

Technologies used for maintaining oligotrophic grasslands and their biodiversity in a mountain landscape

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Abstract

Conservation of oligotrophic grasslands and of biodiversity of mountainous landscapes continues to be a challenge in Europe. Numerous studies have identified technologies for ecological management and maintenance of oligotrophic grasslands especially in remote areas, confronted with large population exodus. The experiments were done in the Apuseni Mountains in Romania with the aim of identifying alternatives to traditional practices that are economically viable and easy to implement, leading to maintain oligotrophic grasslands at an adequate level of diversity. The effects of mulching and of mulching combined with organic fertilization on mountainous semi-natural grasslands were tested in 7 variants (treatment samples). The results, after 6 years, showed minimal changes on composition of vegetation cover, only some modifications on species level. Except for abandonment, all treatments applied and in particular mulching with 10 t/ha manure triennially can be used for conservation management of oligotrophic grasslands in the Apuseni Mountains.

Keywords: oligotrophic grassland, biodiversity, grassland management, mulching, organic fertilization

1. Introduction

Semi-natural grasslands with their high biodiversity are of great importance for Europe. Therefore, semi-natural grasslands especially in Eastern Europe are considered hotspots of biodiversity, some of them holding world records for the number of species per unit of area (WILSON [53]). Most semi-natural grasslands in E. Europe are oligotrophic or mesotrophic. Vascular plant species are adapted to oligotrophic habitats: from 7,394 species, 49.9% prefer soils that are oligotrophic or very oligotrophic (CHALMANDRIER & al. [6]). In Southeast Europe, especially in Romania, there still exist large areas of oligotrophic grasslands (OG) which are subject to extensive management (VÎNTU & al. [50]). Romania has a high level of species and ecosystem diversity, especially in the Carpathian Mts. where 75% of the endemic and sub-endemic species can be found (BRINKMANN & al. [4], IORAS [18]). In Romania, most OG were included in HNV areas, totaling about 2 million hectares (out of 4.8 mil.) and stretching along the Carpathian Mts. (MADR 2018 [54]). The high diversity of OG provides many ecosystem services for farmers and society, including yields, release of nutrients from organic decomposition, protection against soil erosion, pollination (GIBON [17]; SANDERSON & al. [42]). Biodiversity is also a pool of potential chemical compounds for pharmaceuticals, plant breeding and other services for agriculture (CLERGUE [8]). TILMAN & DOWNING [46] showed that conservation of biodiversity is essential to maintaining the stability of ecosystem productivity. A significant decline in semi-natural

