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THE EVALUATION OF DISTURBED GRASSLAND AFTER THE ECOLOGICAL RESTORATION AND PHYTOREMEDIATION IN THE LOW TATRAS NATIONAL PARK

Ján Novák[1], Lýdia Turanová[2], Ľuboš Vadel[2]

[1] Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Department of Grassland Ecosystems and Fodder Crops, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic

[2] Constantine the Philosopher University in Nitra, Faculty of Natural Sciences, Department of Ecology and Environmental Sciences, Tr. A. Hlinku 1, 949 74 Nitra, Slovak Republic

Abstract

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At present the grasslands in the conservation areas are often degraded folowing the abandonment of the pasture and it is necessary to restore them. The aim of this paper was to evaluate the grasslands after the ecological restoration and phytoremediation by different methods. In 2004 the experiment was established on degraded sites at locality Low Tatras National Park (1 126 m a.s.l.) with three treatments (U – unmanaged control, C – managed by cutting, CS – managed by seeding and cutting). In 2013 on C treatment we noticed the increase of the number of species (threefold), the increase of the coverage of plants (twofold) and also the significant increase of the species diversity in comparison with the year 2004. On CS treatment the species diversity has decreased slightly but the forage value has increased more than twofold since 2004. U treatment has remained without changes. The results show the method of seeding the autochthonous species is highly appropriate to increase the forage value of grassland. Spearman correlations between environmental factors ($p \leq 0.05$) prove the effect of treatment on the amount of P-soil, P-fyt, K-soil and K-fyt, which show strong negative correlation with the time. On the other hand number of species and E_{GQ} (The evaluation of the grassland quality) correlate with time positively ($p \leq 0.05$). The restoration by the mowing is recommended on sites, where the increase of diversity is important. Legumes, C, grasses, K-soil, E_{GQ}, number of species, P-soil, time, dry matter hit the variability of the species significantly (to 96.80% of the total variability). The strongest effect on the overall variability of species had legumes, which is 61% of the total variability. Cutting explain 26% of the variability. The soil in the Low Tatras National Park was recovered to the original state through the reduction of soil nutrient – phytoremediation.

Keywords: disturbed grassland, ecological restoration, evaluation of grassland quality, phytoremediation

INTRODUCTION

Extensive deforestation of the Carpathian caused due to Wallachian colonization lasting from 13th century hit also the area of the Low Tatras. Over the centuries the carpathian grazing the sheep particularly and heifers at present has shaped and has been helpful to maintain the historical landscape structures, the character and multifunctionality of secondary created opened areas in the high-elevation mountain (Novák *et al.*, 2013). The grasslands represent the huge production potencial and at the same time they play the important role in maintaining the ecological stability of the landscape (Murgaš, 2009). Moreover, they are characterized also by the non–productive functions. The soil protection as the function of grassland is significant particularly in mountain conditions on the steep slopes to avoid deflation, denudation, landslides, nutrient leaching, etc. (Ondrášek and Martincová, 2009; Novák, 2008b). The landscaping, aesthetic and recreational function lies in the fact that grasslands are the cultural heritage, which has originated for centuries and nowadays it forms the typical country (especially in montane and supra montane areas) where the grasslands near the human settlements varies with the forests (Mikulka *et al*., 2009). There are also other important functions – hydrological (Hanzes *et al*., 2012), health and hygiene, climate, self-regulated, phytotherapy, and so on (Novák, 2008b).

The meadows and pasture as the sub-climax plant communities require regular interventions, grazing and mowing with some frequency and intensity in order to prevent degradation and overgrowing by the bushes and forest vegetation (Jendrišáková and Kizeková, 2011). Grazing is considered as the easiest and most natural way of maintaining grasslands (Golecký *et al*., 2013; Polák and Jančová, 2013). The current status of livestock is not sufficient for grazing at all existing grasslands, therefore, there is a secondary succession, what is causing a degradation. The species with low forage value can start to enforce in the grassland (Beňová *et al*., 2013). Particularly mountain areas are vulnerable by the extensification and abandonment (Válkovcová, 2009), by creating monodominant long-stalk vegetation and expansive grasses at the expense of herbaceous species (Midriak, 1993; Vološčuk, 2005).

