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INFLUENCE OF PLANT SPECIES AND GRASSLANDS QUALITY ON SEQUESTRATION OF SOIL ORGANIC CARBON

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Abstract

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Soil carbon sequestration plays an important role in mitigating the anthropogenic increases in atmospheric carbon dioxide concentrations. Pastures and meadows are the significant localities for the deposition of soil organic carbon (SOC). The objective was the comparison of the impact of plant species and their quality on the deposition of SOC under the grasslands in 18 variants of meadows and pastures at the original unfertilized soils, the overfertilized soils by organic fertilizers in the form of excrements and the soils after the ecological regeneration by regrassing. The plots 5, 8, 9 and 10 were used on a long-term basis as old semi-natural sheep pastures from the 15 century. We took into consideration the deposits of SOC and N_t in soil. The old semi-natural pasture proved the most intensive transformation and accumulation of SOC (even 5.60%) and the highest values were measured in the depth I (0–100 mm) soil layer, the concentrations decreased along with the depth in all treatments. At these plots, there was the lowest yield of dry matter and quality (E_{GQ}). The yield of dry matter in t.ha^{-1}, the number of species, E_{GQ} and C:N in the depth I with the significant impact on the species variability, which were selected by Monte-Carlo permutation test explain up to 47% of the total variability. According to the result of "forward selection" in RDA analysis, out of all significant factors, the number of species has the biggest impact on the total species variability, which represents 17% of the total variability. The total evaluation indicates that from the agricultural aspect of utilization, a more favourable quite high content of SOC was deposited at the ecologically regenerated grasslands by the additional sowing of the valuable autochthonous plant species.

Key words: grasslands, plant species, quality, sequestration, SOC.

Introduction

Grasslands comprise approximately 40% of the earth's land area and play a key role in the global carbon (C) cycle (Wang, Fang, 2009). The potential of grasslands as a sink for carbon is enormous in Europe. The EU (28 countries) currently has a permanent grassland area of about 60 million ha (Eurostat, 2017). Permanent grasslands cover 33% of the total utilized agricultural area. Plant residues and animal excrements continuously supply grassland soils, which generally contain substantial amounts of organic carbon. Grasslands store considerably more carbon in the soil organic matter than in the vegetation. Carbon sequestration under the grasslands brings carbon in the soil, which is one of many ecosystem services. Therefore, it could potentially be a large contributor to the mitigation of greenhouse gases, thus providing a solution to the global problem of the climate change. However, most grasslands have suffered C losses due to the anthropogenic disturbances. Belowground C storage accounts for as much as two to four times the amount stored in the living vegetation in grasslands (Post, Kwon, 2000; Percival et al., 2000). Even a minor increase in soil organic carbon (SOC) has the potential to affect positively the global atmospheric carbon dioxide concentration and the cycle (Bu et al., 2012).

A forest may be converted into grassland by grazing animals. The substitution of one type of vegetation for the other involves destruction, of course, but not merely destruction: it also involves the appearance and gradual establishment of new vegetation. It is a successional process culminating in a climax under the influence of the actual combination of factors present. Since this climax is a well-defined entity, it is also the development of that entity. It is true of course, that when a man introduces sheep and cattle, he protects them by destroying carnivores and thus maintains artificially the ecosystem, which are the essential features of the equilibrium between the grassland and the grazing animals. He may also alter the position of equilibrium by feeding his animals not only on the pasture but also partly away from it, so that their dung represents nutrition for the grassland brought from outside, and the floristic composition of the grassland is thereby altered. In such way, anthropogenic ecosystems differ from those developed independently by a man. The essential formative processes of the vegetation are the same, however, the factors initiating them are directed (Tansley, 1935).

As one of the most important greenhouse gases, the close relationship between CO_2 and soil C is generally accepted in the context of the global climate change. Thus, known soil C stock has become very important for assessing changes in atmospheric CO_2 concentrations and of global climate (Dixon et al., 1994; Schimel, 1995; Søe et al., 2004). As the largest pool of terrestrial organic carbon in the biosphere, more C is stored in soil than it is contained in plants and the atmosphere combined. Also, while forest soils receive large amounts of organic matter coming from the aboveground biomass, in grasslands, the primary organic matter inputs to the soil come mainly from root turnover and deposition. Consequently, the vertical distribution of organic C along the soil profile is typically shallower in forest soils than in grasslands (Jobbágy, Jackson, 2000).

