CONDITION AND QUALITY OF SOILS IN THE PROTECTED AREA

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Abstract

In 2012, grazing was restored in the Hruby Jesenik Mts. (the Praded National Natural Reserve) in the Praded mountain surroundings. The main aim of the cattle grazing reintroduction was the reinforcement of non-production functions of alpine grasslands with special focus on soil conditions. The climatic characteristic of this locality is 0.9 °C (average annual temperature) and 1 231 mm (average annual precipitation). The experimental area is categorized as an open country according to the present Forest Management Plan. For grassland grazing the suckler cows (the Highland breed), the sheep (the Wallachian breed) and the horses (the Shetland pony breed and the Hucul breed) were used. Soil samples were taken twice a year (summer and autumn) from grazed plots and from control (without grazing) plots too. Labile forms and total contents of selected trace elements (Pb, Zn, Cd) and macroelements (Ca, Mg, K, P, and N) were measured. Soil organic matter parameters such as total organic carbon and humic substances were determined. From the soil point of view, the grassland management with proper grazing should be beneficial and do not pose any environmental risk.

Keywords: *grazing, protected area, grassland, trace elements, soil organic matter*

1. INTRODUCTION

In the Czech Republic, the proportion of the protected areas is 21% of the total national territory and a share of 19% of all grasslands in the Czech Republic is in National Parks and Protected Landscape Areas (Prazan & Theesfeld 2014). It is widely known that grasslands play a key role in livestock fodder production and provide valuable ecosystem services that support broader landscape function. Semi-natural grasslands are often hot spots of biodiversity and are threatened both by intensive farming and by the abandonment of farmland in marginal areas. The aim for farmers should be environmentally-friendly farming practices. Soussana & Duru (2007) in their review showed that biodiversity, climate change, C sequestration and farming systems issues are highly interconnected in grassland ecosystems.

Biodiversity of Central European semi-natural upland grasslands is steadily declining, due to either abandonment or management intensification (Merunková & Chytrý 2012). Especially, the biodiversity of species-rich semi-natural meadows is declining across Europe due to ceased management (Hellström et al. 2003). The continuation of traditional ways of grassland management that would best preserve biodiversity is often not compatible with the requirements of an intensive livestock production. Therefore, grassland is at risk of being abandoned from an agricultural use (Isselstein, Jeangros & Pavlů 2005).

Grazing is considered as a suitable tool to maintain grasslands in protected areas (Pavlů et al. 2007). Due to the above-mentioned facts, grazing is renewed in the Czech Republic in the protected areas where it was probably pursued in the past (e.g. the White Carpathians Mountains (Mts.)., the Giant Mts., the Beskydy Mts.). On the other hand Panayiotou, Dimou & Monokrousos (2017) claimed that the intensity of grazing affected mostly the chemical properties of soil. Furtheremore, greater intensity of grazing would result in higher degradation of the soil system.

Large herbivores act as a major driver of plant litter decomposition in grasslands. As Seagle & McNaughton (1992) referred, herbivores can also directly influence soil carbon and mineral nutrients by dung and urine deposition. Although these grazing-induced processes collectively appear to accelerate rates of carbon and mineral cycling processes in grazed ecosystems (Bardgett, Wardle &

Yeates 1998). Animals kept even in low density affect the swards by selective grazing, trampling and leaving dung (Chodkiewicz 2020).

Wang et al. (2018) examined how livestock (cattle and sheep) grazing affects standing litter decomposition of a dominant grass, *Leymus chinensis* in grasslands in northeast China. Their study provides evidence that herbivore grazing can influence litter decomposition by modifying soil conditions and litter quality independently. Therefore, choosing the proper large herbivore(s) in grazing regimes may be important in maintaining nutrient cycling in grassland ecosystems.