In some regions of Slovakia, even in the national parks, the high content of potassium and phosphorus from excrements is accumulated in the soil as the result of unsuitably utilised sheepfold, where cattle is used to be closed overnight during the grazing season. It is fairly common that this state persists number of years in a row (Novák, 1992; Novák and Slamka, 2003). The solid excrements of cattle are characterized by the high content of phosphorus and the lower nitrogen content, the liquid one (urine) contains more potassium and nitrogen than solidstool (Wells and Dougherty, 1997; Whithead, 2000). Furthermore, at abandoned areas, in particular the former sheep farms, the synanthropic species occur (for instance *Rumex* spp., *Urtica* spp., *Cirsium* spp., *Arctium* spp., etc.). Also the valuable species may cause a weed infestation. This happens in the high proportion in the grasslands and after crossing the border harm. It can be caused by species *Taraxacum officinale*, *Daucus carota*, *Achillea millefolium*, *Cichorium intybus,* etc. (Novák, 2009).

Disturbed cultural landscape with grassland is unable to return to its original state by autoregulation, so the only possibility is the restoration through the human, which is controlled by anthropogenic input of energy to the ecosystem/agroecosystems. Succession in conservation areas and national parks, which is supported by habitat conditions, we can manage and guide through the use of appropriate autochthonous grasses, legumes and other herbs. Optimal ratio of these species can increase the species diversity. Suitable technology allows the introduction of native and perennial species, the revegetation of disturbed areas, the reduction of unnatural species and the erosion (Novák, 2008a).

In recent decades, people have begun realise that the environment is becoming worse and worse. The new scientific branch, ecological restoration, has developed in the USA since 1980, the initiators were John Aber and William Jordan (Andal and Anderson, 2006). It deals with the rehabilitation of degraded and damaged ecosystems/agro-ecosystems. The idea is to return these ecosystems to their original state (to the level of functionality), to restore the natural ecological balance, to increase biodiversity and to enhance populations of individual species. The restoration of abiotic environmental conditions plays an important role (Andal and Anderson, 2006). The necessity to restore the damaged and destroyed grassland ecosystems in recent decades is perceived not only by the professionals, but also by the general public. Different methods are used to regulate *Rumex* (Galler, 1989; Dierauer and Thomas, 1994; Niggli, Nösberger and Lehmann, 1993; Martinková and Honek, 2001; Pötsch, 2001). Zaller (2004, 2006) states the method of ecological restoration by the seeding, according to Novák (1993, 1995a, 1995b), as one of the possible alternatives to prevent a germination and a suppression of dominance of *Rumex obtusifolius*. We have dealt with the ecological restoration of disturbed pasture and meadows after the grazing for 25 years at Slovak University of Agriculture in Nitra (Novák, 2015).

Phytoremediation (from Ancient Greek φυτο (phyto), meaning "plant", and Latin remedium, meaning "restoring balance") describes the treatment of environmental problems (bioremediation) through the use of plants that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere. Phytoremediation consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants from the media that contain them (Burken, 2004). Phytoremediation, a subcategory of phytotechnology, uses plants to absorb pollutants from soils or from water. Plants take up or hyperaccumulate contaminants through their roots and store them in the tissues of the stem or leaves. Collectingand removing plants out from the environment ensures purifying it (Greger, Landberg, 1999).

The aim of this reasearch was to evaluate the state of the grassland on the ruderal sites in conservation area after the ecological restoration through the mowing and the seeding of autochthonous species.

MATERIAL AND METHODS

Study Areas and Sample Analysis

The experiment was set up in the Low Tatras National Park (1 126 m a.s.l., 48° 51' 22" N, 19° 14' 57" E) in 2004. The study area is situated on the rocks of Crystalline-Mesozoic zone in the West Carpathians in an eastern exposure with slope about 8–10°. The soil type is Cambisol, subtype Modal Cambisol (Tab. I). The average temperature of air during the growing season (IV.–IX.) is 8 °C and the average annual rainfall is 800 mm. The area of interest was being fertilized by excrements produced by sheepfold at least for 30 years before the establishment of an experiment. In 2004 on this pasture the ruderal plant community occurred.

To determine the available content of potassium and phospohorus (g.kg^{-1}) the soil samples were taken by the sounding rob every year in the spring before growing season and in the autumn after last cutting from the depths 0–100 mm and 101–200 mm in quadruplicate, subsequently analysed using the Mehlich III methodology (Mehlich, 1984).