For instance, most of the root characteristics are specific for the different species. Pohl et al. (2011) showed that in alpine ecosystems graminoids usually have a large proportion of fine roots compared to forbs or shrubs. This feature may enhance the topsoil aggregate stability under grasses (Pohl et al., 2009), which could be relevant for stabilizing C in soils. Other characteristics of the vegetation, such as aboveground and underground productivity, allocation, rooting depth, horizontal root expansion may influence the C inputs and its persistence in soil. But also among herbaceous plants, there can be significant differences, as they occur with N-enriched organic matter produced by legumes.

The ecosystem management that maintains high levels of plant diversity can enhance SOC storage and other ecosystem services that depend on the plant diversity. C enters into soil through both litterfall and rhizodeposition, which leaves the soil mainly as CO_2 via root and microbial respiration (Sulzman et al., 2005; Cleveland et al., 2010; Díaz-Pinés et al., 2011; Sayer et al., 2011). Krajčovič and Ondrášek (2007) detected in the depth 0–200 mm 172 $t.ha^{-1}$ at Krížna and 331 $t.ha^{-1}$ soil organic carbon (SOC) at Kráľova hoľa. Out of the total plant biomass, the roots under the grass covers created the highest weight proportion (from 58 to 81%). The highest proportion of roots was in the variant grazed by sheep (2.59 $g.m^{-2}$) in comparison with the variant grazed by cows (1242.50 $g.m^{-2}$), according to Martincová et al. (2014).

Grassland soils contain significant amounts of carbon because grasses transfer a large proportion of their products of photosynthesis belowground (Baker et al., 2007). The resources of carbon in soil at the pastures represent at least 10% of the total world quantity, however, the other sources constitute even 30% of the world carbon in soil. The aboveground inputs in the forest land were the main source of SOC, with tree roots being a less important source because a majority of the trees had grown for many years and there were little root residues. In contrast, in the perennial grassland, the plant roots were the main source of SOC and played a key role in soil carbon sequestration (Kätterer et al., 2011). Jobbágy and Jackson (2000) also indicated that the decomposition rate of SOC from decaying grass roots is higher than the amount from dying tree roots. In theory, the capacity of soil to sequester organic carbon can be estimated as the difference between the existing SOC and the SOC saturation value (Beare et al., 2014).

The rate of humus oxidation in the undisturbed forest would be considerably lower, because the litter would not be incorporated into the soil and the absence of physical disturbance would result in slower soil respiration. In both soil depths, C:N ratio of grazing land is significantly higher than in dense forest land (Feamside, Barbosa, 1998). The difference is most evident in the topsoil depth than in the lower soil depth for both soil organic matter and total nitrogen. The nearer to the soil surface, the greater influence land use change will have on the carbon content (Walker, Desanker, 2004). We state that from the viewpoint of conditions for the growth and reproduction of the microbial biomass, the grassland ecosystem was more favourable. In the upper soil layer under the grassland, a considerable amount of the plant waste is being accumulated, as well as the necrotic underground parts of very rich root system of grasses and herbs (Mawdsley, Bardget, 1997).

The excessive input of NPK nutrients into soil and heavy sod trampling by grazing animals lead to the development of vigorous and competitively strong ruderal weeds, such as *Rumex obtusifolius, Arctium lappa, Anthriscus sylvestris, Urtica dioica, Cirsium arvense, Stellaria media, Aegopodium podagraria, Anthemis arvensis, Geranium pusillum, Chenopodium bonus-henricus* and others (Klapp, 1963; Lichner et al., 1983; Voigtländer, Jacob, 1987; Novák, 1992, 1997; Šúr, 1994).

The issue of grassland evaluation according to its floristic composition by means of various ranges of values was dealt with by many authors in the past, such as De Vries et al. (1942), Ellenberg (1952), Klapp et al. (1953), Regál (1967), Stählin (1971), Filipek (1973), Šostarič-Pisačič, Kovačevič (1974), Jurko (1990) and Novák (2004).