grassland area has been observed in many places in Europe (TOKARCZYK [47]). After 1989, many agricultural and grassland areas were abandoned in Eastern Europe. Ca. 30% of the grassland area has been abandoned, especially in mountainous and Mediterranean areas (PEYRAUD & PEETERS [35]). Valuable, highly diverse habitats and species of the traditionally used cultural landscape become increasingly endangered (EMANUELSSON [13]). This is related to the livelihood of the people, with emigration from remote or mountainous rural regions, and increased urbanization (MCKINNEY [27]; FIGUEIREDO & PEREIRA [14]). OG are the result of extensive traditional land-use. The reduction of traditional farming practices, especially intensification or abandonment, has become a large-scale problem (DZWONKO [12]; WALLISDEVRIES [52]), related with deterioration of habitats, fragmentation and loss of specific diversity (MARINI & al. [24]). Similar changes have occurred for grasslands all over Europe starting with the 19th century and accelerating over time, leading to significant losses of traditionally managed grassland (STOATE & al. [44]). Economically less productive sites in remote areas were abandoned, while the productive sites were managed more intensively (ISSELSTEIN & al. [20]; PLIENINGER & al. [37]). Related to these changes was a dramatic decrease in the ecological value (COUSINS & ERIKSSON [9]; DAHLSTRÖM & al. [10]) and species richness (VON GLASENAPP [51]; LENKA PAVLŮ [33]) of many grasslands. Management is altering soil nutrient levels, which also affects biodiversity, even in oligotrophic grassland communities (BARBARO & al. [2]). Particularly the influence of fertilization with Phosphorus in oligotrophic grasslands needs to be considered more, since it may be a decisive and irreversible trophic parameter, as evidenced by the Rengen grassland experiments (MILAN & al. [29]). Conservation of semi-natural grasslands is a sensitive topic that involves long term multidisciplinary studies (BRIEMLE [3]). It seems contradictory that improving grassland productivity and quality causes a drop in biodiversity and the reverse. However, based on detailed long term-studies, a compromise can be found. Many studies have focused on the effect of management type on the phytodiversity of grasslands (KAMPMANN & al. [22]; REITALU & al. [38]; PĂCURAR [31]; SAMUIL & al. [40], PLEȘA & al. [36], KARADAVUT & al. [23]). A low-intensity type of management is required to conserve a semi-natural floristic composition (TONN & al. [48]). In the Apuseni Mts. in Romania, OG present a great flora. These grasslands with high plant diversity (MICHLER & al. [28]) are strongly dependent on management (STOIE & al. [45]). Between 1956 and 2001, the population of Ghețari Plateau - Poiana Călineasa dropped from 2414 to 1478 persons (IORDAN & FRĂSINEANU [19]), a trend which continues (GARDA [16]). The decreased production has strongly modified grassland management and affected the diversity of the OG. The aim of this study is to identify alternatives to traditional practices that are economically viable and easy to implement, and to help to maintain OG at an adequate level of diversity. To achieve this objective, we investigated the effect of different management regimes including mulching on the phytodiversity of an oligotrophic grassland to discover the best management solutions for biodiversity conservation. GAISLER & al. [15] and MAŠKOVÁ & al. [25] suggested mulching as feasible practice for maintaining biodiversity and productivity in systems with low productivity (CARBONI & al. [5]; DOLEŽAL & al. [11]). TONN & al. [48] found that mulching could be a less expensive practice for maintaining semi-natural and high-diversity grasslands. The specific aim of this study is to analyze the effect of mulching and mulching combined with organic fertilization at different doses on the phytodiversity of oligotrophic grassland.

2. Materials and Methods

The experiment started in 2010 in Poienile Ursului (1349 m), Ocoale village, Gârda de Sus commune, Apuseni Mts., using a randomized block design with 7 treatments groups in 5 replications: 1: Control, 2: Mulching (Mu). 1x / 1 year (y.), 3: Mu. 1x / 1 y. + 5 t/ha manure 1x / 1 y., 4: Mu. 1x / 1 y. + 5 t/ha manure 1x / 2 y., 5: Mu. 1x / 1 y. + 10 t/ha manure 1x / 2 y., 6: Mu. 1x / 1 y. + 10 t/ha manure 1x / 3 y., 7: abandoned. Grassland type for the experiment was *Agrostis capillaris* – *Festuca rubra*. The manure, derived from local horse and dairy farms, was applied in early spring. Chemical analysis of manure: pH 8.06, dry matter 16.7% t-P 385 mg/kg, t-K 11.37 mg/kg, Kjeldahl-N 18,235 mg/kg, P₂O₅ 17,42 mg/kg, K₂O₅ 14.83 mg/kg. Mulching was done at the end of July (traditional mowing period) with a special mulching machine. The biomass was shredded and left on the surface. Plant composition was recorded when the *Poaceae* species were in flower, with Braun-Blanquet method modified by PACURAR & ROTAR, 2014. We used the PC-ORD for the processing of species data. For data processing and interpretation, we used the Multi Response Permutation Procedure (MRPP), multidimensional scaling NMDS, Summary (for the Shannon index and the number of species) and average abundance and dominance (PECK [34]; MCCUNE & MEFFORD [26]). For the analysis of variance and to evaluate the effect of treatments we used the software STATISTICA. The analysis of variance was performed by Breakdown and One-Way ANOVA test. To analyze in detail the effect of treatment on species with significant reaction we used a post-hoc comparative analysis, Fisher LSD. This paper summarizes the results of the sixth experimental year (2016), showing the effect of treatments on grassland's plant species composition. NMS was carried out several times in autopilot mode to minimize the stress. Distance was measured with the Bray–Curtis distance.

3. Results and discussion

The recommended solution for data presentation was tridimensional (stress 15,987; table 1). The total variance explained by ordination, obtained as an intersection between ordination distances and distances in the original n-dimensional space was 76,9% (as a sum of axis importances reported to entire variation – 100%).