The potential of grasslands as a sink for carbon in Europe is enormous. Despite this significance, our understanding of land use effects on the storage of carbon in rangelands remains limited. Qing et al. (2018) examined effects of moderate grazing by different herbivore assemblages (no grazing; sheep grazing; cattle grazing; mixed grazing by sheep and cattle) on soil organic carbon storage in two types of grassland communities (high forbs/high diversity and low forbs/low diversity). They found that herbivore assemblage generated varying effects on soil carbon storage and the effects were subject to grassland community types. Overall, soil carbon storage was highest in mixed-grazed grassland sites with high diversity. Their study suggests that explicitly incorporating grazer species and the combination of grazing livestock into grassland grazing management may help mitigate greenhouse gas emissions. Moreover, mixed grazing, including multiple herbivore species, may contribute to a reduction in foraging selectivity for a plant community by means of complementary foraging. It could therefore be considered as an optimal grazing management strategy to maintain and improve soil carbon storage.

Soil organic carbon is one of the most important soil components due to its ability to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization (Edwards et al. 1992). Stability or lability of any organic carbon fraction could be due to either chemical composition or protection within the soil aggregates. Stable organic carbon forms are characterized by redox properties and can act as electron acceptors or donors in natural environment. They can influence the oxidation state of metal ions and thus their speciation and mobility (Aeschbacher, Sander & Schwarzenbach 2010). Chemical forms, metal ion complexation by humic substances and their influence onto content of mobile and potential mobile heavy metals in soil was also studied by Dercová et al. (2007) and Gondar et al. (2006). Metals of anthropogenic origin were considered as more available in soils than those from parent rock. Most of metals in plants originate in uptake by roots from soils. Some of heavy metals were accumulated in roots, leafs, stems, and fruits, while others were well mobile in plants. Karabcová at al. (2015) studied phytoavailability of macro-, micro- and trace elements on permanent grassland soils. Hejcman et al. (2010) described relationship between soil and biomass chemical properties, amount of elements applied, and their uptake on grassland. They claimed that there is no simple positive relationship between the applied elements and their concentrations in the plant biomass on grassland.

The group of risk elements (heavy metals) consists of elements having significant toxicological properties. Most of them are at risk of increased exposure to the environment in connection with human activity. For example, this group includes Cd, Zn, Pb. In the conditions of the Czech Republic, risk elements do not represent the main stressor (Uhlířová & Hejdová 1999). Nevertheless, their influence can be very significant, which is related to the general phenomenon of easy influence of systems close to the limit of instability (Rotter et al. 2013).

In 2012, grazing was restored in the Praded National Natural Reserve (the Hruby Jesenik Mts.). The main aim of the cattle grazing reintroduction was the reinforcement of non-production functions of alpine grasslands. This article is focused on the influence of grazing on chosen soil parameters and evaluation of grassland agroecosystem under renewed grazing situated in the protected landscape.

2. MATERIALS AND METHODS

2.1. Study sites

In the Praded locality cattle grazing was introduced after a long-term management cessation in 2012. Our research is conducted in the mountain area situated in the Hruby Jesenik Mts. (the Praded National Natural Reserve; 1 304 m a.s. l.). The climatic characteristic of this locality is 0.9 °C (average annual temperature) and 1 231 mm (average annual precipitation). The agricultural use of the suckler cows (the Highland breed), the sheep (the Wallachian breed) and the horses (the Shetland pony breed and the Hucul breed) for grazing was established in 2012. The main soil type on the experimetal sites was Podzol.

Fig. 1. Position of experimental sites (Praded National Natural Reserve) in the Czech Republic

2.2. Plots design

The rotational grazing system was conducted on two experimental sites in the Praded mountain surroundings.

Experimental site “Praded” - the whole plot area: 6 ha, the stocking rate was up to 1 livestock unit per ha and year, the rotational grazing system (3 grazing cycles per year) – Highland breed and Hucul breed, grazing period from the end of June till the beginning of September, the site was divided into two sub-localities G (grazing plots) and C (control without grazing).

