Effect of Cutting Regime on Soil Physical Properties of Wet Thistle Meadows

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Abstract: Changes of selected soil physical properties (porosity P, soil organic matter SOM, bulk density ρ_d, particle density ρ_z, characteristics of water retention capacity – maximum capillary water capacity θ_{CMC}, and non-capillary porosity P_n) of permanent grassland (wet, non-fertilized, thistle meadows ass. *Angelico-Cirsietum palustris,* crystalline complex area, Czech Republic) in the top soil layer (3–10 cm) managed under three regimes (uncut UC; cut once a year C1; cut twice a year C2) were monitored for one undrained and two drained sites. There were no significant differences in selected soil physical properties among the test plots at the beginning of the study. As the intensity of utilisation decreased, the values of P, SOM, and P_n increased and ρ_d, ρ_z and θ_{CMC} decreased. Within 5–10 years of the beginning of the study, average values were: P at UC = 70, C1 = 69, C2 = 67%; SOM at UC = 10.7, C1 = 10.6, C2 = 10.0%; ρ_d at UC = 0.76, C1 = 0.79, C2 = 0.84 g/cm^3; ρ_z at UC = 2.53, C1 = 2.55, C2 = 2.56 g/cm^3; θ_{CMC} at UC = 50, C1 = 53, C2 = 51%; P_n at UC = 21, C1 and C2 = 16%. Moderate negative dependence of both ρ_z and ρ_d on SOM and of ρ_d on P_n and a moderate positive dependence of P on SOM was observed. θ_{CMC} changes did not show links to other soil physical properties. The greatest looseness of the top soil layer, expressed by a decrease in ρ_d, occurred with the UC regime in direct correlation with SOM, P_n and P.

Keywords: soil physical properties; wet grassland; management; regression; ANOVA

It is broadly believed that problems of Czech agriculture, including its competitive advantage, should be addressed by a reduction in agricultural production intensity and arable land ratio in less favoured areas followed by conversion of arable land to grasslands. Stock breeding intensity was reduced in the Czech Republic after 1990 and it took effect during negotiation of the conditions for accession of the Czech Republic to the EU. This brought about not only a drop in the gross agricultural production index, but also an increase in permanent grassland area (PGA). These changes led to decreased loading of pastures by cattle and a decrease in the average number of annual cuttings of fodder meadows along with the cessation of use of some meadows.

Reduction in intensity of utilisation of grassland affects not only the composition of flora, aboveground phytomass yield (e.g., Haynes & Francis 1990; Rychnovská *et al.* 1994; Joyce & Wade 1998; Grevilliot & Müller 2001; Harmens *et al.* 2004), root systems (Tesařová *et al.* 1982; Tesařová 1983; Fiala 1997), and activities of soil micro-organisms (Lovell *et al.* 1995; Krahulec *et al.* 1996; Lovell & Jarvis 1998; Uhlířová *et al.* 2005), but also the chemical and physical properties of the soil.

Basic soil physical properties (porosity, bulk density, water retention capacity) reflect the condition of soil structure (Revut & Rode 1969; Baver *et al.* 1972). Structural stability, size of soil aggregates, and the condition of aggregation are significantly

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influenced by water (wetting and drying, kinetic energy of rain drops, freezing and thawing, washing of eroded particles into pores). Soil physical properties are also affected by the clay content (the most suitable structure for plant growth are soils with 12–35% clay, Kohnke 1968), adsorbed calcium cation content, presence of sesquioxides, excretion of organic compounds from plant roots, humus and pectin content, and microbe and soil fauna activities. Baver *et al.* (1972) state that, for a large number of soil types, the coefficients of correlation between the percent representation of aggregates larger than 0.05 and 0.1 mm and the content of organic soil carbon are 0.559 and 0.687, respectively. The impact of organic matter on aggregation is greater in soils containing less than 25% clay, while in soils containing more than 35% clay the correlation is less significant. Li and Shao (2006), Quiroga *et al.* (1998) and McVay *et al.* (2006) showed that increased porosity and decreased bulk density occurred as a result of increased content of soil organic matter and aggregate stability. Soil physical properties are also affected by parent rock and terrain incline (Breuer *et al.* 2006).

Changes in land utilisation result in substantial alterations in soil physical properties, due to degradation and destruction of soil structure and/or a change in organic matter content, e.g. through ploughing of natural grassland (Soussana *et al.* 2004), conversion of natural steppe or arable land to pastures and meadows (Schwartz *et al.* 2003; Brye & West 2005; Breuer *et al.* 2006) or compaction of soil by grazing (Mikhailova *et al.* 2000; Villamil *et al.* 2001; Kurz *et al.* 2006).