Samples of aboveground phytomass in quadruplicate was used to determine the dry matter production and the content of phosphorus and potassium on variants in individual years (g.kg^{-1}). The phosphorus was specified using spectrophotometer and the potassium by the atomic absorption spectrophotometry on the flame atomic absorption spectrophotometer. Biomass was dried for 48 h at 70 °C and weighed, and then the yield of dry matter (DM) per hectare was recalculated.

Variants

The experimental sites (each with a size of 15 m^2) were established by means of block method with random layout of experimental plots in triplicate on 3 treatments:

Treatment 1 (U) – unmanaged control (disturbed seminatural grassland with dominance of *Rumex obtusifolius* L.).

Treatment 2 (C) – managed by cutting (cutted two times per vegetation before the formation of seeds *Rumex obtusifolius* L. on disturbed seminatural grassland with dominance of *Rumex obtusifolius* L.).

Treatment 3 (CS) – managed by seeding (disturbed seminatural grassland with dominance of *Rumex obtusifolius* L., 3 weeks after application of total herbicide Roundup Biaktiv 3 l.ha^{-1} seeded by 18 autochthonous species – Tab. II.) and cutting (cutted two times per vegetation).

II: *Autochthonous species in seed mixture*

Plant species	Ratio in mixture [%]	WTS	QS + 75% AC [g.m^{-1}]
Dactylis glomerata L.	25.00	0.83	0.88
Festuca pratensis Huds.	10.00	1.40	0.53
Phleum pratense L.	10.00	0.45	0.26
Poa pratensis L.	10.00	0.23	0.35
Festuca rubra L.	5.00	0.90	0.22
Trisetum flavescens (L.) P. Beauv.	5.00	0.30	0.18
Trifolium repens L.	15.00	0.65	0.39
Trifolium pratense L.*	3.00	1.71	0.11
Lotus corniculatus L.	3.00	1.20	0.06
Plantago lanceolata L.*	2.00	1.50	0.06
Achillea millefolium L.*	2.00	0.09	0.07
Carum carvi L.*	2.00	1.55	0.11
Taraxacum officinale Weber*	2.00	1.02	0.09
Alchemilla vulgaris L.*	2.00	1.05	0.04
Daucus carota L.	1.00	0.80	0.02
Acetosa pratensis M i l l.	1.00	0.80	0.02
Leucanthemum vulgare Lam.	1.00	0.90	0.03
Prunella vulgaris L. *	1.00	0.95	0.04
Total	**100.00**		**3.44**

WTS – weight of thousand seeds, QS – Quantities of the seeds, AC – additional charge * – drug plants

Evaluation of the Grassland on the Study Sites

On each treatment four sqaure–shaped plots (1 m^2) were established. Before the mowing and one week after we made phytosociological analysis through the area divided by nylon fiber into the squares (100×100 mm). A total of 9 plots have been analysed. We specified the percentage of coverage (D – dominance) for different species and floristic groups. Nomenclature of vascular plants followed Marhold and Hindák (1998). The floristic analyses included the method of reduced projective dominance (D in %), the evaluation of the coverage of dominant weed species on the study area (Klapp,

I: *Morphologically depiction of soils profile of modal cambisol (KMm)*

Horizon	Depth (m)	Evaluation and depiction of soils profile
Aoq	**0–0.10**	brown (10YR 4/4), stain-free, moist, fluffy consistency, sandy alumina, containing the skeleton > 20%, grain structure, without neoplasms and coatings, medium rooting, free of carbonates
A/Bv	**0.11–0.27**	brown (10YR 4/6), free of blemishes, moist, cohesive consistency, sandy alumina, containing the skeleton > 20%, granular to polyhedral structure, without neoplasms and coatings, poor rooting, free of carbonates
Bv	**0.28–1.00**	bright yellow-brown (10 YR 6/6) with stains Fe^{3+} in the range of about 10%, moist, cohesive consistency, skeletal, grain structure, without rooting, free of carbonates, 600–650 mm large fragments of parent

Aoq – humus–ochric–silicate horizon, Bv – cambic horizon

1965; Novák, 2004). The evaluation of the grassland quality (E_{GQ} = ΣD.FV/8) based on dominance of species in % (D in %) and forage value of individual plant species (FV) was recorded according to Novák (2004).