Table 1. Importance of axis, final stress and recommended ordination space (2013)

Axis	Axis importance	Cumulative variance (axis*100)	Final stress	Sig.	Recommended solution
1	0.323	32,3	15.987	**	3D
2	0.248	57,1			
3	0.198	76,9			

r- coefficient of determination for the correlations between ordination distances and distances in the original n-dimensional space

Mulching was weakly and negatively correlated with axis 2 ($r = -0.337$), while fertilization was very strongly and negatively correlated with axis 2 ($r = -0.490$) and weakly and negatively correlated with axis 3 ($r = -0.364$) (table 2). Correlations for mowing and abandonment were statistically insignificant, which means they had only a minor role in describing the phenomenon.

Table 2. Correlation of experimental factors (vectors) with the ordination axis in (2013)

Experimental factors	Axis 1		Axis 2		Axis 3	
	r	Sig.	r	Sig.	r	Sig.
Mulching (M)	-0.066	ns	-0.337	*	-0.147	ns
Fertilization & M (F)*	0.245	ns	-0.490	**	-0.364	*
Mowing (C)	0.114	ns	-0.082	ns	-0.283	ns
Abandonment (A)	-0.114	ns	0.082	ns	0.283	ns

* F in fig. 1 a and b refers to treatments that combine mulching and organic fertilization. ns – not significant.

Minor changes were detected produced by treatments without a shift in grassland type (fig 1, table 3). We found highly significant differences in plant composition between mulching once per year (V2) and annual mulching + 10 t/ha manure biennially (V5), and significant differences between annual mulching + 10 t/ha manure biennially (V5) and abandonment (V7, table 4). The dominant species (*Agrostis capillaris* L.) did not respond to the treatments, while the co-dominant species (*Festuca rubra* L.) slightly reduced its cover with annual mulching + 10 t/ha manure biennially (V5). This treatment also produced a decrease in *Poaceae* cover. Abandonment (V7) promoted *Cyperaceae* and *Juncaceae*. The establishing of *Fabaceae* was significant under the treatments (1) annual mulching + 5 t/ha manure yearly (V3); (2) annual mulching + 5 t/ha manure biennially (V4); and (3) annual mulching + 5 t/ha manure triennially (V6). In studies by MAŠKOVÁ [25] mulching produced a larger proportion of *Fabaceae* than of *Poaceae*. In our study, mulching combined with organic fertilization produced only strong establishment of *Fabaceae*, without surpassing the total cover of *Poaceae*.