Perennial plants, such as those in grazed and mown grasslands, have a favourable impact on soil structure and porosity due to the granulation effect of root systems, impact protection from vegetation cover, and production of organic substances which support biological activity (Baver *et al.* 1972). Wiliams (1952) referred to the benefits of (clover) grass mixtures for the stability of soil structure from the first year of its utilisation. Van Lanen *et al.* (1987) also emphasised the ability of PGA to regenerate soil porous structure, due to its high biological activity, thereby enhancing water storage capacity. Grassland and forest soils have higher organic matter content, soil aggregate stability, porosity, and lower bulk density, than cultivated land (Haynes & Francis 1990; Chan & Bowman 1995; Dominy & Haynes 2002; McLauchlan *et al.* 2006; Kaleem Abbasi *et al.* 2007), in which there is an associated loss of soil organic matter due to mineralization, especially of the unstable carbonaceous component, which results in a decline in porosity and pore continuity.

The soil physical properties of PGA and their mutual dependence are affected by management regimes. Tesařová (1992) and Tesařová *et al.* (1999) stated that, after cutting, there is increased decomposition of SOM because most roots of fertile grass sprouts die after cutting. Fiala (1997) found that cut covers had more than 50% less live underground biomass than uncut covers. Decreasing SOM from 4.8% to 4.4% by cutting of natural steppe, hence reducing the above-ground biomass, was also reported by Brye and West (2005). Werth *et al.* (2005) recorded a decrease of SOM from 8.25% to 6.96% on a cut twice site over 27 years. Soussana *et al.* (2004) mentioned the introduction of fallow grassland as a measure to increase storage of soil carbon by 0.2–0.5 t/ha/year. Bauer and Black (1992) state that ρ_d decreases as soil organic carbon content in grassland increases. Mikhailova *et al.* (2000) mention different soil ρ_d values under natural mesoxerophile grass cover (0.80 ± 0.09 g/cm^3) in a plot lying fallow since 1935 and prior to that grazed for 300 years, compared to grassland (originally also natural) now grazed in the spring and cut in the summer (0.97 ± 0.06 g/cm^3).

Eynard *et al.* (2006) found a positive correlation of porosity with the soil organic carbon content in PGA. Evrendilek *et al.* (2004) found out that the content of soil organic carbon was positively correlated with available water capacity and the overall P and negatively correlated with ρ_d. Similarly Kaleem Abbasi *et al.* (2007) established an indirect dependence of ρ_d on the content of humus in the soil of grass and forest covers and in arable land with determination coefficient $R^2 = 0.75$.

The purpose of this study was to evaluate and explain the impact of alternative methods of grassland management (uncut, cut once a year, and cut twice a year) on soil physical properties.

MATERIAL AND METHODS

The experimental plots were located on three meadow sites near Velký Rybník (Region Vysočina, 49°30'N, 15°18'E, Czech Republic). The average annual rainfall totals for the period 1951–2000

Table 1. Characterisation of individual sites Velký Rybník

Site	Average underground water level during vegetation season (cm)		Drainage 1986–1988	Reclamation 1988
	1994–2001	2002–2003		
L1	54.8	66.0	no	no
L2	75.8	66.0	yes	yes
L3	44.1	50.5	yes	yes

for Czech Hydrometeorological Institute stations Pelhřimov and Humpolec were, respectively, 660 and 666 mm, and 425 and 417 mm during the growing period. Average air temperature (Přibyslav, 1951–2000) was 6.7°C, and 12.8°C during the growing period. This is a potato-growing agricultural production area (Němec 2001) at the altitude of 506–513 m above sea level. Two meadows (L1 and L2) were located in the floodplain of the Jankovský stream and the third (L3), in the floodplain of Kopaninský stream, and were approximately 1000 m apart. The sites had different water regimes (Table 1): L1 was undrained with natural grass cover, watered by nearby springs. Its underground water level (UWL) fluctuated according to rainfall and the flow rate in the stream. From 1986 to 1988, sites L2 and L3 were drained by a tile drainage system (spacing and depth of collecting drains was 15.0 and 0.9 m, respectively) which offered the possibility of retaining drained water at site L3, from 1988–1992 (Kvítek 1992). In 1988, grassland was reclaimed at L2 and L3. Following soil preparation, NPK fertilisation, and liming, a grass stand was established as a cover crop along with oats for fodder using the mixture *Trifolium repens, Phleum pratense, Festuca pratensis, Festuca rubra, Poa pratensis,* and *Alopecurus pratensis*. The sites comprised the soil types gleyic Fluvisol (L1, L2) and modal Gleysol (L3) and soil class sandy loam (L1) and loamy soil (L2, L3). The soil depth was 0.8–1.0 m over a gravel-sand terrace. The parent rock is cordieritic paragneiss.

Prior to the establishment of the trial in 1990, L1 was cut at a variable time, once a year. From 1990 to 1992 all plots on all sites were cut three times a year. Since 1993, plots on each of the three sites have been subjected to one of three management regimes: uncut (UC), cut once a year (C1) and cut twice a year (C2). Each regime was triplicated, i.e. at each site there are 9 test plots (15 m^2 each). Since 2002 accumulation of water due to blockage of the drainage system at L2 caused an increase in UWL (Table 1).

The experimental plots were subjected to varying fertilisation treatments (1990–1997), but the selected soil physical properties for the entire monitoring period were established on the non-fertilised parts of the experimental plots (in aisles between plots) which were subjected to the same cutting regime (i.e. UC, C1 and C2).