Material and methods

Study locality

We studied the localities of the grasslands at the territory of Poland (1, 2): Terespol (138 m a.s.l., 52°04′27″N, 23°36′40″E) – in the eastern part of Poland near the border with Belorussia, in the Duchy of Lublin (gmina Terespol) and Ruchnia (141 m a.s.l., 52°37′83″N, 22°05′60″E) – in the central part of Poland, in the Duchy of Mazowiec (gmina Liw). At the territory of Slovakia, the following meadows without fertilizing were included (3, 4, 6, 7): Chyzerovce (near Zlaté Moravce, under Tribeč, 147 m a.s.l., 48°54′36″N, 18°29′17″E), Gápeľ (Protected landscape area Strážovské vrchy, 420 m a.s.l., 48°53′12″N, 18°24′53″E), Suchý vrch (Kremnické vrchy, 680 m a.s.l., 48°44′54″N, 19°09′23″E) and pasture in the locality Diel (over Ďubákovo, Slovenské Rudohorie, 920 m a.s.l., 48°25′15″N, 19°34′26″E). The plots at the old pastures were used for sheep grazing from 15th century (sheep fold in the period of mountain sheep farming) and heifer grazing in the 20th century in the Protected landscape area (5a,b,c) in Chvojnica (Protected landscape area Strážovské vrchy, 586 m a.s.l., 48°53′39″N, 18°32′17″E). In the national parks (8a,b,c; 9a,b,c; 10a,b,c) – Strungový príslop (National park Malá Fatra, 936 m a.s.l., 49°13′12″N, 19°08′19″E), Pod Kečkou (NAPANT, 1,126 m a.s.l., 48°51′22″N, 19°14′57″E) and Pod Ploskou (National park Veľká Fatra, 1,234 m a.s.l., 48°56′31″N, 19°06′37″E) – there were three variants:

a. old extensive semi-natural pasture (unfertilized),
b. disturbed old semi-natural pasture (long-term eutrophic, fertilized with animal excrements, with dominance *Rumex obtusifolius* and *Urtica dioica*), unmanaged – were without the use of cutting,
c. disturbed old semi-natural pasture (long-term eutrophic, fertilized with animal excrements, with dominance R*umex obtusifolius* and *Urtica dioica*), ecologically restored – seeded by 18 autochthonous valuable plant species in a mix, than grass: *Dactylis glomerata* (25%) , *Festuca pratensis* (10%), *Phleum pratense* (10%), *Poa pratensis* (10%), *Festuca rubra* (5%), *Trisetum flavescens* (5%); legumes: *Trifolium repens* (15%), *T. pratense* (3%), *Lotus corniculatus* (3%); other herbs: *Plantago lanceolata* (2%), *Achillea millefolium* (2%), *Carum carvi* (2%), *Taraxacum officinale* (2%), *Alchemilla vulgaris* (2%), *Daucus carota* (1%), *Acetosa pratensis* (1%), *Leucanthemum vulgare* (1%), *Prunella vulgaris* (1%) and cut two-times per vegetation; 10 years after sowing and draining of excess nutrients from soil by aboveground crop phytomass.

Field activities, sward and laboratory analyses

The soil samples (Cambisol) were taken by the probes rod from soil depth I (0–100 mm) and depth II (101–200 mm) in the quantity of 0.50 kg in 3 repetitions. The values pH in KCl (pH/KCl) were set by potentiometric way. Humus (organic matter) was calculated by the factor of 1.724*percent organic carbon in soil (Fiala et al., 1999). From the values of SOC (C_{org} = humus/1.724) by Tjurin (Arinuškina, 1961) and N_t by Kjeldahl (Peterburskij, 1963), we calculated the ratio C:N.

We specified the percentage of coverage (D – dominance) for the different species and floristic groups – sampling three times during vegetation (spring, summer, autumn). The floristic analyses included the method of reduced cover (D in %), the evaluation of the coverage of dominant weed species at the experimental area (Klapp, 1963). We evaluated the quality of grasslands (range from 0 to 100) by the judgement of grassland. The evaluation of the grassland quality (E_{GQ}) proceeds from the floristic composition and forage values of the individual plants species. The evaluation of the grassland quality ($E_{GQ} = \Sigma D*FV/8$) based on cover in % (D in %) and forage value of individual plant species (FV) was recorded according to Novák (2004). The forage value (FV) is the result of combination of digestibility and palatability of the individual plant species in the floristic composition of the grassland. The plant communities differ in the forage value, which also depends on the content of the high-grade, valuable, low-grade, valueless, harmful even poisonous species in vegetation. Each plant species disposes with the forage value out of thirteen-point scale in the interval from - 4 to 8, where the lowest value - 4 refers to the poisonous species, while the high value 8 refers to the high-grade species. The very valuable and high-grade species with the forage value FV = 8 and valuable ones with FV = 5–7 have the positive impact on the grassland quality as well as the animal nutrition. The species with FV = 3–4 are low-grade, the species with FV= 0–3 are valueless, even harmful, and they are being grazed less by herbivorous animals. We also register the occurrence of the poisonous (toxic) species with FV= -1 to -4, which are not acceptable for animals and they can cause the digestive problems even death. These species decrease significantly the forage value E_{GQ}.