Statistical Analysis

As the gradient length in DCA analysis was short (2.896 and 1.106 for the first two axes), the RDA (redundancy analysis) within direct gradient analysis was applied which is included in the program Canoco 4.5 (Ter Braak and Šmilauer, 2002). Species data were log-transformed. For values of environmental variables square-root transformation were used. All studied environmental factors were tested by the Monte Carlo permutation test with unrestricted permutations (499 permutations, $P \leq 0.05$). Finally, the pure effect (where the percentage variance is explained by the variable, while the remaining significant variables were used as co-variables) was calculated (Ter Braak and Prentice 1988). Pure variance is expressed as percentage of total inertia. Marginal effect is percentage variance The conditional effect of a variable is given by the additional variance explained by the variable at the time it was included in the forward selection. Correlations among the environmental variables were evaluated by Spearman correlation test in Statistica 7 (Statsoft, 2005).

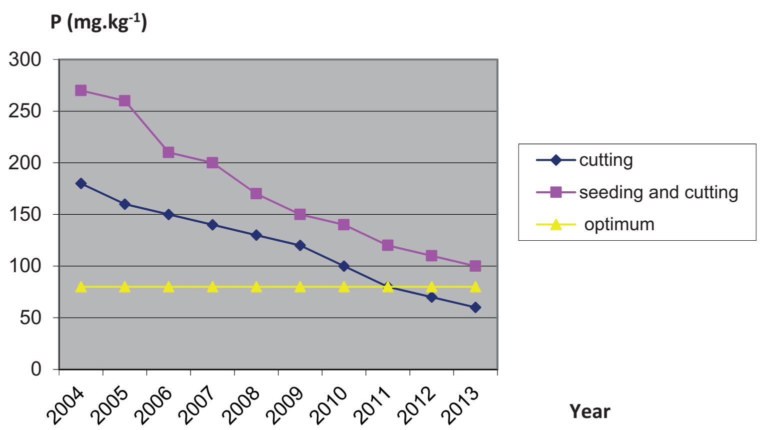
RESULTS AND DISCUSSION

The area of interest was being fertilized by excrements produced by cattle at least for 30 years before the establishment of an experiment. Long-term retaining of solid and liquid excrements at the cattlefold has led to the eutrophication – overfertilization of soil which was reflected notably as the high content of potassium and phosphorus in soil. The concept "euthropication of soil" we have started to use since 1992 (Novák, 1992).

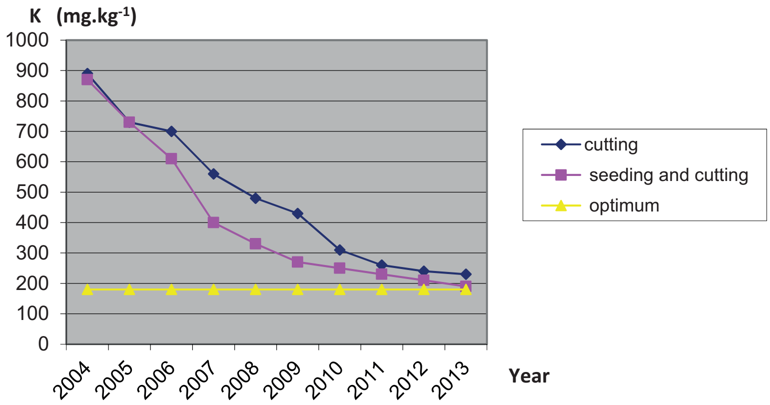
Upon the first measurement in the autumn 2004 on the treatment without management (U) in the depth 0–100 mm we determined the average value of the phosphorus in the soil 0.40 g.kg^{-1}. Ten years later this figure remained the same. On the treatment C, the cutting two times per growing season contributed significantly to reduce the phosphorus concentrations, where we recorded more than twofold decrease from 0.21 g.kg^{-1} to 0.08 g.kg^{-1}. Management by the mowing and the seeding with native species on the CS treatment has also a positive effect on reducing the concentration of phosphorus in soil where the amount of 0.25 g.kg^{-1} decreased to 0.12 g.kg^{-1}.

