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Spatial and seasonal variability of some soil characteristics of A horizon in Zhůří enclave

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Abstract

The analysis of the effect of grassland use on some soil characteristics is complicated, among others because of spatial and seasonal variability of the soil parameters. Tables 4 and 5 document the highest variability in the proportion of skeleton in the samples. The second highest variability was determined for organic matter content in soil samples where the coefficient of variation (CV) ranged from 8.96% to 19.43%. The coefficient of variation for bulk density was between 7.89% and 17.31%. Variability in the coefficient of variation for bulk density was high although remote values were discarded. Figs. 3 and 4 illustrate seasonal courses of average values of bulk density and total organic matter content in the soil at a depth of 0.03–0.10 m. The seasonal course of bulk density shows a decrease in the values until June, followed by an increase culminating in July and August, and a subsequent steep fall in the bulk density values. The seasonal course of average monthly values of total organic matter content in the soil has its maximum one month earlier in June and/or July, then the values moderately decrease. Taking into account a small number of years of observation (four) and high variability in the values, we cannot, for the time being, either confirm or refute the hypothesis about the effect of grassland use on physical parameters of soil. To answer any question involved in such a hypothesis, it is necessary to analyze changes in the trend of bulk density values. The variability of soil characteristics at this grassland site does not allows to use a different method.

Key words: grassland management (mulching, no cut, one cut), infiltration, method of Nestěrov, macropores

INTRODUCTION

Spatial variability of site soil characteristics has been a well-known phenomenon for a long time, but its study has only recently become one of the major lines of research in the field of soil physics (ORFÁNUS 2000). Variability of soil characteristics is a result of particular conditions of the natural environment at the locality concerned.

In order to answer any questions involved in the hypothesis concerning the potential effect of different use of grassland sites on physical characteristics of soil, it is necessary to study the spatial variability of soil characteristics at the given locality as well as the seasonal variations in some soil characteristics. It is very difficult to draw a line between the variability of soil characteristics on the site and the seasonal variations in soil characteristics. Such a research would require a large set of observations. Bulk density is one of the most important physical characteristics. It is the result of many soil processes, depending on the organic matter content in A horizon of the soil at grassland sites.

But the amount of root biomass is highly variable in permanent grassland. Good nutrition, intensive sunshine and cuts reduce the amount of roots. Decomposition of dead plant parts is prevented by water surplus or deficit, acid soil reaction and nutrient deficit, while the total amount of underground biomass increases (Fiala 1979). Tesařová (1999) reported on the influence of grassland management on the content, distribution and quality of organic matter in grassland. Andrzejewska (1991) considered variable amounts of precipitation during the year as the main reason for varying amounts of underground biomass. Fiala (1979) described the dynamics of changes in grassland underground biomass in a *Polygalo-Nardetum* stand in the course of one season.

The seasonal variation in physical parameters (except soil moisture) has not yet been fully described in the literature, besides some exceptions. The authors pay attention to spatial variation e.g., in soil moisture content (Šútor 1998), bulk density (Orfánus 2000) or macropore flow (Litschmann 2000) influencing the rate of filtration.

Material and Method

Our research was carried out on the experimental plots in the Zhůří enclave in the Bohemian Forest (see Mašková & al. 2001b), where the impact of different management on mountain meadows was tested. Soil cover on the locality is formed by Dystric Cambisol on paragneiss, sandy loam, slightly gravelly, medium deep with no clear-cut structure, middly moistured, with loose consistence, slight biological activity, deeply and densely rooted. For further detailed description of the enclave Zhůří – Huťská hora Mt. see Mašková & al. (2001a).

Three variants of extensive use were established at the locality concerned; the size of each plot managed in the same way was ca. 1 ha (one cut a year, no cut, and one cut a year with a mulching machine, when crushed biomass was left on the plot decompose). Samples were taken from each plot along the contour line on the slope of ca. 5–7° within a rectangular space of 20×30 m, in the middle of each 1-ha variant.

Kopecký's washing cylinders were used for sampling in the growing seasons of 1997–1999 according to the following schedule: a total of 10 samples were taken in the period from 11 May to 28 September at fortnightly intervals with five replicates (the first sample of 1997 with three replicates) from depths of 0.03–0.10 m and 0.10–0.16 m, in each of the three experimental treatments. In the growing seasons of 1999–2000 (another project), the sampling schedule was as follows: 4 sampling terms per season (9–11 May, 20–22 June, 18–20 July and 12–14 September) from depths of 0.03–0.10 m and 0.10–0.16 m, 15 cylinders from each depth. The cuts in the one-cut and mulching treatments were performed around 10 July of each year.

