period, and A is the value relating the Van Genuchten Parameters for the soil type given to the set amount of tension and radius of the infiltrometer disc.

The values were measured every 30 s for 30 mins, repeated three times, at the beginning and the end of the vegetation period. At the same time, soil samples were collected to measure soil moisture using the gravimetric method.

To statistically evaluate the recorded data of unsaturated hydraulic conductivity was used analysis of variance and, consequently, tested it with the Tukey HSD method in Statistica 12 program.

RESULTS

Figures 1 and 2 evaluate infiltration in individual years in both monitored locations. The graphs show that infiltration is affected not only by vegetation variants and soil composition of the dikes, but also by the year, as shown in the statistical evaluation

(see Tab. I). The least infiltration during the years of monitoring was found in variant 3 in both locations.

Tables I–III show average $K_{(h)}$ values reflecting soil infiltration capability in the monitored locations. On the Rohatec pond dike a high infiltration capability was found in comparison to the Horní Šatlava pond dike where medium infiltration capability was found according to Gardner *et al.* (1999).

The highest $K_{(h)}$ on the Rohatec pond dike was measured in variant 2 (heavy duty grass mix), but the increase, in comparison to the other variants, was not statistically conclusive. The influence of climatic conditions showed in this location – springtime $K_{(h)}$ values were evidently lower when compared to autumn measurements.

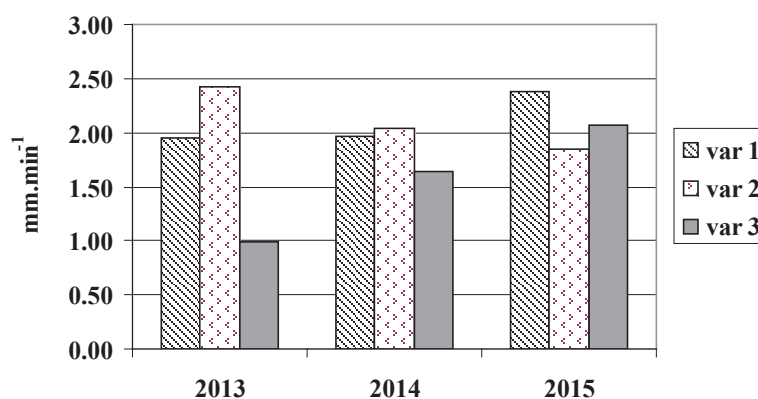
The highest $K_{(h)}$ on the Horní Šatlava pond dike was measured in variant 1 (grass mix for extensively dry conditions) and the increase was statistically conclusive in comparison to variant 3 (grass mix for intensively moist areas). The influence of climatic conditions also showed in this location, but springtime $K_{(h)}$ values were evidently higher here.

In measuring $K_{(h)}$, moisture conditions in the soil of the grass-covered dikes were also monitored

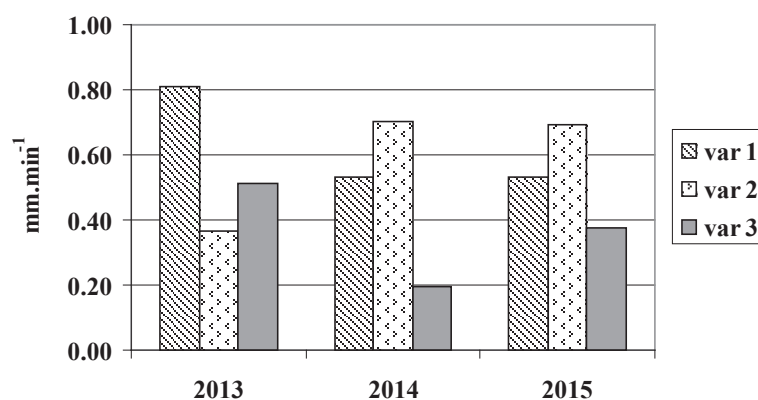
(Tab. IV). The values show the real soil moisture affecting the infiltration of water.