Experimental site “Ovcarna” - the whole plot area: 0,9 ha, the stocking rate was up to 1 livestock unit per ha and year, the rotational grazing system (2 grazing cycles per year) – Wallachian breed and Shetland pony, grazing period from the end of June till the beginning of September, the site was divided into three sub-localities G (grazing sites G1 and G2) and C (control without grazing)

2.3. Evaluated parameters

Soil samples were taken twice a year (summer and autumn) from grazed plots and from control (without grazing) plots, too. Sampling was done from a depth 0.05–0.15 m during 2013 and 2020. Evaluated parameters: soil organic carbon (C_{org} organic carbon, HA humic acids, FA fulvic acids); content of nitrogen (N_{tot}); Mehlich III extract (Mg, Ca, P, K); C/N ratio; pH (pH/$CaCl_2$); plant available and total trace elements (Zn, Pb, Cd). Total organic carbon (C_{org}) was determined by elemental analyzer (Primacs100, Skalar). Fractional composition of humic substances (HA and FA) was determined by short fractionation method. Total contents of trace elements (Zn, Pb, Cd) were determined after microwave extraction in aqua regia. Plant available element contents were determined in 0.01 M $CaCl_2$ solution using AAS spectrometer. Macroelements (Ca, Mg, K, P) were detected by Mehlich III method. Total nitrogen was determined according to Kjeldahl method. The soil reaction pH was determined in solution $CaCl_2$. All methods are described in Zbíral et al. (2016).

2.4. Statistical analyses

Statistical data analysis was undertaken using the statistical program SPSS 13.0 for Windows. Analysis of variance (ANOVA) was performed by statistical program. Mean statistical differences

(95% significance level) were calculated by Tukey's HSD test ($P < 0.05$). We tested homogeneity of variances by Cochran–C's test.

3. RESULTS

The mean concentrations of chosen soil parameters from Ovcarna experimental site are given in Table 1. Statisticaly significant difference between grazing plot and control was found. In both case of grazing plots pH value increased and was higher than control pH value. As it is evident macronutrient contents were not directly influenced by grazing. On the other hand there is the highest average contents of Mg, P, Ca, and K detected on grazing plots in comparison to control.

Organic carbon (C_{org}) was at its maximum on grazing plot G1. Grazing plot G2 and control plot have the same amount of C_{org}. The qualitative parameters of organic carbon are C/N and HA/FA. Ration C/N was higher than 10 on all plots and the ration HA/FA was under 1 on all plots.

The mean concentrations of trace elements weren´t influenced by grazing and diffreneces between particular treatments were similar. Although, the maximum of Zn total content was found on grazing plot (G2), maximum Pb total content on control plot (C) and the maximum of Cd total content on grazing plot (G2).

Treatment	**pH**	**Mg**	**Ca**	**K**	**P**	**C_{org}**	**N_{tot}**	**C/N**	**HA/FA**	**Zn**	**Pb**	**Cd**
		mg/kg	**mg/kg**	**mg/kg**	**mg/kg**	**%**	**%**			**mg/kg**	**mg/kg**	**mg/kg**
G1 (grazing)	3.68^{ab}	90	341	71	16	6.7	0.451	14	0.17	44	51	0.16
G2 (grazing)	3.92^{b}	71	323	90	12	5.4	0.685	11	0.41	65	48	0.20
C (control)	3.52^{a}	87	222	77	10	5.4	0.526	11	0.30	59	58	0.16
P	0.001	0.61	0.44	0.56	0.26	0.54	0.13	0.36	0.62	0.83	0.53	0.96

Table 1. Average values of selected soil parameters on Ovcarna experimental locality

($^{a, b}$ - values with the same letter are not statistically different within the column $P < 0.05$)

The second locality (Praded) showed similar results as above mentioned locality (Ovcarna). There was only one grazing plot on this locality (table 2). The mean pH values were similar on both plots and were close to minimum 3.5. The same trend was found for grazing and control plots where concentration of Ca, Mg, K didn´t differ. The concentration of P was higher in comparison with locality Ovcarna and the mean value was close to 20 mg/kg.