A total number of 888 cylinders were sampled within the project of the Ministry of Environment in 1997–1999, 720 cylinders were within the project of the Grant Agency of CR in 1999–2000; this means 1608 cylinders in total. Graphical representation of average values and

Table 1. – Numbers of samples taken during the years of observation.

Year	Number of sampling dates	Number of depths in A horizon	Number of treatments	Number of samples per treatment	Total number of samples per year
1997	10[1]	2	3	10	288
1998	10[1]	2	3	10	300
1999	10[1]	2	3	10	300
	4[2]	2	3	30	360
2000	4[2]	2	3	30	360

[1] Project of Ministry of Environment
[2] Project of Grant Agency of CR

trends was plotted on the basis of all 1608 data except for those that were discarded as remote values.

The following soil characteristics, determined in Kopecký's cylinders, were chosen for the analysis of their variability: specific weight, bulk density, total organic matter content, skeleton content (from 1308 values – the 1999 data were not included to provide data sets of approximately the same size in all years). Their determination is indicated below.

i) **Specific weight analysis – SW (g.cm^{-3})** – determined from the soil removed from Kopecký's cylinder (fine earth) after finishing the analyses of physical soil properties, and it was calculated as the ratio of the sample weight (20 g fine earth) to the sample volume determined in a pycnometer.

ii) **Bulk density analysis – BD (g.cm^{-3})** – the cylinder was oven dried at 105° C to constant weight; then it was weighed and this weight was divided by the cylinder volume (100 cm^3).

iii) **Analysis of total organic matter in soil – TOM (percent. dry weight)** – after the complex determination of physical properties of soil, the organic matter contained in the soil sample was burnt in a muffle oven at 550° C; organic matter content was determined from the difference in the sample weight before and after burning; this difference was divided by the original weight of the dried sample (20 g of fine earth taken for specific weight determination) and multiplied by 100.

iv) **Skeleton content analysis – SC (percent. dry weight)** – following the determination of organic matter content, the sample was divided into skeleton (> 2 mm) and fine earth on a 2 mm sieve. Skeleton was weighed and the percentage of skeleton was expressed as the ratio of skeleton weight to total original dry weight of the sample (20 g of fine earth) multiplied by 100. The original measured values were used to determine variability of the values.

After elimination of gross errors, Tukey's test was applied. Remote values were discarded by so called box and whisker plots, i.e. all values lying at a distance of more than a 1.5 times the interquartile range were evaluated as remote values and discarded from the set.

In the first stage of evaluation of variability in soil properties, the remote values for each year, variant and depth of sampling were discarded, and the following statistical characteristics were calculated (LEPŠ 1996): arithmetic mean, standard error and coefficient of variation. Systematic and methodological errors were neglected at this stage of evaluation.

In the second stage, the effect of skeleton content on the tested characteristics was suppressed in order to evaluate the seasonal variation in the soil bulk density and organic matter content. The values of bulk density and total organic matter content (without discarding the remote values) were converted to average percentage of skeleton content for each particular sampling depth. Subsequently, remote values were discarded for each sampling date treatment, and depth, and means were calculated from the remaining data. As the variability (CV) was still high after such adjustment, the means were also tested for remote values (for each depth separately).

RESULTS AND DISCUSSION

Table 2 shows the number of discarded, i.e. remote values of the samples. The highest number of discarded values was found for the skeleton content (64 samples), the balanced and lowest number were for organic matter content and bulk density, and 46 samples of specific weight were discarded. As different numbers of samples were taken throughout the years, Table 3 shows the percentage of discarded samples. The number of discarded values of the particular soil characteristics is fairly balanced over the years, the most balanced being the values for skeleton with a difference of 1.11%. The percentage difference between the years is highest for the specific weight: 5.58%.

Table 2. – Number of samples after discarding remote values for the years of observation, treatments and sampling depths.