Statistical analyses

The repeated measurements ANOVA were used to evaluate the species diversity and functional group data. The community response was analysed by the constrained ordinations. The redundancy analysis (RDA; Lepš & Šmilauer, 2003) in the CANOCO package (Ter Braak, Šmilauer, 2002), followed by a Monte Carlo permutation test was used to evaluate the trends in the plant species composition, because of linear species responses, 52 and rather homogenous species composition over the plots (Lepš, Šmilauer, 2003). All the studied environmental factors were tested by the Monte Carlo permutation test with unrestricted permutations ($P \leq 0.05$). A split-plot design was used in the permutation type to cope with the repeated measures. We used 499 permutations in all performed analyses restricted to the split-plots, freely exchangeable whole plots, time series or linear transect at the split-plot level. The centring by species was applied. Species cover data for RDA were log-transformed. A standard biplot ordination diagram constructed by the CanoDraw program (Ter Braak, Šmilauer, 2002) was used to visualize the results of the CANOCO analyses. In the graphs, the significant factors are depicted by a solid line, the nonsignificant environmental variables are depicted only as passive, or complementary variables (broken line).

Result and discussion

Grasslands absorb carbon dioxide during the growth from the plants species. The remaining plant species and roots will eventually decompose and the carbon will be stored in the soil organic matter. Exploitation of pasture and meadows play a critical role in the global carbon cycle, and the land management activities influence their ability to absorb and sequester carbon. Grazing and livestock stay on pasture has a direct impact on the plant production and thereby on soil C inputs. It also influences the amount and composition of soil organic matter through its effects on litter accumulation and decomposition.

When comparing N_t, we claim that the values varied from 0.15 to 0.29% at the extensive semi-natural grasslands (1, 2, 3, 4, 5a, 6, 7, 8a, 9a, 10a) in the horizon I (0–100 mm) and at the eutrophic soils (overfertilized sheep folds, stands loaded by sheep, or heifers in the long term in the past) by more than a half higher from 0.48 to 0.70%. The ruderal vegetation at the eutrophic soils (5b, 8b, 9b, 10b) as monocenosis *Rumex obtusifolius* or *Urtica dioica* were without the use of cutting, where the residue of the aboveground phytomass was gathered at the soil surface and it was liable to mineralization at the end of the vegetation period. The quality (E_{GQ}) of this vegetation was very low (from 21.37 to 29.75 out of 100-point scale) with the crop of dry matter from 3.66 to 4.48 $t.ha^{-1}$. SOC varied from 1.58 to 3.43% at the extensive semi-natural grasslands and from 3.90 to 5.60% at the eutrophic soils. The most favourable variants were (5c, 8c, 9c,10c) with the additional sowing of 18 autochthonous species in the mixed fodder plants after 10 years from the ecological regeneration (phytoremediation), where N_t was in the range from 0.34 to 0.50%, along with a high crop of dry matter (from 7.16 to 9.30 $t.ha^{-1}$), E_{GQ} from 72.75 to 80.75 and the content of SOC from 3.18 to 5.35%. In horizon II (100–200 mm), the lower values were recorded of all studied variants. The results prove that carbon depositing into soil under the grasslands is related to the production of the aboveground phytomass. The higher the content of total N_t in soil, the higher was the yield of dry matter of aboveground phytomass. The total evaluation indicates that the highest content of organic carbon was deposited in soil at the ecologically regenerated grasslands by the additional sowing of the valuable autochthonous plant species.

Each intensive utilization brought the invasion into the ecosystem, which was reflected mostly by the decrease of pH and the increased mineralization (decline of N_t and SOC).