Treatment	**pH**	**Mg**	**Ca**	**K**	**P**	**C_{org}**	**N_{tot}**	**C/N**	**HA/FA**	**Zn**	**Pb**	**Cd**
		mg/kg	**mg/kg**	**mg/kg**	**mg/kg**	**%**	**%**			**mg/kg**	**mg/kg**	**mg/kg**
G (grazing)	3.49	113	555	104	21	6.8	0.731	13	0.25	33^{a}	64	0.49
C (control)	3.54	111	521	94	17	5.9	0.686	12	0.26	22^{b}	64	0.55
P	0.57	0.89	0.80	0.49	0.29	0.25	0.52	0.38	0.75	0.026	085	0.51

Table 2. Average values of selected soil parameters on Praded experimental locality

($^{a, b}$ – values with the same letter are not statistically different within the column $P < 0.05$)

The mean content of organic carbon (C_{org}) was higher on the grazing plot but this trend was not statistically significant. Total N content was on high level too and the highest concentration was found on grazing locality, as well. There was not found statistically significant increase on this plot.

The quality of soil organic carbon is represented by C/N ration a HA/FA ration. C/N ratio was under value 10 and HA/FA ration was under value 1. Again, there was no statistically significant differences between both plots.

Total contents of risk elements are presented in table 2. It was very interesting the findings about total content of Zn which shows differences between both plots. Statistically significant higher concentration was found on plot with grazing management. The concentration of total Pb was equal on both plots and the opposite effect was found in concentration of Cd. Higher concentration was found on control plot but this was not significant.

Concentrations of plant available Pb are shown in figure 2. It is clearly shown that there was no significant difference between plots ($P > 0.05$). The highest average concentration of plant available Pb was measured on control plot of Ovcarna locality (OvC) and the average minimum on control plot of Praded locality (PrC).

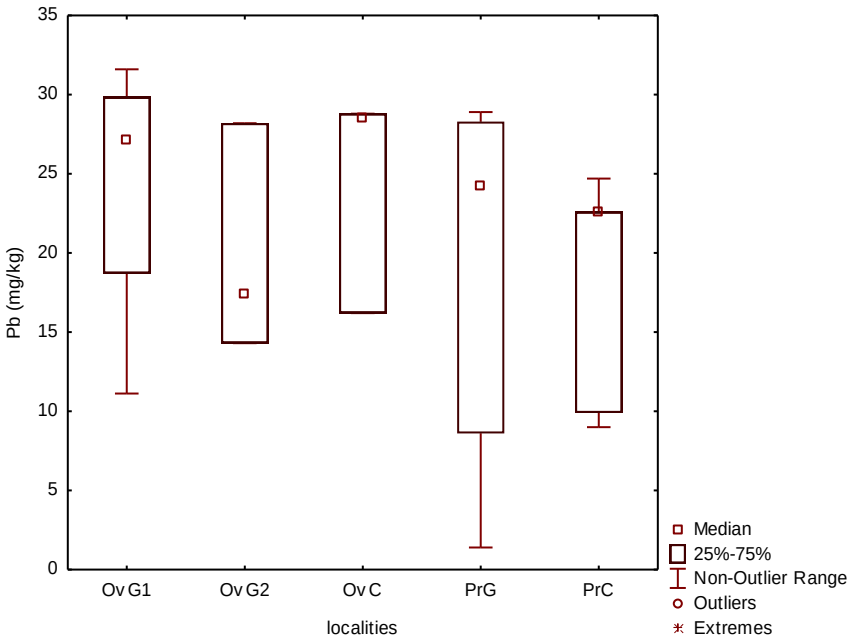

Fig. 2. Concentration of plant available Pb on both experimental sites (Ov – locality Ovcarna; Pr – locality Praded; G1,G2,G – grazing plots; C – control)

The values of plant available Zn (figure 3) differed more in comparison with Pb element but still these differences were not statistically significant ($P > 0.05$). The average meximum was found on grazing plots at locality Praded and Ovcarna, too. The avarege minimum was found on both control plots. The same trend was found for plant available Cd concentration (figure 4). The average minimum was found on control plots and the average maximum on grazing plots. This was evident for both localities but still without statistical significance ($P > 0.05$).