The overall amount of phosphorus in the deeper layer of soil 101–200 mm was lower in comparison with the less deep layer, however, the changes in concentrations had the similar character due to management. On the study site U the content hasn't changed over the years, conversely on the treatments with management the possitive effect on depletion of phosphorus was recorded. As the result of mowing on the C treatment the content of phosphorus has decreased by half from 0.14 g.kg^{-1} to 0.07 g.kg^{-1}. More significant decrease from 0.25 g.kg^{-1} to 0.10 g.kg^{-1} was achieved through the combination of mowing and seeding of species on the treatment CS (Fig. 1). By the statistical data processing at the significance level $p < 0.05$ the effect of treatment on the values of phosphorus in the soil was proven.

At the beginning of the experiment in 2004 the measured values of potassium were similiar between treatments. On the treatment U the impact of the years on the change of potassium wasn't proved, as well as in the case of phosphorus. Though,on the treatments C and CS the marked reduction of potassium concentration was established through the effect of management. The amount of potassium has decreased from 0.91 g.kg^{-1} to 0.27 g.kg^{-1} through the cutting (treatment C), similarly the value has decreased from 0.92 g.kg^{-1} to 0.24 g.kg^{-1} through the cutting and seeding (treatment CS).



1: *Phytoremediation of phosphorus on the treatment during the years*
Optimum – according to Mehlich (1984)



2: *Phytoremediation of potassium on the treatment during the years*
Optimum – according to Mehlich (1984)

The total reduction of potassium due to cutting and seeding are confirmed by the measured values at a depth of 101–200 mm, while the concentration of potassium on C and CS treatments has decreased more than threefold over the years: from 0.85 $g.kg^{-1}$ to 0.24 $g.kg^{-1}$; from 0.86 $g.kg^{-1}$ to 0.22 $g.kg^{-1}$ (Fig. 2). The values of potassium and phosphorus decrease significantly in the years and on the treatments on the significance level $p < 0{,}05$.

In 2004 control unmanaged study site U was composed of species *Rumex obtusifolius* (77%), *Urtica dioica* (18%) and *Myosotis sylvatica* (5%). We also noticed in small quantities *Geranium phaeum* (+) and *Veronica chamaedrys* (+). The same composition as in 2004 on U treatment has persisted in 2013.

On the study site with C treatment restored only by the mowing we noticed more than threefold increase in the number of species from 2004 to 2013. In the group of grasses *Poa trivialis* L. persisted, 6 new species appeared. There was also the new species of the family *Cyperaceae*, *Carex hirta* L. and the legumes increased by species *Trifolium pratense* L. and *Trifolium repens* L. In the group of other families of dicotyledonous species the number of species increased significantly from 5 to 14, however, there were only 2 same species (*Urtica dioica* L., *Veronica chamaedrys* L.). Colonization of new species and multiple increase in the number of species after the mowing over several years also report Prach *et al.* (2009), Hanzes *et al.* (2013), Klimeš (2008). On the site with CS treatment managed by the seeding the number of grasses remainded the same. *Festuca pratensis* Huds. and *Poa trivialis* L. replaced *Deschampsia cespitosa* (L) P. Beauv. and seeded species *Poa pratensis* L., *Lotus corniculatus* L. in the group of legumes dissapeared. Significant decrease from 14 to 9 was recorded in the group of other families of dicotyledonous species, the new species *Taraxacum officinale* Weber and *Hypericum maculatum* Crantz occured.

The large increase (from 6 to 37%) of coverage we observed in the group of grasses in C treatment. To confirm our results, Hanzes *et al.* (2013) described the increase in presence of the grassess and the decrease in proportion of the other families after the mowing for three years (two times per growing season) in the Low Tatras National Park. In C treatment the low coverage of other families is caused mainly by elimination of *Rumex obtusifolius* L., which covered 77% of the study area in 2004. In 2013 we didn't record this species at all. It can be stated that the long-term mowing eliminated *Rumex obtusifolius* L., what also the results of Novák (2009) in Malá Fatra National Park confirm. Total coverage in CS treament reached double in value. In both years, the grasses occupied the largest percentage of coverage. The most widespread species of grasses was *Phleum pratense* L. (13%) in 2004. In 2013 *Trisetum flavescens* (L) P. Beauv. was the dominant species and its coverage value increased from 4 to 30%. Therefore, we agree with the statement of Kohoutek and Komárek (2007) that it is possible to increase successfully the share of productive grasses by the method of seeding.