From a phytocenological perspective the ground covers may be classified as:

L1 – cl. *Molinio-Arrhenatheretea*, o. *Molinietalia*, all. *Calthion*, ass. *Angelico-Cirsietum palustris* (angelica meadow with marsh thistle), i.e. thistle meadows of submontane region, more acidic soils with rather less nutrients and underground or spring water and gleyzation in the upper part of the soil profile.

L2 – cl. *Molinio-Arrhenatheretea*, o. *Arrhenatheretalia*, all. *Arrhenatherion*, ass. *Angelico-Cirsietum palustris* – dryer form at transition to ass. *Trifolio-Festucetum rubrae.* Prior to drainage all. *Calthion.*

L3 – ass. *Angelico-Cirsietum palustris,* wettest form.

In 1994 and annually from 1999–2003, samples of undisturbed soil were removed to determine soil physical properties from a column 3–10 cm high using steel cylinders of volume 100 cm^3 (Kopecký's rings). In 1994, two samples were taken, annually from 1999–2003 10 samples from each plot from each site, i.e. a total of 18 samples in 1994 and 90 samples in 1999–2003. The following soil physical properties were evaluated:

particle density (ρ_z) – in g/cm^3, weight of a unit volume of soil without pores, method according to ISO 11 508 (1998): Soil quality – Determination of particle density;

bulk density (ρ_d) – in g/cm^3, weight of a unit volume of dry soil, method according to ISO 11 272

(1998): Soil quality – Determination of dry bulk density;

porosity (P) – % volume of sample in natural deposition not filled with solid particles, established by means of the formula:

$$P = (\rho_z - \rho_d)/\rho_z \times 100 \qquad (1)$$

A slight increase in P occurred because ρ_d was based on samples that included non-decomposed organic matter in the Kopecký's rings, e.g. roots, and pieces of undecomposed organic matter which were removed prior to determining ρ_z;

maximum capillary water capacity (θ_{CMC}) – % volume of capillary soil pores which corresponds approximately to field water capacity (θ_{FC}), determined in the laboratory using an empirical procedure according to Novák (Klika *et al.* 1954). Its determination is based on the mass change after 2 h water suction from a Kopecký ring fully soaked with capillary water on dry filter paper.

soil organic matter content (SOM) – % weight, determined by the weight change after incineration of the sample in a muffle furnace at 550°C, (not performed in 1994).

non-capillary porosity (P_n) – % volume, determined by the difference in values P and θ_{CMC}.

Further samples were taken to determine particle size distribution, i.e. percent representation of particles of various sizes (< 0.001 mm, < 0.010 mm, 0.010–0.050 mm, 0.051–0.250 mm, 0.251 to 2.0 mm), and particle-size distribution curve (Figure 1). Classification of soil according to particle size was performed according to the Kopecký method which was adjusted to the needs of a complex soil survey (Sirový *et al.* 1967). Subsequently, soil texture type was determined (Figure 1). Samples were taken at all sites at a depth of 0–20 cm evenly in a diamond network. Twenty-five samples were taken from each site. Analysis was conducted using the ISO 11277 (1998/Cor 1:2002): Determination of particle size distribution in mineral soil material – method by sieving and sedimentation.

To assess the systematic effect of categorical independent variables (utilisation, site, year) on a quantity type dependent variable (soil physical properties) a t-test was used together with a one-to-three-way analysis of variance (ANOVA) with a significance level of $\alpha = 0.05$.

To identify differences in effects of levels of a given factor, the test of simultaneous comparison according to Scheffe, using the software Statgraphics 5 Plus, was applied to the ANOVA data.

A multivariate analysis of data was done by the Canoco 4.5 software (ter Braak & Šmilauer 2002). Direct redundancy analysis RDA was used to identify linear responses of selected physical properties to explanatory variable (cutting regime). Biplot ordination diagram created in CANODRAW programme (ter Braak & Šmilauer 2002) was used for the graphical visualisation of results, where the relationship between the selected physical properties and the explanatory variable can be determined by perpendicular projection of the end point of the "soil property's" arrow onto the

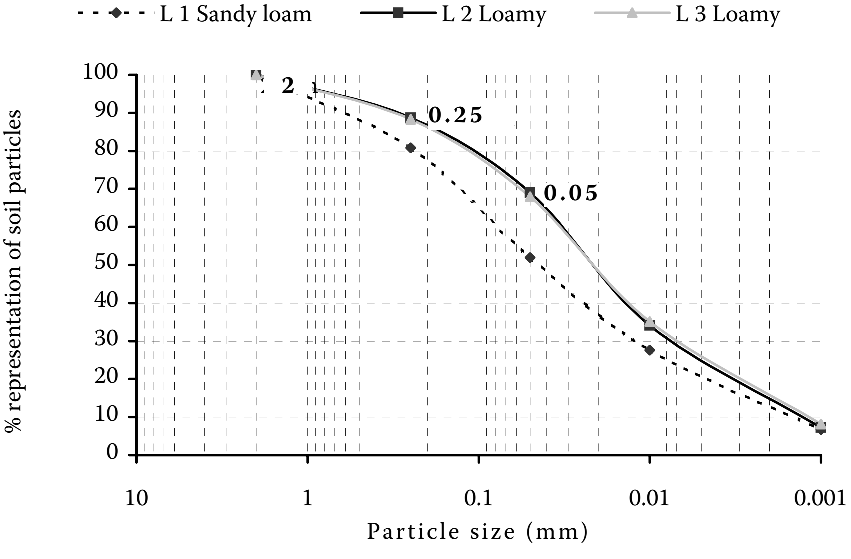

Figure 1. Particle-size distribution curve of individual sites, depth 0–20 cm, Velký Rybník 2005