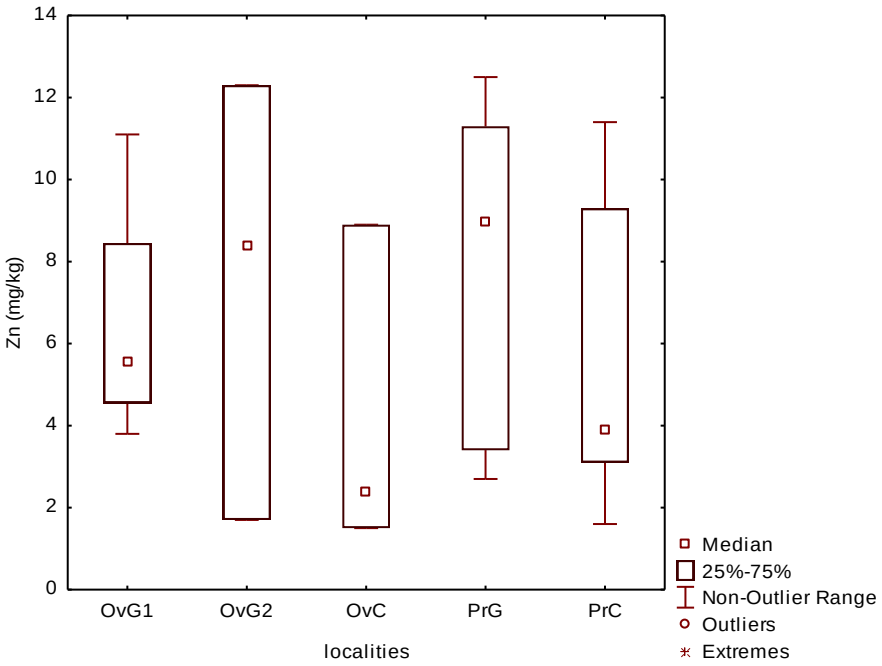

Fig. 3. Concentration of plant available Zn on both experimental sites (Ov – locality Ovcarna; Pr – locality Praded; G1,G2,G – grazing plots; C – control)