The increase in E_{GQ} values was shown in both managed treatments from 2004 to 2013. In U treatment without management E_{GQ} has remained in the same value since 2013. Dominance of *Rumex obtusifolius* L. signed markedly on the low value of grassland in C treatment. Especially through the successful elimination of this species by the mowing the grassland has ranked to the category of least valuable – less valuable. Positive influence had also the occurence of grasses *Poa pratensis* L. (FV = 8 – most valuable), *Phleum pratense* L. (FV = 8 – most valuable), *Poa trivialis* L. (FV = 7 – highly valuable) with coverage 7% and other families *Alchemilla vulgaris* L. (9%), *Achillea millefolium* L. (7%) a *Taraxacum officinale* Weber (8%) with forage value 5 (less valuable – valuable).

In spite of the reduced number of species, according to the classification, treatment CS in 2013 was included in category of less valuable – valuable. Positive impact on bonitation had *Phleum pratense* L. (12%), *Dactylis glomerata* L. (8%), *Poa pratensis* L. (7%), which rank to the classification of highly valuable – most valuable species. Larger percentage of the seeded species from the other families occured with forage value 5 (less valuable – valuable). There

III: *Redundancy analysis (RDA): variance explained by individual environmental variables*

	Marginal effects	Conditional effects	Pure effect
L	0.61**	0.61**	0.012**
C	0.58**	0.26**	x
G	0.25**	0.04**	0.022**
K-soil	0.31**	0.04**	0.005n.s.
E_{GQ}	0.6**	0.01**	0.007*
NOS	0.58**	0*	0.009*
P-soil	0.13n.s.	0.01n.s.	x
Time	0.22*	0.01*	0.004n.s.
DM	0.04n.s.	0n.s.	x
CS	0.58**	x	x

DM – dry matter; G – grasses; L – legumes; NOS – number of species; n.s. – not significant; ** – significant at $p \leq 0.01$; * – significant at $p \leq 0.05$

were species *Achillea millefolium* L. (10%), *Alchemilla vulgaris* L. (8%), *Taraxacum officinale Weber* (8%). In small amounts we recorded toxic species *Hypericum maculatum* Crantz and *Ranunculus repens* L. with forage value –1 (deleterious – slightly toxic). In comparison with the results of Novák (2008a) in Malá Fatra National Park on the mowed grassland after 5 years we noticed the more significant increase in number of species and in E_{GQ} value in CS treatment. However, this could be due to a longer duration of management.

The content of phosphorus and potassium in the aboveground phytomass has decreased proportionally as well as in to soil. On the C treatment with the mowing two times pre year the dry matter production was increasing by the year 2010, subsequently it decreased slightly and in the last year it has increased to value 6.05 $t.ha^{-1}$.

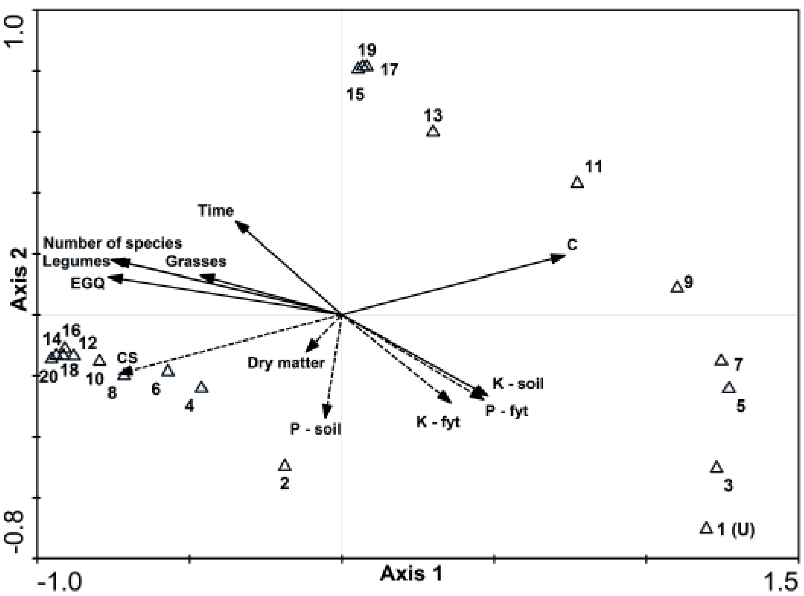
On the treatment CS (seeding and cutting two times pre year) the production of dry matter lower sharply, nevertheless, in the next three years it increased to 7.46 $t.ha^{-1}$, finally, in the recent years it has stabilized at 6.75 $t.ha^{-1}$. In terms of the grassland quality on the treatment C after cutting two times yearly it has grown from the original value 15.75 (worthless valuable grassland) to 76.50 (valuable grassland). On the CS treatment after seeding by 18 atochtonous plant species thehighly valuable grassland has been established (it has reached up 80.75 point from 100 point scale) from previos worthless grassland.

