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Buffer zone water repellency: effects of the management practice

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Abstract

Water repellency index R was measured in a heavy clay and a sandy loam, used as arable land or buffer zone (BZ). Further, effect of management practise and ageing of BZs were studied. Water repellency was proved to be a common phenomenon on these soils. Harvesting and grazing increased water repellency as does ageing. Low water repellency is supposed to prevent preferential flows and provide evenly distributed water infiltration pattern through large soil volume, which favours nutrient retention.

1. Introduction

Soil water repellency (WR) is a world wide known phenomenon. Pietola *et al.* (2005) have tentatively found that WR does exist also in Finnish heavy clay soil pasture. There is inadequate data about water repellent behaviour of Finnish soils situated in humid climate zone. WR has an impact on soil hydrological properties, especially water infiltration into the soil. Delayed soil wetting process increases preferential flow and results in an uneven wetting pattern (Dekker & Ritsema 1996a) or may expose soil to surface runoff and consequent erosion.

Buffer zones (BZ) are established to prevent soil erosion and nutrient transport to surface waters. However, Uusi-Kämppä (2005) reported unability of BZs to reduce molybdate-reactive (i.e. bioavailable) phosphorus. We assume that low WR promotes evenly distributed water infiltration through the entire soil volume and favours nutrient retention, especially that of bioavailable phosphorus.

BZs vary by age and management practice (e.g., natural state, harvested or grazed), which may influence soil WR. How should we manage BZs to prevent WR and attain evenly distributed water infiltration through the whole soil profile? The aim of this paper is to determine the severity of WR in cultivated Finnish heavy clay and sandy loam soils and in BZs established on these soil types. Further we investigated how the age and different management practice of BZ affect WR.

2. Material and methods

Soils samples were taken from two experimental sites. The Lintupaju soil in Jokioinen, South-Western Finland, was classified as a Vertic Cambisol. Experiments were conducted on six BZs and on an adjacent cultivated field. BZs were 1) old (15 years) natural vegetation with wild hay and scrubs or 2) without scrubs, 3) old and 4) young (3 years) BZ with grass species harvested annually, 5) old and 6) young BZ with grass species grazed by cattle. In Maaninka, Central Finland, the soil was classified as a Dystric Regosol. Experimental sites were two BZ and cultivated field. BZs were 1) old (10 years) natural vegetation with grass species, and 2) young (2 years) BZ with grass species harvested annually. Soil characteristics are presented in Table 1.

Table 1. Soil characteristics.

Site	CEC $cmol(+)kg^{-1}$	Base saturation%	Clay %	Silt %	Sand %	C	pH
Lintupaju 0–6 cm	28.3	85	51	42	7	5.4	6.2
Maaninka 0–30 cm	9.4	81	8	47	45	1.4	6.6

Six replicates of undisturbed 100 cm^3 soil cores were collected from each site at the depth of 0–5 cm. The WR measurements were carried out under various water contents, first field moisture (at the time of sampling) and then from saturated soil to oven dried at 105°C.

The infiltration of water and ethanol (95%) on 20°C was measured using apparatus described by Leeds-Harrison *et al.* (1994) and modified by Hallett and Young (1999). Sorptivity (S) of water (Sw) and ethanol (Se) was calculated according to equation 1 (Leeds-Harris *et al.* 1994).

$$S=(Qf/4br)^{-1/2} \quad (1)$$

where Q is steady rate of water flow (measured within 75 s), f is the air-fillable porosity and r is the radius of the infiltration tip 1.5 mm. The value for parameter b is 0.55 (White & Sully 1987). The pressure head of –2 cm was used. The WR index (R) is calculated (2) from Sw and Se (Tillman *et al.* 1989) as follows:

$$R=1.95(Se/Sw) \quad (2)$$

R index > 1.95 represents water repellent soil. Statistical analysis was carried out for R index measured after oven drying at 40°C i.e. potential water repellency. Tukey's test (p 0.05) was used to define differences between treatments.

3. Results and discussion

Soil WR proved to be a common phenomenon in BZs. This is in agreement with findings of Dekker and Ritsema (1996a), who measured WR on alluvial heavy clay soil used as a grassland pasture in Netherlands. Old annually harvested BZ with grass species resulted in highest potential R index (Fiq. 1 and Table 2), water infiltration was delayed by 10-fold. This site was apparently covered with mosses, which is supposed to be reason for high WR. Mosses were not present at the young annually harvested BZ with grass species, which had statistically lower R index (3.6). Statistically lower R index (5.4) was measured also in old natural BZ with wild hay although accumulation of organic matter was expected (data for content of organic matter not yet available). This old natural BZ with wild hay had only slightly lower R index than the old natural BZ with scrubs (5.9). The quality of organic matter and waxes excreted by plants differ in their water repellent properties, but this divergence was proved to be minor.