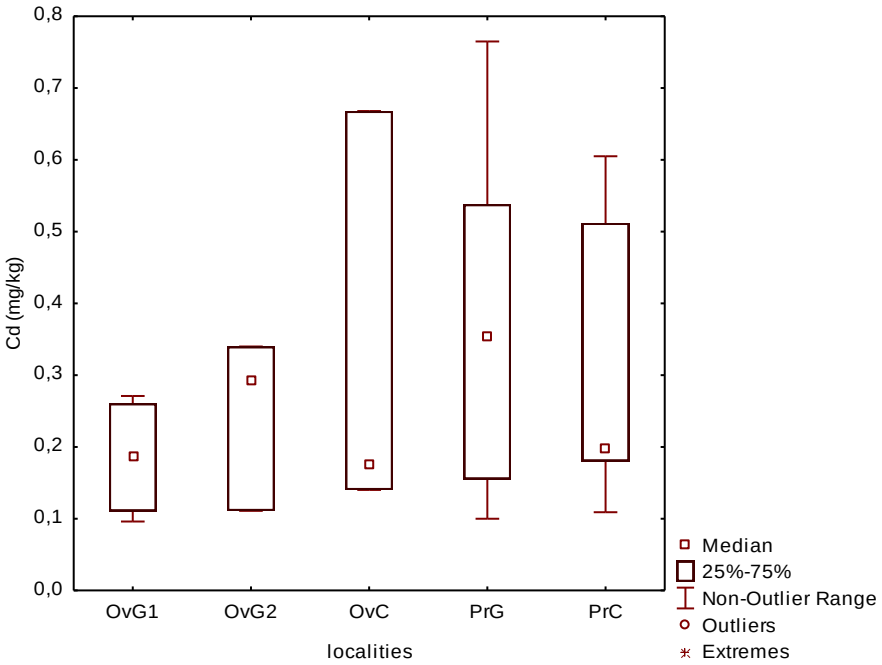

Fig. 4. Concentration of plant available Cd on both experimental sites (Ov – locality Ovcarna; Pr – locality Praded; G1,G2,G – grazing plots; C – control)

4. DISCUSSION

Evaluation soil of both experimental sites from the pH point of view was extremely acid (Sáňka & Materna 2004). This is consistent with overall soil characteristic of the area. Grazing did not affect directly pH values of soil.

Measured concentrations of macronutrients were evaluated as good, except high concentration of magnesium, as reported for permanent grassland (Fiala & Krhovjáková 2009). Very optimistic is fact that grazing did not cause decrease the amount of nutrients in the soils. Especially the concentration of P was higher on grazing plots. Parvage et al. (2011) described that horse grazing at high stocking rates may pose a risk of high P losses to nearby water bodies. In our studies we recorded an increase from the limit 10 mg P/ kg up to a maximum 20 mg P / kg, which still corresponds to a low P concentration. Even though it is an extensive management, this type of grazing is an optimal function which improves mineral availability and increases nutrient amount by supply of urine and excrement into soil.

Amount of soil organic carbon and total nitrogen was on high level for both localities. On the other hand, the quality of soil organic carbon was very low. Grassland soils located in the mountains are represented with huge amount of soil organic matter but with predominance of fulvic acid. This is consistent with low pH and low nutrient availability. We found trend which showed that grazing plots reported higher amount of soil organic carbon. Liáng et al. (2020) said that the length of the fallow period, renewal timing, and associated environmental conditions are important factors that can affect SOC temporally. This supports our results with soil organic carbon stock. Schipper & Sparling (2011) pointed out, that changes in soil C and N in the shallow upper soil layers are easily masked by the relatively small changes in C and N contents and much greater masses of soil at lower depths.

Concentrations of all analyzed risk elements in soil did not exceed the limits permitted by the Czech national legislation (Sáňka & Materna 2004). On the other hand, we realized that control plots shown higher total concentration of the risk elements in comparison to grazed plots. This trend indicates that grazing was not the main source of risk elements in the experimental area.

In most of the world's soils, the total content of selected risk elements follows the descending series: Zn, Pb, Cd (Kabata-Pendias 2004). If we find land in which this order is significantly shifted in favor of one element, there is the possibility of anthropogenic inputs. Anthropogenic entry into agricultural soils is mainly from air pollution fallout, e.g. Cd or Pb. This could be the explanation for higher total concentration of Pb at both localities. Another reason, for total Pb concentration could be tourism, especially winter tourism associated with the maintenance of tracks by heavy mechanization. The number of visitors and motor vehicles represents a greater burden on the environment than the extensive grazing.

Plant-availability of Cd and Zn increases with a decrease in soil pH and cannot be related to the total concentrations of elements (Uprety et al. 2009).

5. CONCLUSIONS

Nowadays, pasture renewal is a common management practice preferred in protected areas. This type of management aimed at biodiversity enrichment and ecosystem improvement. That is why it is important to understand the impact of pasture renewal on soil organic carbon stocks, nutrient cycling and other soil parameters. Our study showed that renewed grazing in the protected areas could be beneficial and do not pose any environmental risk.

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