The relationship between species composition and selected environmental factors was analysed using redundancy analysis. The first RDA axis explained 69.90% variance of the species data and 71.40% of the species-environment relationship, which means that 71.4% of the variability of our data set caused by the selected environmental factors was reflected by the first canonical axis. All 10 environmental variables together explained 97.90% of the variability of the species composition. The 7 factors legumes, C, grasses, K-soil, E_{GQ}, number of species, P-soil, time, dry matter (DM) that were significant in the Monte Carlo permutation test explained 96.80% of the whole variability. Of all significant environmental factors, legumes had the strongest effect on the variability of our data set (61%). Cutting explain 26% of the variability.

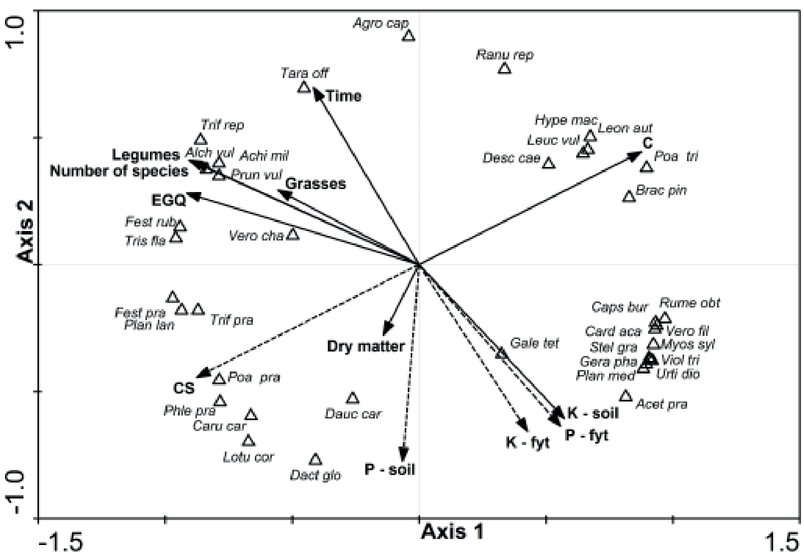
IV: *Spearman correlations between environmental factors*

	P-soil	K-soil	P-fyt	K-fyt	DM	E_{GQ}	NOS	G	L	Time	C	CS
P-soil	1.00											
K-soil	**0.78**	1.00										
P-fyt	**0.79**	**0.99**	1.00									
K-fyt	**0.84**	**0.98**	**0.98**	1.00								
DM	**0.52**	0.18	0.20	0.31	1.00							
E_{GQ}	–0.24	**–0.75**	**–0.70**	**–0.71**	0.01	1.00						
NOS	–0.48	**–0.88**	**–0.88**	**–0.84**	–0.03	**0.81**	1.00					
G	0.03	–0.29	–0.27	–0.28	–0.03	**0.52**	0.26	1.00				
L	**–0.47**	**–0.89**	**–0.88**	**–0.84**	–0.03	**0.87**	**0.97**	0.31	1.00			
Time	**–0.89**	**–0.97**	**–0.98**	**–0.98**	–0.34	**0.61**	**0.79**	0.22	**0.80**	1.00		
C	–0.43	0.21	0.16	0.12	–0.42	**–0.71**	**–0.53**	–0.42	**–0.56**	0.00	1.00	
CS	0.43	–0.21	–0.16	–0.12	0.42	**0.71**	**0.53**	0.42	**0.56**	0.00	–1.00	1.00

DM – dry mater; G – grasses; L – legumes; NOS – number of species; boldfaced values show statistically significant correlation on the level of significance ($p \leq 0.05$)