DISCUSSION

The most common method of reinforcing water body dikes is by grassing as Part of construction work relating to landscaping. Well-maintained grass vegetation of good quality makes a flexible, coherent cover for a soil slope of various steepness. It should be able to resist temporary water flow of up to 4 m.s^{-1} and have a tensile strength of 100 Pa. It should normally resist water flow of up to 2 m.s^{-1} with a tensile strength of 80 Pa. Such resilience is demanded from Q_{180} to Q_{90} (Suchoň, 2003). According to Ambasht (2008), waterside vegetation is very important. In wetland areas of river corridors and around lakes it sustains soil, water and dissolved nutrients, it prevents eutrophication and the related danger of biochemical consumption of oxygen. After establishing a pond dike, Anderson *et al.* (2010) found that rainfall causes its erosion and they therefore stabilised sandy slopes of the dike by sowing grass and legumes.



1: Average $K_{(h)}$ values in 2013–2015 in Rohatec location



2: Average $K_{(h)}$ values in 2013–2015 in Horní Šatlava location

Unsaturated water flow through soil aggregates is controlled by the contacts between aggregates. The contacts are highly conductive when wet and become bottle-necks for flow when drained (Carminati *et al.*, 2008). According to Licher *et al.* (2007) vegetation affects water flow in the soil if capillary forces are reduced due to water-repellent substances. Berli *et al.* (2008) found that, on the one hand, soil structure breakup causes a reduction in

soil retention ability, but on the other hand, larger contact areas improve water flow in unsaturated conditions. According to Klípa *et al.* (2014), reduction in soil hydraulic conductivity in springtime is most likely due to winter frosts followed by loosening in the soil. Conductivity may also be affected by colonization of the soil by algae and fungus. However, this phenomenon has not been confirmed so far by any tests or biological soil analysis.

I: Analysis of variance of unsaturated hydraulic conductivity in years 2013–2015 (mm.min⁻¹)

Effect	Rohatec		Horní Šatlava	
	d.f.	Mean square	d.f.	Mean square
Season	1	0.01346*	1	0.00125**
Variant	2	0.00292 n.s.	2	0.0006*
Year*Season	2	0.01714**	2	0.00100**
Error	40	0.00305 n.s.	40	0.00016 n.s.

*** P = 0.001; **P = 0.01; *P = 0.05; n.s. non-significant

II: Tukey HSD test

Variant	Rohatec	Horní Šatlava
	Average K _h (mm.min ⁻¹)	Average K _h (mm.min ⁻¹)
1	2.10224 a	0.62497 b
2	2.10916 a	0.58666 ab
3	1.56537 a	0.36024 a

Note: Average values indicated by various letters are statistically different (P = 0.05)

III: Tukey HSD test

Season	Rohatec	Horní Šatlava
	Average K _h (mm.min ⁻¹)	Average K _h (mm.min ⁻¹)
Start of vegetation	1.53883 a	0.64193 b
End of vegetation	2.31235 b	0.40597 a

Note: Average values indicated by various letters are statistically different (P = 0.05)

IV: Average soil moisture in monitored locations (wt. %)

Locality	Variant	2013		2014		2015	
		Start of vegetation	End of vegetation	Start of vegetation	End of vegetation	Start of vegetation	End of vegetation
Rohatec	1	7.27	3.21	5.28	11.59	4.56	5.78
	2	7.22	4.93	8.01	9.38	8.76	4.47
	3	8.29	4.67	6.21	7.98	3.10	3.95
	mean	7.59	4.27	6.50	9.65	5.47	4.73
Horní Šatlava	1	16.30	9.31	11.20	7.41	6.91	3.98
	2	14.28	9.49	11.26	9.50	5.60	4.31
	3	14.52	15.39	10.65	8.72	5.38	5.80
	mean	15.03	11.40	11.03	8.54	5.96	4.70

CONCLUSION

Infiltration ability of the soil represents one of the important factors in erosion protection of the soil. Insufficient infiltration properties of the soil surface reduce the amount of water entering the soil which, in combination with intensive (or persistent) rainfall can cause surface runoff and relating negative erosion processes.

From the results it is obvious that infiltration ability of the soil is affected not only by soil composition in the pond dikes and different grass mix cover, but also by climatic conditions. A heavy duty grass mix proved the most suitable for water infiltration on the Rohatec pond dike while a grass mix for extensively dry conditions succeeded on the Horní Šatlava pond dike. The lowest average unsaturated hydraulic conductivity was found in the variant with a grass mix for intensively moist areas which was statistically proven in the Horní Šatlava location.

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