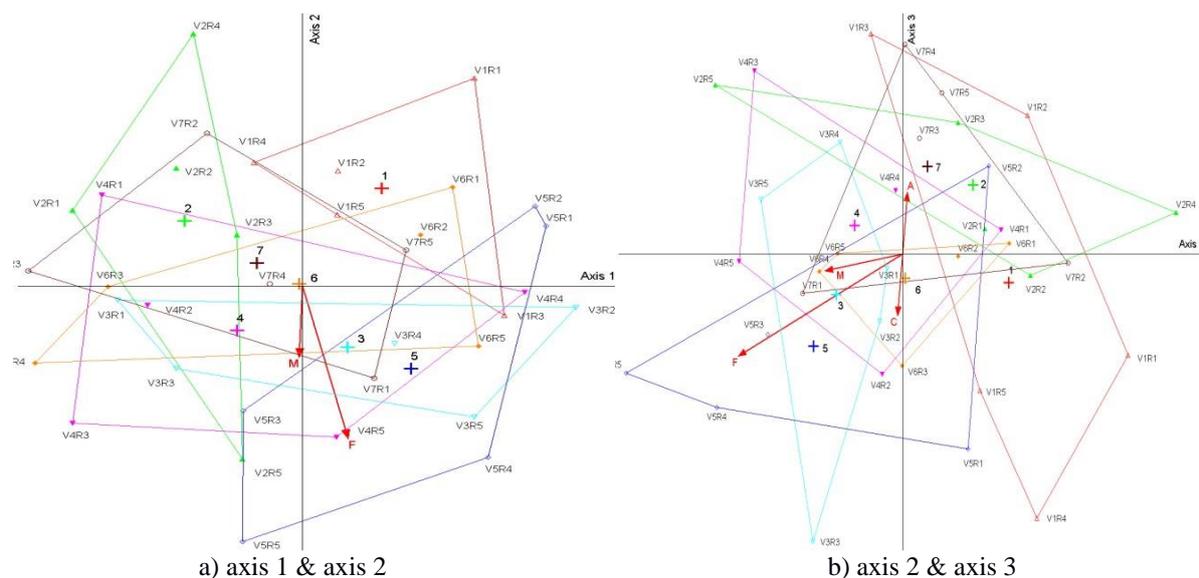


Figure 1. a and b - Ordination of treatments influenced by organic fertilizers. Mulching (M), Fertilization & M (F), Mowing (C), Abandonment (A)

Table 3. Comparison of the floristic composition of experimental variants (MRPP, 2013)

Treatments	T	A	p	Sig.	Treatments	T	A	p	Sig.
V1 vs. V2	-2.582	0.077	0.012	*	V3 vs. V4	-0.264	0.010	0.311	ns
V1 vs. V3	-1.800	0.061	0.045	*	V3 vs. V5	0.759	-0.027	0.761	ns
V1 vs. V4	-2.467	0.089	0.017	*	V3 vs. V6	0.569	-0.026	0.662	ns
V1 vs. V5	-2.225	0.085	0.024	*	V3 vs. V7	-0.478	0.018	0.272	ns
V1 vs. V6	-1.895	0.065	0.039	*	V4 vs. V5	-0.367	0.012	0.313	ns
V1 vs. V7	-1.843	0.055	0.039	*	V4 vs. V6	0.272	-0.012	0.518	ns
V2 vs. V3	-2.011	0.071	0.043	*	V5 vs. V6	-0.282	0.011	0.312	ns
V2 vs. V4	0.188	-0.007	0.493	ns	V5 vs. V7	-2.072	0.069	0.028	*
V2 vs. V5	-3.345	0.120	0.004	**	V6 vs. V7	0.213	-0.008	0.527	ns
V2 vs. V6	-0.853	0.030	0.188	ns					
V2 vs. V7	0.592	-0.019	0.693	ns					

T – t test, A – group homogeneity, p – statistical significance, Sig – significance level

Many studies have demonstrated that fertilization with manure promotes the establishment of *Fabaceae* (GAISLER & al. [15]; NOWAK 2002; SAMUIL & al. [39], SIMA [43]). Legumes play an important part in grass cover due to adding Nitrogen to soils and altering physical and chemical properties because of the symbiosis with N fixing *Rhizobium* bacteria. Like mulching, fertilization with manure at higher doses than ours promotes the establishment of *Fabaceae* in various types of grasslands (SAMUIL [41]; VÎNTU [49]). Unlike legumes, forbs reduced their cover to 47%, compared with control (61%) after annual mulching + 5 t/ha manure annually (V3). DOLEŽAL [11] could show that mulching promotes legumes and certain low forbs which are suppressed in mowed or abandoned treatments. We didn't find significant changes for species that had <5% cover, except for those with <1% cover which showed a very significant positive effect, growing to 19.25% compared with control (11.00%) with the annual mulching + 10 t/ha manure triennially treatment (V6). The applied treatments did not produce significant changes in the number of species (biodiversity), even if there were changes at the level of species groups. However, we found a very significant increase of the Shannon diversity index with the annual mulching + 10 t/ha manure triennially treatment (V6) and the abandoned treatment (V7), compared with control, thus promoting diversity (table 4). Our results are in concordance with DOLEŽAL's findings [11], where the first changes in diversity indicators (Simpson) occurred after 3 years, and specific diversity after 6 years. BAKKER & al. [1] had similar findings, showing an increase in vascular plant species in recently abandoned grasslands. For the *Agrostis capillaris* – *Festuca rubra* grassland, fertilizer doses bigger than 10 t/ha manure many studies have noticed significant decreases in the number of species, often leading to a change of grassland type (CHIDOVETŢ [7]; PĂCURAR [32]; SAMUIL & al. [40]).