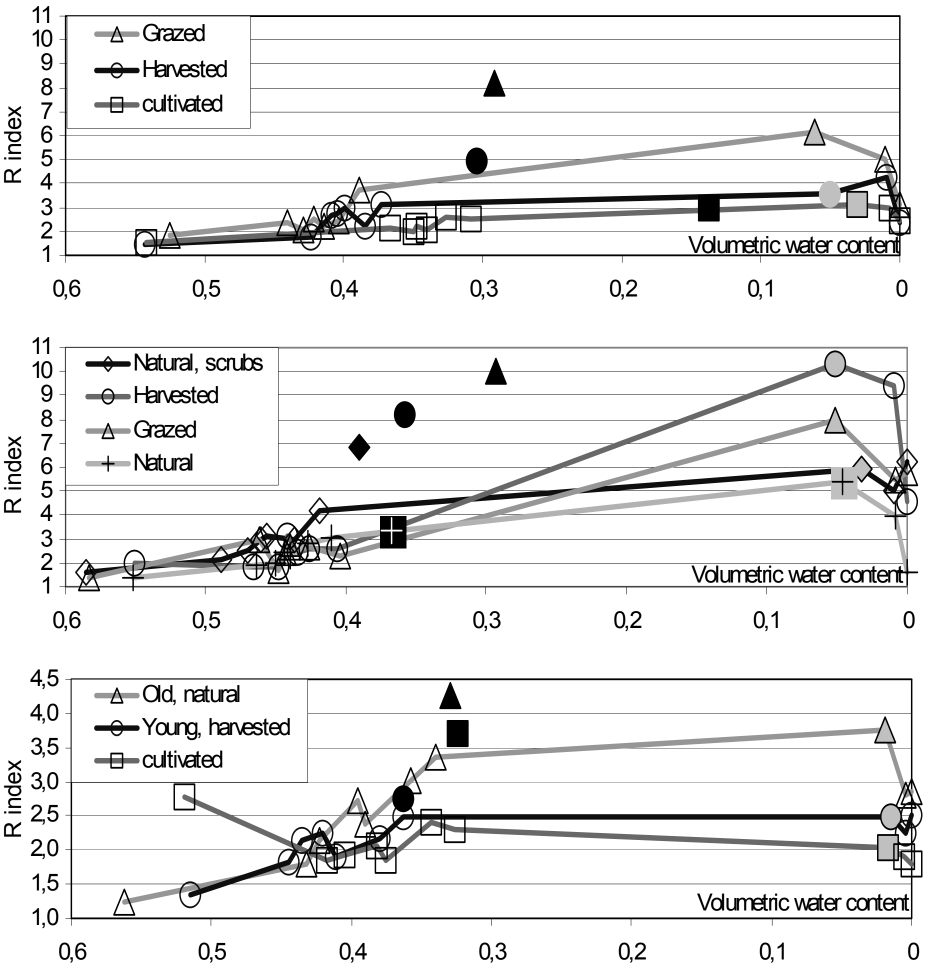

Figure 1. R index measured at various water contents.

In Figure 1 the topmost chart represent data for 3 years old young BZs and cultivated field in Lintupaju, the middle chart represent data for 14 years old BZs in Lintupaju and the lowest chart for BZs and cultivated field in Maaninka. Symbols connected by line represent drying treatments (as mentioned in the text). Black symbols stand for R index at field moisture at the time of sampling. Gray symbols stand for potential WR after drying at 40°C.

The young (R = 6.1) and old (R = 7.9) grazed BZs exhibited higher WR than either the old natural or the young harvested BZs. Pietola *et al.* (2005) found also that in the heavy Finnish clay soil pasture, intense cattle trampling increased water repellency compared to pasture with no visible trampling.

WR was less severe in Maaninka and no statistical differences were found between the experimental sites. However, the old BZ showed the highest R index (3.8) and the index for the harvested young BZ with grass species was only slightly lower (R = 2.5).

Table 2. Potential (drying at 40°C) R index and R index measured at field moisture.

Management *	Potential R index	S.E. **	P 0.05 ***	R index at field moisture	S.E.
Old, natural, wild hay, scrubs (L)	5.9	0.92		6.8	0.92
Old, grass species, harvested (L)	10.3	1.53	a, b, c	8.2	0.90
Young, grazed (L)	6.1	1.07		8.2	1.58
Old, grazed (L)	7.9	1.55		9.9	0.97
Young, grass species, harvested (L)	3.6	0.75	b	5.0	0.64
Old, natural, wild hay (L)	5.4	0.69	a	3.3	0.50
Cultivated field (L)	3.1	0.31	c	3.1	0.32
Old, grass species (M)	3.8	0.53		4.3	0.54
Young, grass species, harvested (M)	2.5	0.33		2.7	0.21
Cultivated field (M)	2.0	0.17		3.7	0.45

* (L) stand for Lintupaju and (M) stand for Maaninka
** S.E. stand for standard errors of the mean
** *values with the same letter differ significantly according to Tukeys´s test

Cultivation reduces soil WR (Hallett *et al.* 2001) and presumably potential WR was lowest at cultivated sites in both experimental areas. In Maaninka cultivated field proved to be almost totally non repellent (R = 2.0) after drying at 40°C, whereas at the Lintupaju R index was 3.1. This is in agreement with Dekker and Ritsema (1996a), who measured more severe WR in soil under grass compared to arable land. WR measurements at various water contents showed that only the old harvested BZ with grass species had an R index (2.0) indicating minor WR at saturation. There is an obvious trend that WR increases when soil is drying. Dekker and Ritsema (1996a) proposed that low water uptake of irrigated clay cores at initial volumetric water content range of 34–42% resulted from WR of the aggregates and prisms. Our findings are in agreement with that result, because all the BZs were water repellent at volumetric moisture contents below 41%.

4. Conclusions

In the Lintupaju soil, volumetric soil water content at the moment of sampling was lower at grazed and harvested BZ than in the old natural BZs, due to lack of covering vegetation. Frequently drying top soil is often recognized water repellent, which is in agreement with our results. Moreover we found that ageing (also in Maaninka) increases soil WR and combined with harvesting it may prepare the way for mosses, which we assume to further increase water repellency.

In shrinking and swelling clay soils, drying (i.e. shrinking) combined with increasing WR expose soil to preferential flow and uneven wetting pattern (Dekker and Ritsema 1996a). This may contribute to leaching of bioavailable phosphorus from BZs. Fast water movement through macro pores and cracks does not allow sorption or at least diminishes contact between soil and water (Dekker and Ritsema 1996b).

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