Year	Treatment	Sampling depth in m	Soil characteristic	BD g.cm^{-3}	SW g.cm^{-3}	TOM weight %	SC weight %
			Number s of sample	Number of samples after discarding remote values by Tukey's test			
1997	One cut	0.03–0.10	48	47	48	46	43
		0.10–0.16	48	48	44	48	47
	No cut	0.03–0.10	48	48	45	46	47
		0.10–0.16	48	47	45	47	44
	Mulching	0.03–0.10	48	47	45	46	47
		0.10–0.16	48	48	46	48	48
	Total for 1997		288	282	270	281	276
1998	One cut	0.03–0.10	50	49	50	46	46
		0.10–0.16	50	49	49	50	48
	No cut	0.03–0.10	50	50	50	50	48
		0.10–0.16	50	47	50	49	49
	Mulching	0.03–0.10	50	50	50	50	48
		0.10–0.16	50	50	49	49	47
	Total for 1998		300	295	298	294	286
1999	One cut	0.03–0.10	60	59	59	56	57
		0.10–0.16	60	60	58	60	59
	No cut	0.03–0.10	60	60	57	58	55
		0.10–0.16	60	58	58	59	56
	Mulching	0.03–0.10	60	53	58	60	58
		0.10–0.16	60	59	57	58	56
	Total for 1999		360	349	347	351	341
2000	One cut	0.03–0.10	60	60	59	59	56
		0.10–0.16	60	58	54	60	58
	No cut	0.03–0.10	60	59	56	59	58
		0.10–0.16	60	59	58	60	56
	Mulching	0.03–0.10	60	59	59	56	55
		0.10–0.16	60	58	58	60	58
	Total for 2000		360	353	344	354	341
Total number of samples			1308	1282	1262	1280	1244
Total number of discarded remote values				26	46	28	64

The sampling in the years of observation did not produce any large errors. The number of discarded values decreases throughout the years, except for the skeleton. The proportion of skeleton in samples cannot be influenced anyhow as, it results from spatial variability of the soil.

Tables 4 and 5 document that the highest variability was determined for skeleton content in the samples. The coefficient of variation ranged from 29.41–79.68%. The range of the average values was from 7.95% to 13.00 weight %. Standard error varied between 0.377 and 1.27. Variability was lowest in specific weight; CV ranged from 0.96 to 1.68%. mean values were 2.41–2.5 g.cm^{-3}. The time course of these two soil characteristics is not analysed below.

Table 3. – Number of samples used for spatial variability description (%).

Year	Soil characteristic			
	BD	SW	TOM	SC
1997	97.91	93.75	97.56	95.83
1998	98.33	99.33	98.00	95.33
1999	96.94	96.38	97.50	94.72
2000	98.05	98.05	98.33	94.72

The second highest variability was calculated for the proportion of organic matter in the samples: coefficient of variation was 8.96–9.43%. The mean organic matter content ranged from 9.33% to 13.52 %. The range of standard error was 0.133–0.294. The resultant bulk density was, on average, from 0.71 to 0.92 g.cm^{-3}, with standard error content of 0.0092–0.0189 and CV from 7.89% to 17.31%. Coefficients of variation in organic matter and bulk density were very similar.

Orfánus (2000) reported the coefficient of variation between 3% and 8 % for bulk density in the eastern part of the lowland island of Žitný ostrov while the variability in the Zhůří enclave was more than twice as high. The differences can result from the fact that Zhůří enclave is a grassland locality, a mountain site, and from one of the principles of scaling theory (Bloesch 199). This theory postulates that the variability of a studied environmental trait increases with the density of measurements in space and in time.

The results of our analyses confirmed the conclusions drawn by Fiala (1985) on the distribution of underground biomass (total organic matter of soil in our case): it decreases at greater depths of soil profile. Bulk density, which is directly influenced by the content of mineral fraction in the sample, increases with sampling depth.

Even though remote values were discarded, the coefficient of variation of bulk density is high. Therefore, the second analysis that of average remote values, of average remote values, was made to evaluate the seasonal variation in bulk density and organic matter content. Aver-

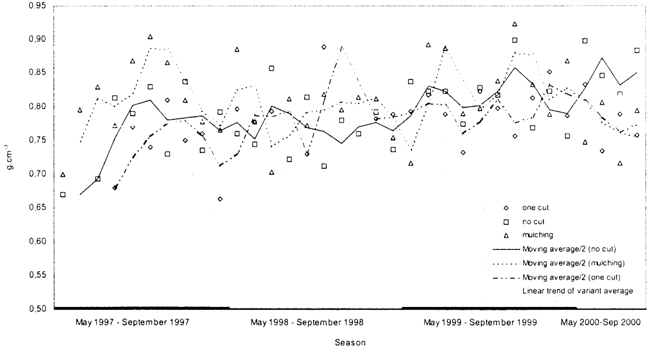

Fig. 1. – Average values and trend of bulk density in A horizon in the three meadow management tratments from May to September in 1997–2000 at the depth of 0.03–0.10 m.