Table 4. Flora structure of grassland type in 2013 (ANOVA and LSD tests)

Phytocoenosis indicators		Treatments						
2013	Species groups	V1	V2	V3	V4	V5	V6	V7
Grassland type: A.c. – F.r.	<i>Agrostis capillaris</i> L.	23.50	18.25	23.50	17.00	21.50	22.25	22.25
	<i>Festuca rubra</i> L.	16.25	15.00	13.75	12.50	10.00°	16.25	13.75
Economic groups	<i>Poaceae</i>	42.05	36.00	40.00	31.80	33.80°	41.70	36.95
	<i>Cyperaceae & Juncaceae</i>	0.30	0.40	0.20	0.30	0.40	0.30	0.70*
	<i>Fabaceae</i>	2.20	4.10	12.00*	11.25*	12.70***	11.00*	7.70
	FORBS	60.55	59.70	46.55°°	51.70	51.05	52.60	57.15
Species under 5%	<5%	7.00	11.00	14.00	11.00	13.00	17.00	18.00
	<1%	11.00	12.65	14.30	15.95	13.20	19.25**	15.40
	<0.1%	9.10	9.30	8.20	7.60	7.00	7.10	9.10
Phytodiversity	Nr. of species	27.20	28.80	27.40	26.40	24.80	27.60	30.20
	Shannon index	2.36	2.49	2.58	2.51	2.50	2.67**	2.68**

A.c.= *Agrostis capillaris* L., F.r.=*Festuca rubra* L., positive changes: *= p<0.05, **= p<0.01, ***= p<0.001, negative changes: °= p<0.05, °°= p<0.01, °°°=p<0.001, ns – not significant,

As we can see from figure 2 a and b and table 6, mulching has a positive effect on *Trifolium repens* L., *Colchicum autumnale* L., *Leucanthemum vulgare* Lam., *Plantago lanceolata* L., and a negative effect on *Arnica montana* L., *Knautia dipsacifolia* Kreutzer. GAISLER & al. [15] found similar results where mulching promoted *Trifolium repens* L. from 1% up to 21%. The frequency of *Colchicum autumnale* L. is higher in grasslands with extensive management, which is undesirable due to its toxicity, and this has become a problem for extensively managed grasslands in Germany and Austria (JUNG & al. [21]). *Plantago lanceolata* L. appears to be indifferent to nutrient supply, and is a heliophyte, tolerant to mowing (PĂCURAR & ROTAR [30]), which explains why it favors the conditions created by mulching. Heliophytes like *Arnica montana* L., *Knautia dipsacifolia*

Kreutzer were suppressed by mulching, but are moderately tolerant to mowing. Organic fertilization with mulching has a positive effect on *Trifolium pratense* L., *Trifolium repens* L., *Alchemilla vulgaris* L., *Ranunculus acris* L., *Centaurea mollis* Waldst. & Kit., *Plantago lanceolata* L. and a negative effect on *Arnica montana* L., *Cerastium holosteoides* Fr., *Silene nutans* L. Through mulching promoted species are medium tolerant to the supply of soil N (except for *C. mollis* Waldst. et Kit.), which confirms their preference for this treatment, while the disfavored ones do not tolerate eutrophic environment (*A. montana* L., oligotrophic) or the shading produced by the accumulation of decomposing vegetation (*A. montana* L., extreme-heliophyte; *C. holosteoides* Fr., heliophyte; *S. nutans* L., heliophyte).