The nitrogen content in soil (N_t) is one of the indicators of the nitrogen reserve in soils for the plant nutrition and the yield of the aboveground phytomass. Pod Kečkou found that the increase of N_t content (0.70%) and increase of SOC (5.14%) lowered the ratio C:N to value 7.34:1. Many authors (De Ruiter et al., 1993; Števlíková, Kopčanová, 1996) point out that the monolateral organic fertilization, which provides the sufficiency of carbon and energic sources for the soil microflora, causes the microbial immobilization of nutrients, mostly nitrogen and its subsequent stabilization in the humus substances. After a longer time, this fact could result in the insufficient mobilization of nitrogen for plants and be reflected in the yield decrease.

In the soil (depth 0–100 mm) under the semi-natural grassland and seeded one, the ratio C:N varied in the interval from 9.35 to 14.94. The sequestration of the SOC (semi-natural grassland from 1.58 to 2.74%, seeded from 3.18 to 5.35%) was higher compared with the soil under the forest vegetation. Liaudanskienė et al. (2013) claims that at the old semi-natural pasture, there was established the most intensive transformation and accumulation of organic carbon (SOC) and the highest values were measured at 0–100 mm soil layer, concentrations decreased with the depth in all treatments. Significantly higher SOC amount was determined in 0–100 mm soil layer in (4.95%), which coincides with the results at the plots 5a,b,c; 8a,b,c; 9a,b,c and 10a,b,c that were used for sheep grazing from the 15th century in the mountain sheep farming, and by heifer grazing in the 20th century.

The exclusive importance of the agrarian soil of grasslands and long-lived swards and soils of protected areas occupied with pastures for environmental quality was revealed, because organic carbon was accumulated and sequestrated in the form of stable compounds.

Ciais et al. (2010) claim 3- or 4-times higher content SOC in the soil under the grassland in comparison with the soil under the forest vegetation. Prichard et al. (2000) observed a strong effect of slope and impact on the SOC stock of the subalpine forest in the Olympic Mountains of the Washington State. The SOC concentration was relatively higher on the northeastern slopes, ranging from 0.43 to 1.43%, than in the southwestern slopes ranging from 0.27 to 1.62%. Wei et al. (2012) report the interval of SOC content from 0.68 to 0.99% (secondary forest) and from 1.79 to 2.04% (restored grassland) in the Chinese Loess Plateau (depth of soil 0–400 mm). Three times more carbon occurs in the soil under the grass covers compared with the soil in the forests. In the secondary forest, the proportion C:N (from 8.90 to 9.30) was relatively higher than in the restored grassland (from 6.90 to 7.80).

Wasak, Drewnik (2015) pursued their research study in Jaworzynka Valley in the Tatra Mts. in southern Poland (the Carpathian mountain system, from 1200 to 1220 m a.s.l.). In calcareous soils (rendzic hypersceletic Leptosols, the depth of soil 0–420 mm), the average SOC content was from 0.94 to 5.33% (larch forest, *Larix* spp.) and from 2.79 to 6.20% (mountain grassland, which has been grazed mainly by sheep since the 15th century). Also three times more carbon is found in the soil under the grasslands compared with the soil in the forests. The ratio C:N in larch forest (from 11.80 to 15.40%) was relatively higher than in mountain grassland (from 11.20 to 12.80%). Mountain grasslands are generally rich in soil organic carbon. Due to high fine root density and rhizosphere exudation rates, grassland soils show higher priming effect on C mineralisation than in woodland soils (Waldrop, Firestone, 2004).