Table 4. – Basic statistical characteristics of recorded data sets by the years, depths and meadows management tratments.

Year	Treatment	Depth m	Soil characteristic							
			BD (g.cm^{-3})		**SW (g.cm^{-3})**		**TOM (weight %)**		**SC (weight %)**	
			$x \pm s_x$	CV %	$x \pm s_x$	CV %	$x \pm s_x$	CV %	$x \pm s_x$	CV %
1997	One cut	0.03–0.10	0.71 ± 0.018	17.31	2.42 ± 0.006	1.68	13.52 ± 0.223	11.18	10.32 ± 0.878	55.80
		0.10–0.16	0.88 ± 0.015	11.67	2.46 ± 0.004	1.18	11.1 ± 0.266	16.77	11.27 ± 1.270	77.25
	No cut	0.03–0.10	0.75 ± 0.016	14.84	2.44 ± 0.005	1.46	13.18 ± 0.294	15.15	7.95 ± 0.924	79.68
		0.10–0.16	0.85 ± 0.012	9.81	2.47 ± 0.006	1.68	11.36 ± 0.221	13.36	8.6 ± 0.810	66.65
	Mulching	0.03–0.10	0.82 ± 0.015	13.4	2.47 ± 0.005	1.34	11.11 ± 0.177	10.80	10.54 ± 0.914	59.44
		0.10–0.16	0.92 ± 0.015	11.27	2.50 ± 0.005	1.26	9.64 ± 0.189	13.55	12.54 ± 0.829	45.79
1998	One cut	0.03–0.10	0.81 ± 0.019	16.35	2.43 ± 0.005	1.42	11.67 ± 0.273	15.86	8.97 ± 0.680	51.41
		0.10–0.16	0.90 ± 0.014	10.84	2.46 ± 0.005	1.41	9.78 ± 0.269	19.43	11.83 ± 0.777	45.50
	No cut	0.03–0.10	0.77 ± 0.014	13.9	2.44 ± 0.005	1.32	11.99 ± 0.268	15.79	8.75 ± 0.624	49.40
		0.10–0.16	0.86 ± 0.010	8.24	2.48 ± 0.004	1.23	10.58 ± 0.180	11.91	8.82 ± 0.665	52.76
	Mulching	0.03–0.10	0.79 ± 0.016	13.89	2.44 ± 0.005	1.47	11.52 ± 0.246	15.7	9.50 ± 0.764	55.73
		0.10–0.16	0.90 ± 0.011	8.98	2.47 ± 0.004	1.15	10.35 ± 0.201	13.61	10.8 ± 0.638	43.38
1999	One cut	0.03–0.10	0.77 ± 0.012	12.22	2.41 ± 0.004	1.29	11.65 ± 0.182	11.67	8.86 ± 0.562	47.87
		0.10–0.16	0.88 ± 0.013	11.25	2.45 ± 0.004	1.21	10.5 ± 0.238	18.31	10.67 ± 0.732	52.70
	No cut	0.03–0.10	0.79 ± 0.016	15.56	2.42 ± 0.004	1.19	11.45 ± 0.236	15.71	9.29 ± 0.681	54.33
		0.10–0.16	0.86 ± 0.012	10.77	2.45 ± 0.003	0.98	9.93 ± 0.236	18.23	10.75 ± 0.569	39.63
	Mulching	0.03–0.10	0.90 ± 0.011	9.14	2.45 ± 0.003	1.1	10.75 ± 0.232	16.72	9.59 ± 0.669	53.12
		0.10–0.16	0.90 ± 0.010	8.31	2.47 ± 0.003	1.5	9.92 ± 0.133	10.21	9.2 ± 0.377	31.29
2000	One cut	0.03–0.10	0.79 ± 0.012	12.51	2.44 ± 0.003	1.7	11.41 ± 0.181	12.18	10.70 ± 0.585	40.91
		0.10–0.16	0.89 ± 0.009	7.89	2.46 ± 0.003	1.1	9.59 ± 0.200	16.16	13.00 ± 0.786	46.07
	No cut	0.03–0.10	0.79 ± 0.013	12.96	2.43 ± 0.005	1.49	11.35 ± 0.242	16.40	9.58 ± 0.646	51.32
		0.10–0.16	0.82 ± 0.011	10.62	2.43 ± 0.004	1.15	10.40 ± 0.236	17.57	9.53 ± 0.506	39.71
	Mulching	0.03–0.10	0.86 ± 0.011	9.57	2.48 ± 0.004	1.10	10.30 ± 0.123	8.96	11.7 ± 0.439	29.41
		0.10–0.16	0.91 ± 0.012	10.33	2.48 ± 0.003	0.96	9.33 ± 0.180	14.93	11.51 ± 0.456	30.19