3: *Redundancy analysis (RDA) with significant soil variables chosen by method of forward selection in Canoco 4.5 (solid line) (Ter Braak and Šmilauer, 2002). Insignificant variables with dashed line are only supplementary*
E_{GQ} – Evaulation of the grasslad quality, Times – years, Dry mater (DM) – dry mater yield in t.ha^{-1}, P-soil – the phosphorus content in the soil (g.kg^{-1}), K-soil – the potassium content in the soil (g.kg^{-1}), P-fyt – the phosphorus content in the aboveground phytomass, K-fyt – the potassium content in the aboveground phytomass, C, CS – variants, 1(U) – variant 1 in 1st year and U – unmanaged control (disturbed seminatural grassland with dominance of *Rumex obtusifolius* L.) during the survey years they were in the same state, odd numbered – sites mowed 2 times, even numbered sites – mowed 2 times and seeded



4: *Redundancy analysis (RDA) with significant species variables chosen by method of forward selection in Canoco 4.5 (solid line) (Ter Braak and Šmilauer, 2002). Insignificant variables with dashed line are only supplementary*
E_{GQ} – Evaulation of the grasslad quality, Times – years, Dry mater (DM) – dry mater yield in t.ha^{-1}, P-soil – the phosphorus content in the soil (g.kg^{-1}), K-soil – the potassium content in the soil (g.kg^{-1}), P-fyt – the phosphorus content in the aboveground phytomass, K-fyt – the potassium content in the aboveground phytomass, C, CS – variants,
Acet pra – Acetosa pratensis, Agro cap – Agrostis capillaris, Achi mil – Achillea millefolium, Alch vul – Alchemilla vulgaris, Brac pin – Brachypodium pinnatum, Cap bur – Capsella bursa–pastoris, Card aca – Carduus acanthoides, Caru car – Carum carvi, Dact glo – Dactylis glomerata, Dauc car – Daucus carota, Desc cae – Deschampsia caespitosa, Fest pra – Festuca pratensis, Fest rub – Festuca rubra, Gale tet – Galeopsis tetrahit, Gera pha – Geranium phaeum, Hype mac – Hypericum maculatum, Leon aut – Leontodon autumnalis, Lotu cor – Lotus corniculatus, Leuc vul – Leucanthemum vulgare, Myos syl – Myosotis sylvatica, Phle pra – Phleum pratense, Plan lan – Plantago lanceolata, Plan med – Plantago media, Poa pra – Poa pratensis, Poa tri – Poa trivialis, Prun vul – Prunella vulgaris, Ranu rep – Ranunculus repens, Rume obt – Rumex obtusifolius, Stel gra – Stellaria graminea, Tara off – Taraxacum officinale, Tris fla – Trisetum flavescens, Tri pra – Trifolium pratense, Tri rep – Trifolium repens, Urti dio – Urtica dioica, Vero fil – Veronica filiformis, Vero cha – Veronica chamaedrys, Viol tri – Viola tricolor

CONCLUSION

The results show that the restoration of disturbed and degraded grasslands is possible through the ecological methods as the seeding of autochthonous plant species and the regular mowing two times per growing season. In view of the increase in the value of forage for polygastric animals for shorter period (at least 2 years) the ecological restoration by using the mixtures of the native species may be recommended as the best method. At the unused agricultural areas, where is required mainly to enhance the species richness, to preserve the aesthetic landscape and to retain non-productive functions, the mowing can be also used to restore. This method reduces slightly the cost and the maintenance and at the same time biodiversity increase significantly, on the other hand the restoration takes a relatively long period (at least 8 years). Both methods can suppress to completely eliminate the dominant synanthropic species and therefore to improve the grassland quantitatively and qualitatively. It can be shown on *Rumex obtusifolius* L., which was the dominant species at study area before the restoration and we managed to almost completely eliminate it. These methods can be recommended for use in conservation areas and national parks, where the state of rare grassland habitats are getting worse and worse due to abandonment of farming. They are particularly suitable for use in organic farming. The use of grassland as the good forage for livestock is in accordance with the sustainable management and can contribute to its development. Through the phytoremediation based on the reduction of soil nutrient in the Low Tatras National Park the soil was recovered to the original state, what is in fact especially suitable for aesthetic reasons considering the fact that the study area is located in the attractive tourist area (close to this area the main track leads over the ridge of the Low Tatras mountain).

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Contact information

Ján Novák: jan.novak@uniag.sk
Lýdia Turanová: lydia.turanova@ukf.sk
Ľuboš Vadel: lubos.vadel@ukf.sk