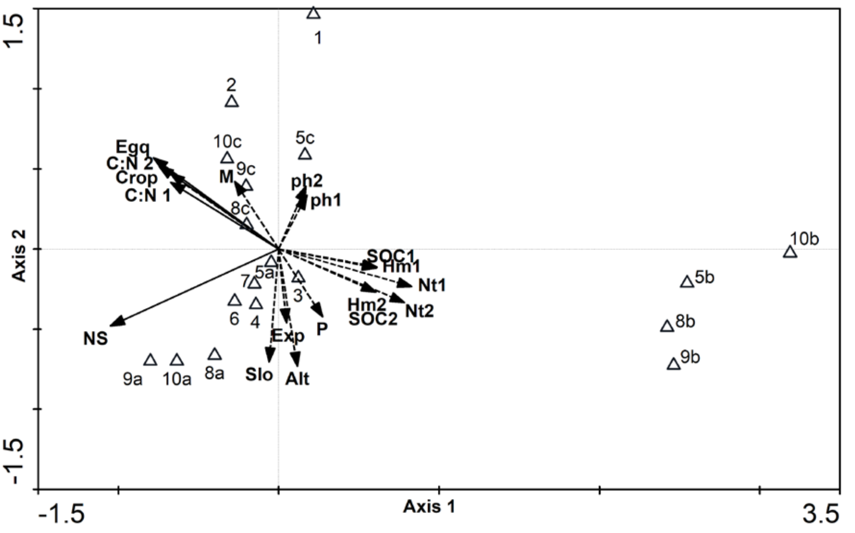

Fig. 1. Redundancy analysis (RDA) with the significant factors selected by the method of sequential sampling "forward selection" in program Canoco 4.5 (Ter Braak, Šmilauer, 2002).
Notes: 1 (I) – depth 0–100 mm; 2 (II) – depth 101–200 mm; Hm – humus; ph – pH/KCl; Nt – total nitrogen; Alt – altitude; Exp – exposure; Slo – slope; NS – number of species; E_{GQ} (Egq) – Evaluation of the grasland quality (bonitation); Crop – crop of dry mater ($t.ha^{-1}$); P – pasture; M – meadow; SOC – soil organic carbon.

The average values of the organic carbon in Chernozem varied from 0.42 to 0.12% SOC in the arable soil. On average, N_t in the soil profile was in the interval from 0.14 to 0.05% and SOC from 1.17 to 0.32%. The ration C:N on average did not exceed the value 8.50 in the humus horizon at the locations. Along with depth, the values N_t, SOC and C:N had the falling tendency (Javoreková et al., 2008). Hanes (1995) states that the value 1.88% SOC under the arable soil means a high content. Maková et al. (2011) detects the value SOC 1.35% (pH/H_2O 7.77, N_t 0.16%, C:N 8.90) in the arable soil (Luvisols, Chernozems, Planosols) in the depth to 0.48 m and the value SOC 4.69% (pH/H_2O 5.67, N_t 0.35%, C:N 13.20) in the soil under the pasture vegetation (Cambisols), where the different letters mark the significant differences (LSD; $p \leq 0.05$). This fact indicates that pasture soil had more easily decomposable organic compounds than arable soils.

The pasture and meadow vegetation is represented by the multicomponent phytocoenoses, where grasses dominate (50–60%) and leguminous plants create 15–25% under the favourable conditions. The predominance of two-seeded plants at the pasture areas 5b, 8b, 9b and 10b is the symptom of degradation – disturbance of the ecological conditions in the grass agroecosystem (extremely high reserves of nitrogen and potassium in soil which is 5-times higher than in the semi-natural vegetation). The optimal proportion occurred in grasses only at the localities (experimental plots 1, 2, 9a) from 63.70 to 70.60%, the other localities did not achieve the required values. We registered leguminous plants at the localities 2, 4 and 5, and