Table 5. – Mean, standard error and coefficient of variation in some soil characteristics by the depth and years.

Depth (m)	Year	BD (g.cm^{-3})		SW (g.cm^{-3})		TOM (weight %)		SC (weight %)	
		$x \pm s_x$	CV (%)	$x \pm s_x$	CV (%)	$x \pm s_x$	CV (%)	$x \pm s_x$	CV (%)
0.03–0.10	**1997**	0.76 ± 0.010	16.8	2.44 ± 0.004	1.72	12.60 ± 0.163	15.22	9.58 ± 0.530	64.75
	1998	0.79 ± 0.010	14.61	2.44 ± 0.003	1.41	11.73 ± 0.151	15.57	9.7 ± 0.398	52.22
	1999	0.82 ± 0.009	14.7	2.43 ± 0.002	1.31	11.27 ± 0.129	15.13	9.25 ± 0.367	51.78
	2000	0.81 ± 0.007	12.13	2.45 ± 0.003	1.55	11.3 ± 0.116	13.86	10.44 ± 0.329	40.98
	Average	0.80 ± 0.009	14.22	2.44 ± 0.003	1.50	11.66 ± 0.140	14.95	9.59 ± 0.406	52.43
0.10–0.16	**1997**	0.88 ± 0.008	11.29	2.48 ± 0.003	1.55	10.66 ± 0.145	16.22	10.69 ± 0.594	65.47
	1998	0.89 ± 0.007	9.70	2.47 ± 0.003	1.33	10.23 ± 0.130	15.41	10.23 ± 0.412	48.36
	1999	0.88 ± 0.007	10.22	2.46 ± 0.002	1.12	9.97 ± 0.120	16.3	10.15 ± 0.341	43.91
	2000	0.87 ± 0.007	10.65	2.46 ± 0.003	1.31	9.77 ± 0.123	16.93	11.37 ± 0.363	41.83
	Average	0.88 ± 0.007	10.47	2.47 ± 0.003	1.33	10.16 ± 0.129	16.15	10.61 ± 0.437	49.89

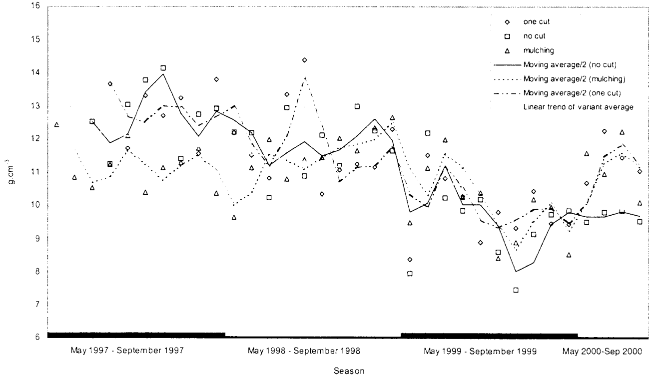

Fig. 2. – Average values and trend of total organic matter content in A horizon in the meadow management treatments from May to September in 1997–2000 at the depth of 0.03–0.10 m.

age monthly values (May-September) were calculated for the years of observation of the soil characteristics as illustrated in Figs. 1–4. The variation in most values of bulk density at a depth 0.03–0.1 ranges from 0.65 to 0.9 g.cm^{-3}. The linear trend slightly increases after the remote average values (of the samplings) have been discarded (Fig. 1). The sampling depth of 0.1–0.16 m shows a high stability of the trend, with the range of average values being 0.75–1.03 g.cm^{-3}. Total organic matter content decreases at the first sampling depth in relation to an increase in bulk density (Fig. 2). On the contrary, at the second sampling depth bulk density slightly decreases along with a decrease in organic matter content.