Table 2. *F*-test (*F*) values and significance level α of tested factors (cutting regime, site, year) one-, two- and three-way ANOVA for individual periods and soil physical properties

Period	ANOVA factors criterion	One-way				Two-way				Three-way					
		cutting regime		site		cutting regime		site		cutting regime		site		year	
		F	α	*F*	α	*F*	α	*F*	α	*F*	α	*F*	α	*F*	α
1994	θ_{CMC}	0.855	0.449	26.085	$< 10^{-4}$	4.611	0.307	33.937	$< 10^{-4}$						
	ρ_d	0.282	0.758	31.210	$< 10^{-4}$	1.497	0.2599	33.279	$< 10^{-4}$						
	ρ_z	0.736	0.4955	32.500	$< 10^{-4}$	5.921	0.0149	53.825	$< 10^{-4}$						
	p	0.164	0.8499	26.085	$< 10^{-4}$	0.691	0.5188	25.008	$< 10^{-4}$						
	P_n	0.831	0.4546	0.087	0.9173	0.730	0.5008	0.0084	0.9203						
1999–2003	θ_{CMC}	17.349	$< 10^{-4}$	77.838	$< 10^{-4}$	23.934	$< 10^{-4}$	85.825	$< 10^{-4}$	37.576	$< 10^{-4}$	134.74	$< 10^{-4}$	64.411	$< 10^{-4}$
	ρ_d	24.423	$< 10^{-4}$	80.734	$< 10^{-4}$	34.456	$< 10^{-4}$	92.820	$< 10^{-4}$	41.026	$< 10^{-4}$	110.519	$< 10^{-4}$	22.214	$< 10^{-4}$
	ρ_z	22.081	$< 10^{-4}$	69.110	$< 10^{-4}$	29.686	$< 10^{-4}$	77.980	$< 10^{-4}$	32.900	$< 10^{-4}$	86.424	$< 10^{-4}$	13.047	$< 10^{-4}$
	P	20.973	$< 10^{-4}$	72.071	$< 10^{-4}$	28.474	$< 10^{-4}$	80.931	$< 10^{-4}$	33.082	$< 10^{-4}$	94.028	$< 10^{-4}$	19.004	$< 10^{-4}$
	SOM	12.414	$< 10^{-4}$	32.700	$< 10^{-4}$	14.797	$< 10^{-4}$	35.261	$< 10^{-4}$	24.744	$< 10^{-4}$	58.962	$< 10^{-4}$	80.541	$< 10^{-4}$
	P_n	24.149	$< 10^{-4}$	15.373	$< 10^{-4}$	17.085	$< 10^{-4}$	25.887	$< 10^{-4}$	38.070	$< 10^{-4}$	25.126	$< 10^{-4}$	53.358	$< 10^{-4}$

Table 3. Pair comparison of average values θ_{CMC}, ρ_z, ρ_d, P and P_n using *t*-test (α = probability value).

Cutting regime	Compared pair	θ_{CMC}		ρ_z		ρ_d		P		P_n	
		t	α	*t*	α	*t*	α	*t*	α	*t*	α
UC	1994 *vs.* 1999–2003	1.209	0.2285	0.550	0.5829	2.526	0.0126	–2.815	0.0055	–2.599	0.0102
C1	1994 *vs.* 1999–2003	0.628	0.5308	–1.667	0.0975	1.929	0.0556	–2.193	0.0298	–1.703	0.0906
C2	1994 *vs.* 1999–2003	2.529	0.0125	–4.135	0.0001	0.042	0.9667	–0.959	0.3391	–2.723	0.0072

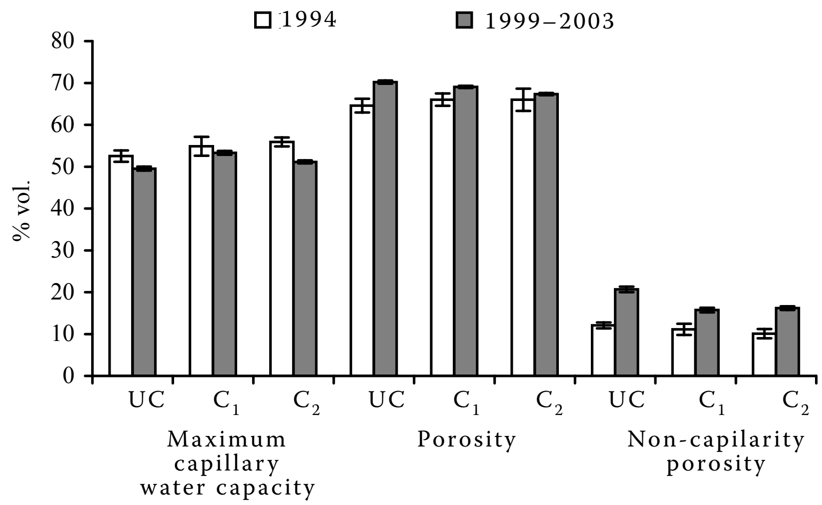

Figure 2. Average values maximum capillary capacity, porosity and non-capillary porosity (%) with mean errors of cutting regimes (3–10 cm), Velký Rybník, 1994 *vs.* 1999–2003