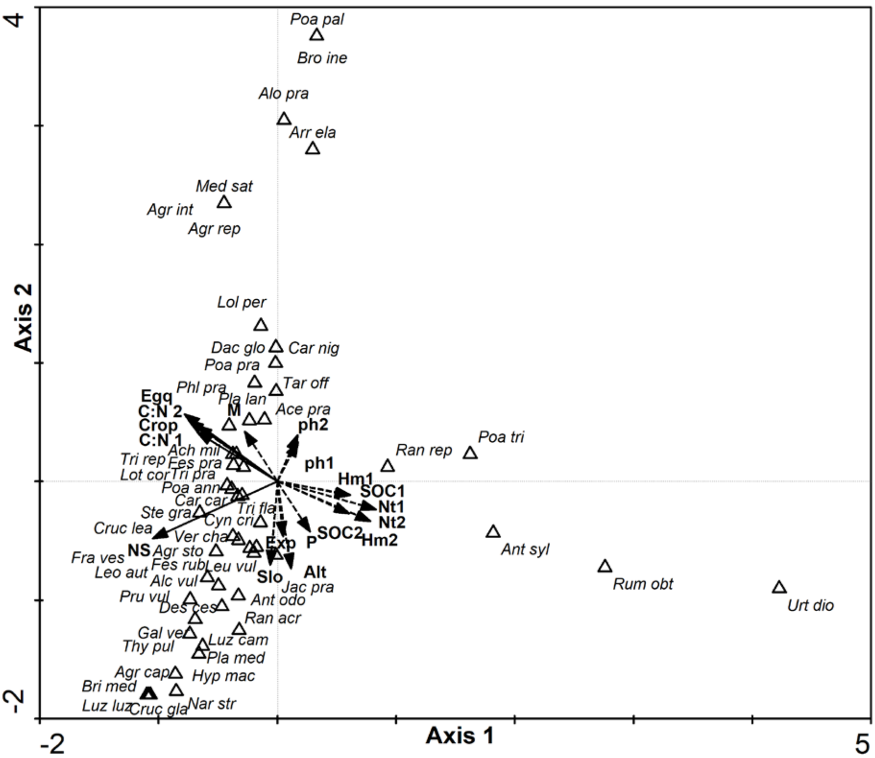

Fig. 2. Redundancy analysis (RDA) with significant species variables chosen by method of forward selection in Canoco 4.5 (Ter Braak, Šmilauer, 2002).
Notes: Ace pra – *Acetosa pratensis*; Ach mil – *Achillea millefolium*; Agr cap – *Agrostis capillaris*; Agr int – *Agropyron intermedium*; Agr rep – *Agropyron repens*; Agr sto – *Agrostis stolonifera*; Alc vul – *Alchemilla vulgaris*; Alo pra – *Alopecurus pratensis,* Ant odo – *Anthoxanthum odoratum,* Ant syl – *Anthriscus sylvestris,* Bri med – *Briza media,* Bro ine – *Bromus inermis,* Car car – *Carum carvi,* Car nig – *Carex nigra,* Cruc gla – *Cruciata glabra,* Cruc lea – *Cruciata leavipes,* Cyn cri – *Cynosurus cristatus,* Dac glo – *Dactylis glomerata,* Des ces – *Deschampsia cespitosa,* Fes pra – *Festuca pratensis,* Fes rub – *Festuca rubra,* Fra ves – *Fragaria vesca,* Gal ver – *Galium verum,* Hyp mac – *Hypericum maculatum,* Jac pra – *Jacea pratensis,* Leo aut – *Leontodon autumnalis,* Leu vul – *Leucanthemum vulgare,* Lol per – *Lolium perenne,* Lot cor – *Lotus corniculatus,* Luz cam – *Luzula campestris,* Luz luz – *Luzula luzuloides,* Med sat – *Medicago sativa,* Nar str – *Nardus stricta,* Phl pra – *Phleum pratense,* Pla lan – *Plantago lanceolata,* Pla med – *Plantago media,* Poa ann – *Poa annua,* Poa pal – *Poa palustris,* Poa pra – *Poa pratensis,* Poa tri – *Poa trivialis,* Pru vul – *Prunella vulgaris,* Ran acr – *Ranunculus acris,* Ran rep – *Ranunculus repens,* Rum obt – *Rumex obtusifolius,* Ste gra – *Stellaria graminea,* Tar off – *Taraxacum officinale,* Thy pul – *Thymus pulegioides,* Tri fla – *Trisetum flavescens,* Tri pra – *Trifolium pratense,* Tri rep – *Trifolium repens,* Urt dio – *Urtica dioica,* Ver cha – *Veronica chamaedrys*.

also at places that were ecologically regenerated by the additional seeding (8c, 9c and 10c); even at locality 2, there also grew *Medicago sativa* (8.20%). This species does not occur as the standard species in the semi-natural grasslands and it is sown as a monoculture in the arable soil. Grasses and leguminous plants did not occur at the ruderal areas. There herba-

T a b l e 1. RDA: variability explained by the individual environmental variables.