The trends of bulk density and total organic matter at the first depth are consistent with the general theory of the increase in organic matter content after a different crop was cultivated (arable crop × grassland), see e.g. DROOGERS 1997. But the second sampling depth coincides with the finding of VELICH & al. (1984) that an extremely dense system of fine adventitious rootlets penetrates every clod of topsoil where 80–95% of all rootlets are located. It would imply the consolidation and compaction of A horizon, and an increase in soil resistance. This assumption has been confirmed by ŠANTRŮČEK (1993). Partial conclusions presented here are influenced by the variability of the site conditions and length of observation.

Figs. 3–4 show the seasonal course of bulk density and total organic matter content. This variation could not have been plotted without statistical analysis of the seasonal course, mainly because of high variability and fluctuations of the measured and average values.

The seasonal course of bulk density at both depths shows a decrease until June, followed by an increase in the values culminating in July or August; then a steep fall in bulk density folows. This course is in close relation to a similar seasonal course of total organic matter content in soil at the second sampling depth. With increasing content of total organic matter, bulk density increases, with an evident decrease in both characteristics in June. No similar relation was determined for the first sampling depth.

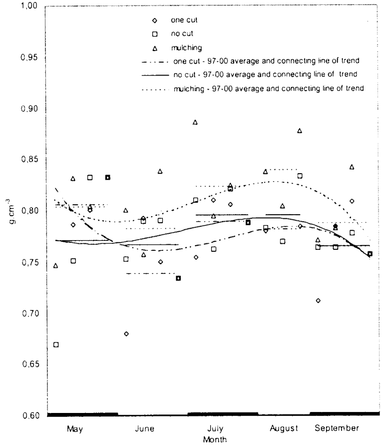

Fig. 3. – Seasonal course of bulk density in A horizon in the meadow management treatments from May to September in 1997–2000 at the depth of 0.03–0.10 m.

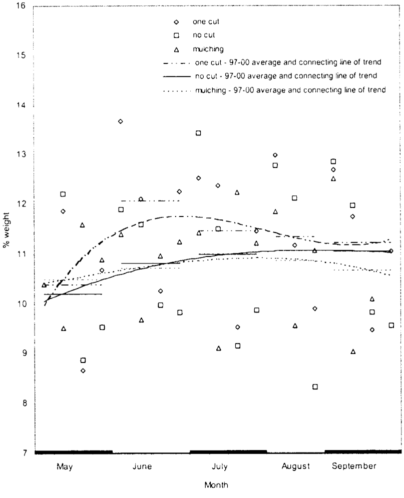

Fig. 4. – Seasonal course of total organic matter content in A horizon in the meadow management treatments from May to September in 1997–2000 at the depth of 0.03–0.10 m.

The results of total organic matter content at the first sampling depth are consistent with conclusions drawn by Klapp (1971), who reported that the seasonal variation in root biomass in unfertilized grassland documented its maximum production in the period from the beginning of spring regrowth to mid-July, in dependence on site conditions. Then root biomass decreases, apparently as a result of the dieback of roots on mown generative shoots of grasses and their increased destruction. A June decrease in the content of total organic matter in soil at the second sampling depth is in accordance with the results of Fiala (1979), who described the dynamics of grassland underground biomass in the course of one season (*Polygalo-Nardetum*). Underground biomass decreased from late April to late July (from about 3.44 to 1.72 kg.m^{-2}), then total underground biomass was increasing during August until the second half of September (to 2.3 kg.m^{-2}), and finally the amount of underground biomass dropped to 1.87 kg.m^{-2} until November.

The evaluation of spatial and time variability in some soil properties in Zhůří enclave provides background data for a subsequent detailed analysis aimed at answer questions posed by the hypothesis whether or not the physical characteristics of soil were influenced by different ways of grassland use in the course of four-year observations. Bulk density and specific weight have a direct effect on the physical characteristics determined in Kopecký's cylinders. As the number of the years of observation was low (four) and variability of the values high, we cannot either confirm or refute this hypothesis for the time being. This hypothesis can be proved only by an analysis of the bulk density trend. The proved variability in soil characteristics at this grassland site does not allow to use a different method.

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