connecting line of the explanatory variable with the intersection point of the axes (Figure 4). The longer the distance from the intersection point of the axes, the higher the correlation of the physical property with the given variable. The soil properties pointing in an opposite direction to the connecting line of the explanatory variable and the intersection point of the axes are in negative correlation with the variable.

Mutual dependence of soil physical properties was tested by a correlation analysis or by multiple linear regression. The closeness of a relationship was assessed by means of a correlation coefficient, r, and the coefficient of determination, R^2, the latter expressing the ratio of explained variability to the overall variability of the dependent variable. The significance of dependencies was evaluated by an F-test comparing the variance of averages of groups defined by a certain factor level and the variance within the groups.

RESULTS AND DISCUSSION

Change of soil physical properties

In the period immediately after the introduction of alternative methods of management (1994), following the foregoing three cuttings regime (1990–1992), the average values for θ_{CMC}, P, ρ_d, ρ_z and P_n (Figures 2, 3) were not significantly affected by the use of grass cover (Table 2).

Between 1999 and 2003, a change due to the cutting regime in all physical properties (Figures 2, 3, Table 2) at all sites was observed. In the case of SOM, there was always a significant difference between the values of C2 (lowest values) and UC or C1 regimes. Previous work evaluating the content of soil organic oxidable carbon (C_{ox}, using chromium-sulphur mixture) and organic carbon (C_{org}, using thermal combustion) in the top soil layer (3–20 cm) at the same sites and in the same

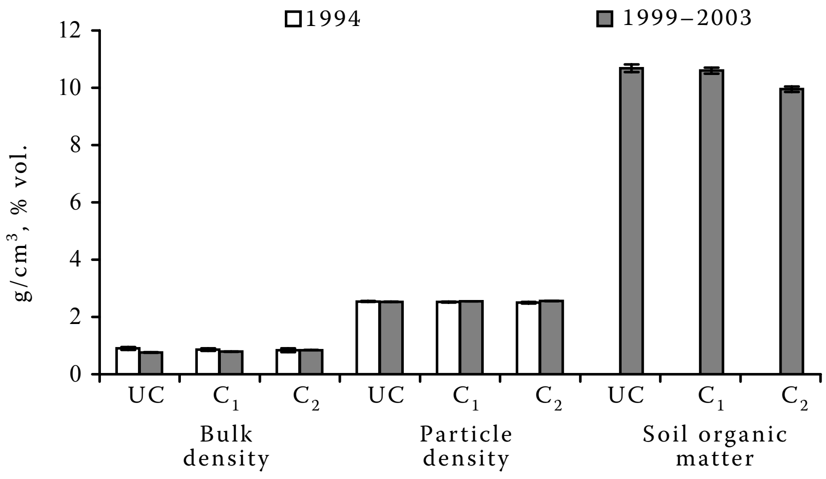

Figure 3. Average values bulk density, particle density (g/cm^3) and soil organic matter (%) with mean errors of cutting regimes (3–10 cm), Velký Rybník, 1994 *vs.* 1999–2003

time period (Duffková *et al.* 2005) produced similar conclusions: the cut twice regime showed the lowest content of both forms of soil organic carbon (C_{ox} 2.53%, C_{org} 2.36%), and there was a significant difference between the values of the cut twice regime and no cut regime (C_{ox} 2.97, C_{org} 2.80%). The decreased SOM of the C2 regime compared to other regimes was probably related to a reduction in nutrients, together with the removal of harvested above-ground biomass, and further to the increased mineralization of SOM, especially of dying roots after cutting (similarly Tesařová 1992; Fiala 1997; Tesařová *et al.* 1999; Brye & West 2005; Werth *et al.* 2005). The surveys of the content of the soil microbial biomass at all three sites in September 2005 and 2006 confirmed these conclusions (UC = 1784 and 1295, C1= 1898 and 1390, C2 = 2075 and 1528 mg C/kg).

There were no significant differences in soil particle size among the test plots (not shown). This implies that physical soil properties (P, ρ_d, ρ_z) were affected solely by the content of organic matter and not the mineral soil component. As SOM decreased, i.e. as the intensity of cutting increased, the values ρ_z and ρ_d increased. The highest values ρ_d and ρ_z were observed with C2 regime, the lowest with the UC regime (similarly Bauer & Black 1992; Mikhailova *et al.* 2000).