	Marginal Effects	Conditional Effects	Pure effect
ph1	0.05n.s.	0.04n.s.	x
ph2	0.06n.s.	0.03n.s.	x
Hm1	0.09n.s.	0.02n.s.	x
Hm2	0.10*	0.05n.s	x
SOC1	0.09n.s.	0.06n.s.	x
SOC2	0.10*	0.00 n.s	x
Nt1	0.13**	0.04n.s.	x
Nt2	0.13**	0.03n.s.	x
C:N 1	0.12**	**0.09****	**0.09***
C:N 2	0.13**	0.05n.s	x
Alt	0.10*	0.06n.s	x
Exp	0.06n.s.	0.04n.s	x
Slo	0.10*	0.05n.s	x
M	0.09*	0.05n.s	x
P	0.09*	0.05n.s	x
NS	0.17**	**0.17****	**0.15****
Crop	0.12**	**0.08***	**0.08***
Egq	0.14**	**0.13****	**0.10****

Notes: n.s. – nonsignificant; ** – significant at significance level $p \leq 0.01$; * significant at significance level - $p \leq 0.05$.

ceous, weed ruderal species dominated. *Urtica dioica* as monocenosis occurred at the locality 10b (95%), at localities 5b, 8b and 9b (from 15 to 30%). *Rumex obtusifolius* grew at the localities 5b, 8b and 9b (form 23 to 45%).

The grasslands in colder submountain areas with higher altitude and rainfall are covered by the species from low to high quality of grasslands. The floristic species of poor grasslands tend to be more valuable in terms of forage feeding; forage value is supported by highly valuable grasses into the growth phase of flowering, in particular, *Dactylis glomerata, Festuca pratensis, Phleum pratense, Poa pratensis* but also less valuable species *Festuca rubra*, highly valuable leguminous species *Trifolium repens, T. pratense*, possibly valuable species *Lotus corniculatus* and other valuable herbaceous species *Achillea millefolium, Alchemilla vulgaris, Plantago lanceolata, Taraxacum officinale* and so on. According to the forage value, in the species of rich grassland, the higher percentage of least valuable even to toxic plant species occurs. Forage grassland quality is decreased by grasses *Agrostis* spp., *Nardus stricta* and herbaceous species *Carex* spp., *Cruciata glabra, Hypericum maculatum, Leucanthemum vulgare, Luzula campestris, Potentilla erecta, Veronica officinalis* and so on. Some of the mentioned species occur at species of poor habitats according to Stanová and Valachovič (2002). Under agricultural conditions, a clear effect of species richness on a site's primary or secondary production has not been demonstrated yet. To enhance phytodiversity, grazing has been found superior over mowing, as selective grazing, treading and excreta deposition increase the heterogeneity of a sward, and thus, the niches available (Wrage et al., 2011).

We determined the marginal, conditioned and absolute effect of the particular measured environmental variables via RDA analysis (Figs 1, 2). The correlation between the soil factors and species composition was analysed by using correspondence analysis. The first RDA ordinal axis explains 19.80% variability of the species data and 20.90% of relation between the species composition and the environmental variables, which means that 20.90% variability of the whole data file explained by the selected environmental factors is depicted by the first ordinal axis. Four factors: crop of dry matter in $t.ha^{-1}$, number of species, E_{GQ} and C:N in depth I (0–100 mm) with the significant impact on the species variability selected by Monte-Carlo permutation test explain even 47% of the total variability. According to the results "forward selection" in RDA analysis, the number of species has the most important impact on the total species variability out of all significant factors, which is 17% of the whole variability (Table 1). The plots 5b, 8b, 9b and 10b (abandoned sheep fold without usage with the ruderal species *Rumex obtusifolius* and *Urtica dioica*, the lowest number of species and eutrophised soil) and the highest sequestration SOC are selected markedly at the margin in the graph on the right (Figs 1, 2).

Conclusion

Vegetation controls the magnitude of SOC stocks as well as the composition of SOC in soils, and thus, it is regarded as one of the critical factors in SOC composition. The plant species change associated with the long-term land use changes have the strong impact on the chemical composition of SOC. Depositing of organic carbon into soils under the grasslands depends not only on the quantity of the produced aboveground phytomass but predominantly on the species composition and quality of the individual plant species, which is expressed by the qualitative composition of vegetation (E_{GQ}). The plant species, mainly root residues and aboveground phytomass, enrich the soil by the organic biomass. The results indicate that the lowest number of valuable plant species, yield of dry matter and the lowest E_{GQ} occurred at the disturbed (ruderal) plots (old extensive semi-natural sheep pastures), however, a high content SOC was deposited in soil through plants. From the agricultural aspect, more favourable is the area with a high content of SOC, which was deposited at the ecologically regenerated grasslands by the additional sowing of the valuable autochthonous plant species.

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