Bulk density depends not only on SOM but also on the total volume of soil pores, which increases with decreasing intensity of cutting. The present study showed differences of P among all cutting regimes tested. The values of θ_{CMC} were significantly higher in cut regimes (highest being in C1). The highest value of P of UC (Figure 2) is determined by the volume of P_n (Figure 2). Hejduk & Kasprzak (2005) similarly observed a significant reduction of non-capillary porosity and an increase in capillary porosity with increased intensity of cutting (cut once PGA – P_n 25.8; capillary P 27.6% *vs.* cut four times PGA – 22.1; 31.6%).

The visualisation of the significant effect of cutting regime on selected physical properties in the period 1999–2003 is shown by biplot ordination diagram (Figure 4). Conclusions of previous

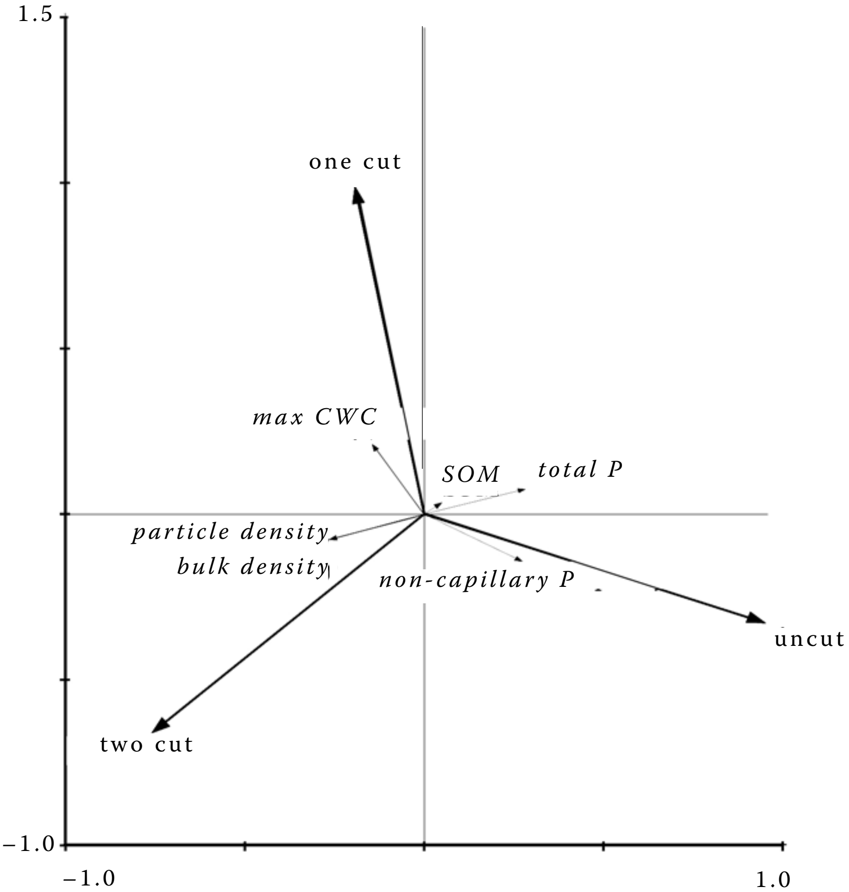

Figure 4. The effect of cutting regime on selected physical properties, Velký Rybník, 1999–2003

Table 4. Correlation analysis and multiple linear regression (last three lines) of soil physical properties of individual ways of utilisation, Velký Rybník, 1999–2003

Dependent variable	Independent variables	Cutting regime	Correlation coefficient r	Determination coefficient R^2	Values of F-test	α
P	SOM	UC	0.599	0.3590	66.0838	$< 10^{-4}$
P	SOM	C1	0.379	0.1434	19.7512	0.00002
P	SOM	C2	0.342	0.1172	15.6719	0.00013
ρ_d	SOM	UC	−0.613	0.3756	70.9857	$< 10^{-4}$
ρ_d	SOM	C1	−0.427	0.1821	26.2691	$< 10^{-4}$
ρ_d	SOM	C2	−0.349	0.1221	16.4041	0.00009
ρ_z	SOM	UC	−0.715	0.5118	123.7213	$< 10^{-4}$
ρ_z	SOM	C1	−0.681	0.4633	101.8672	$< 10^{-4}$
ρ_z	SOM	C2	−0.419	0.1755	25.1117	$< 10^{-4}$
ρ_d	P_n	UC	−0.630	0.3965	97.2497	$< 10^{-4}$
ρ_d	P_n	C1	−0.378	0.1426	24.6074	$< 10^{-4}$
ρ_d	P_n	C2	−0.491	0.2407	46.9122	$< 10^{-4}$
ρ_d	SOM, P_n	UC		0.5766	79.6740	$< 10^{-4}$
ρ_d	SOM, P_n	C1		0.3713	34.5496	$< 10^{-4}$
ρ_d	SOM, P_n	C2		0.4137	41.2825	$< 10^{-4}$

results can be given: C2 is characterized by the decreased SOM and P, and by the increased ρ_d and ρ_z, C1 by the increased θ_{CMC} and UC by the increased P_n.

Comparing 1994 and the period 1999–2003, all cutting regimes showed an increase in P (in case of UC and C1 this was a significant increase) as a result of the increase of volume of P_n (in case of UC and C2 this was a significant increase), and, in the case of the C1 regime, it was also due to the lowest decrease of θ_{CMC} compared to other regimes (Figure 2, Table 3). Accordingly, decreased

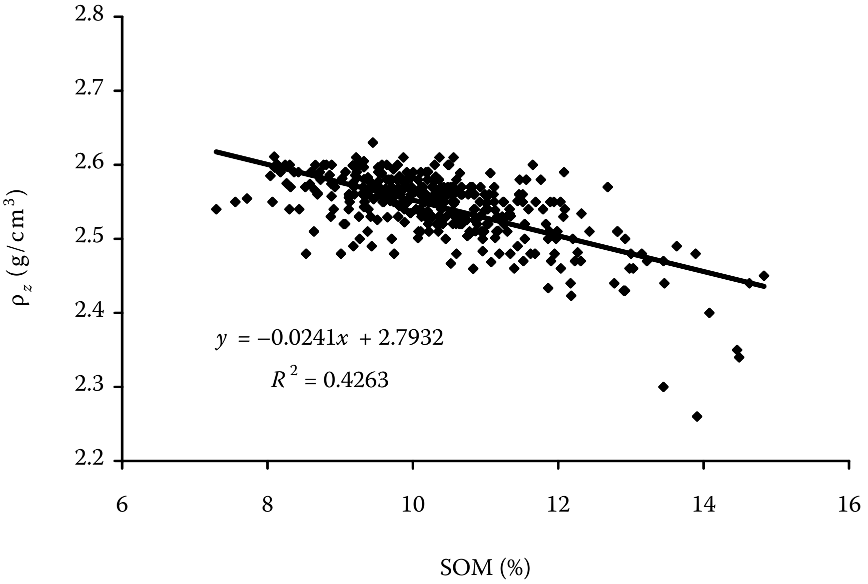

Figure 5. Correlation between particle density and content of soil organic matter (all sites), Velký Rybník, 1999–2003

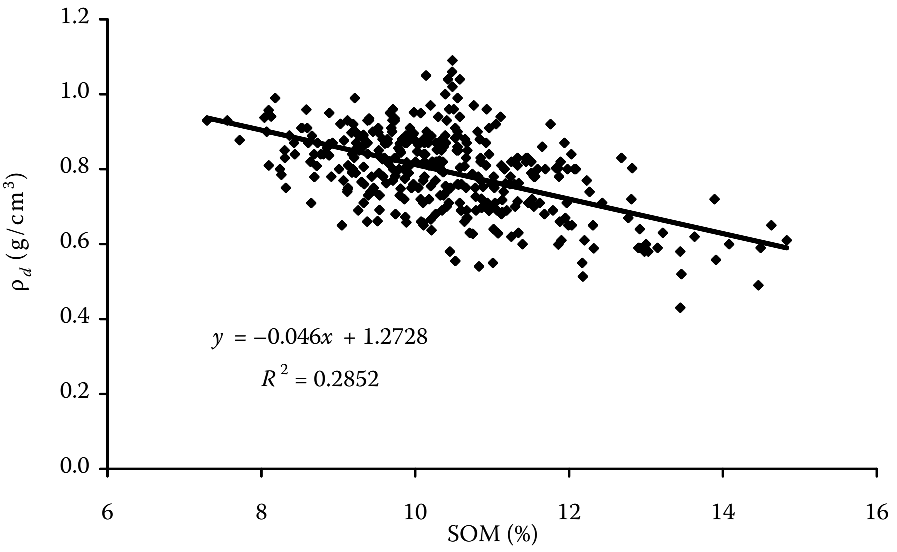

Figure 6. Correlation between bulk density and content of soil organic matter (all sites), Velký Rybník, 1999–2003

levels of ρ_d (Figure 3 and Table 3) were observed for C1 and UC.

The results arising from Table 2 showed that it is the site that had the greatest systematic effect on the majority of soil characteristics, followed by the cutting regime, and year (SOM, P_n). All the factors showed a significant effect ($\alpha < 10^{-4}$) on the division of values of all soil properties in 1999–2003.

Determined dependencies of soil physical properties

Table 4 shows the results of evaluation of correlation analysis or multiple linear regression within cutting regime. Moderate negative dependencies of ρ_z and ρ_d on SOM (correlation coefficients $r = -0.35$ to -0.68) were observed (similarly Evrendilek *et al.* 2004; Kaleem Abbasi *et al.* 2007), which are also shown in Figures 5 and 6. Similar results were obtained for dependence of ρ_d on P_n ($r = -0.38$ to -0.63, also Figure 7). Further, moderate positive dependence of P on SOM was observed in all cutting regimes (similarly Eynard *et al.* 2006) with correlation coefficients 0.34–0.60 (also Figure 8). Between θ_{CMC} and ρ_d or SOM none or very weak dependence was established (also McVay *et al.* 2006).

The greatest loosening of the top soil layer, expressed by a decrease in ρ_d, occurred with the introduction of non-cutting in direct relation to the increase of SOM and the volume of P_n. The

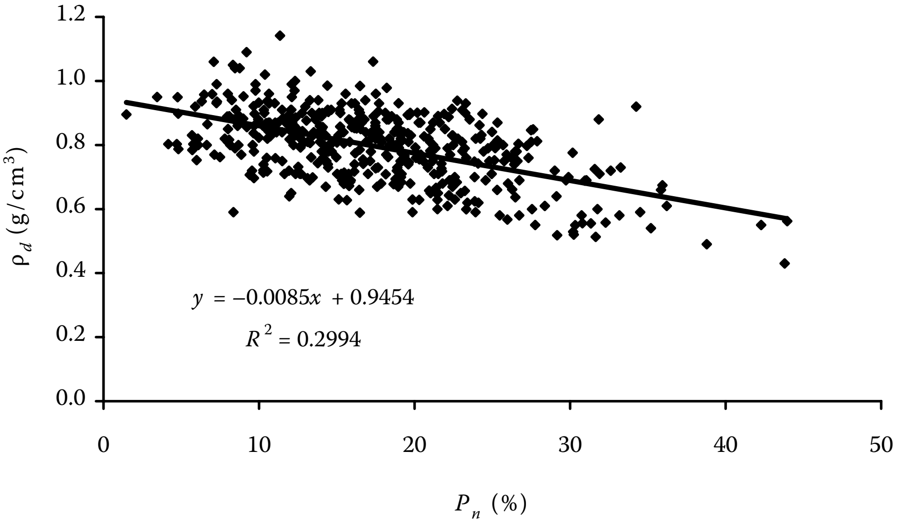

Figure 7. Correlation between bulk density and non-capillary porosity (all sites), Velký Rybník, 1999–2003

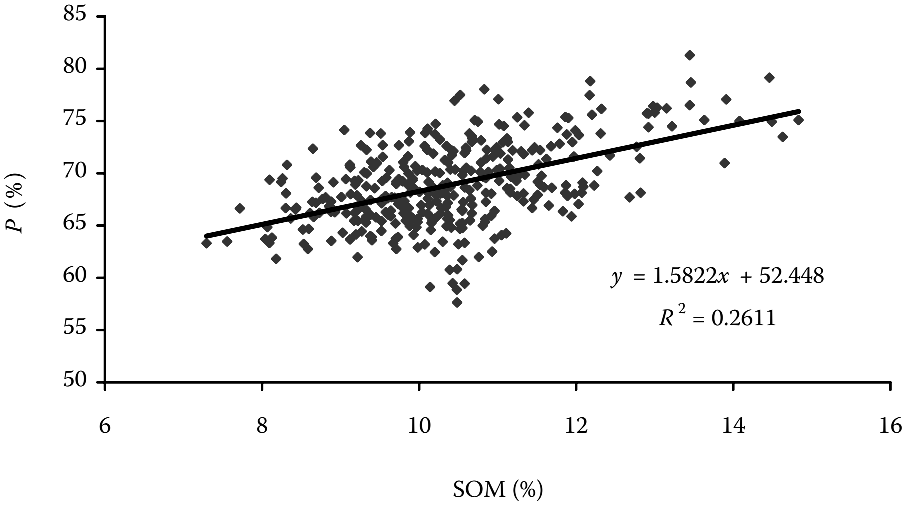

Figure 8. Correlation between porosity and the content of soil organic matter (all sites), Velký Rybník, 1999–2003

soil under UC plots showed the greatest heterogeneity of soil physical properties (see mean errors, Figures 2, 3). The lines expressing the correlation have the highest incline in case of UC plots and therefore the closeness of relation expressed by means of correlation coefficient is the highest here (Table 4).

CONCLUSION

Absorption of precipitation into grass cover soil may be supported by its non-utilisation or by minimising utilisation intensity. Related to C2, porosity of UC and C1 was increased by 4.5 and 3.0%, respectively, in relation to increasing SOM (by 7.0 and 6.6%, respectively), bringing about an increase of P_n of UC by 31.3% and a decline of ρ_d of UC and C1 by 9.5 and 6.0%, respectively. This process is particularly important and necessary in recharge areas of underground water resources, where there are usually soils with higher infiltration capacity, lighter with respect to granularity, a shallower soil profile, and lower production capacity (Doležal & Kvítek 2004). Relatively low growth of above ground phytomass may be expected and therefore a single annual cutting regime, combined with occasional non-cutting, is a suitable type of management without causing excessive risk of accumulation of standing dead material. However, permanent non-cutting of grass cover may not be appropriate for aesthetic reasons and for the reasons of flora composition (e.g. Grevilliot & Müller 2001; Pykala *et al.* 2005; Kahmen *et al.* 2002). Water retention in soil may be supported by cutting the grass cover, which is important in areas of accumulation of water (discharge zones), which are threatened by flooding and where it is necessary to remove a relatively large amount of above-ground phytomass (deep soil profile). However, cutting once a year brings about a risk of accumulation of standing dead material caused by late growing of grass cover and due to minimal withdrawal of nutrients the increased risk of washing out of nitrates from the soil. Therefore it may be more suitable to cut twice a year, even though it provides less support for ground water retention than cutting once a year.

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