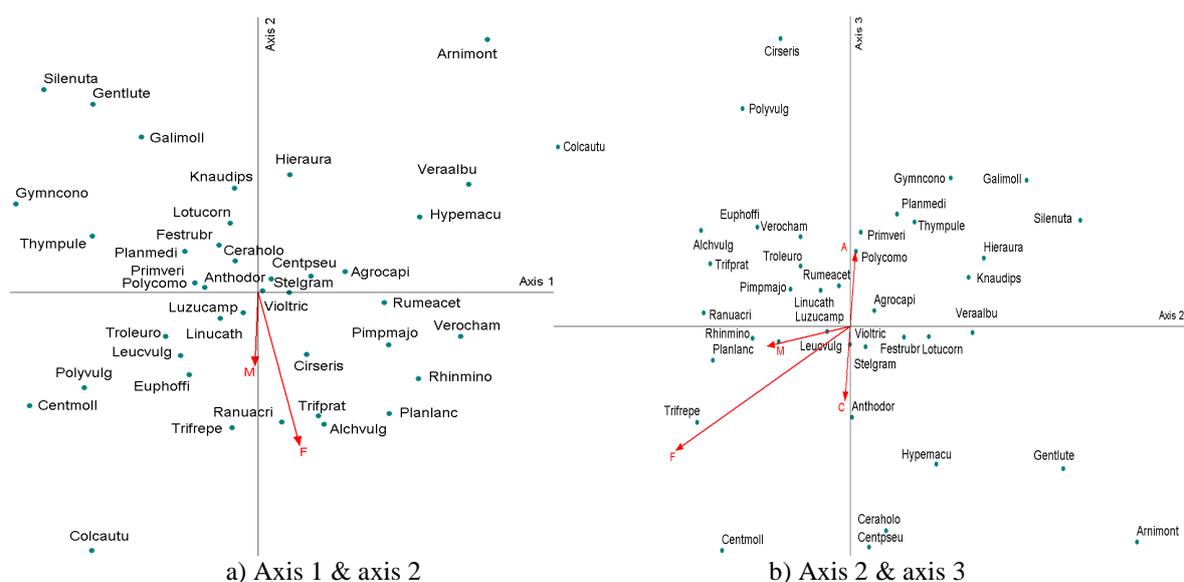


Figure 2.a and b Ordination of species influenced by organic fertilizers (2013). Mulching (M), Fertilization & Mowing (F), Mowing (C), Abandonment (A)

Table 6. Correlation of species (significance) with the ordination axis in 2013

Species	Axis 1		Axis 2		Axis 3	
	r	Signif.	r	Signif.	r	Signif.
<i>Agrostis capillaris</i> L.	0.785	***	0.249	ns	0.139	ns
<i>Anthoxanthum odoratum</i> L.	0.026	ns	0.013	ns	-0.532	**
<i>Festuca rubra</i> L.	-0.394	*	0.624	***	-0.106	ns
<i>Trifolium pratense</i> L.	0.140	ns	-0.377	*	0.144	ns
<i>Trifolium repens</i> L.	-0.103	ns	-0.690	***	-0.367	*
<i>Alchemilla vulgaris</i> L.	0.164	ns	-0.430	**	0.235	ns
<i>Arnica montana</i> L.	0.259	ns	0.374	*	-0.239	ns
<i>Centaurea mollis</i> Waldst. et Kit.	-0.475	**	-0.308	ns	-0.457	**
<i>Cerastium holosteoides</i> Fr.	-0.051	ns	0.090	ns	-0.439	**
<i>Colchicum autumnale</i> L.	-0.197	ns	-0.399	*	0.208	ns
<i>Gymnadenia conopsea</i> (L.) R.Br.	-0.355	*	0.169	ns	0.213	ns
<i>Hypericum maculatum</i> Crantz	0.474	**	0.291	ns	-0.397	*
<i>Knautia dipsacifolia</i> Kreutzer	-0.068	ns	0.391	*	0.139	ns
<i>Leucanthemum vulgare</i> Lam.	-0.368	*	-0.391	*	-0.071	ns
<i>Pimpinella major</i> (L.) Huds.	0.493	**	-0.261	ns	0.139	ns
<i>Plantago lanceolata</i> L.	0.339	*	-0.409	*	-0.085	ns
<i>Polygala comosa</i> Schkuhr	-0.244	ns	0.031	ns	0.335	*
<i>Polygala vulgaris</i> L.	-0.338	*	-0.242	ns	0.415	*
<i>Ranunculus acris</i> L.	0.080	ns	-0.577	***	0.045	ns

<i>Rhinanthus minor</i> L.	0.391	*	-0.275	ns	-0.029	ns
<i>Rumex acetosa</i> L.	0.353	*	-0.036	ns	0.112	ns
<i>Silene nutans</i> L.	-0.311	ns	0.386	*	0.151	ns
<i>Thymus pulegioides</i> L.	-0.680	***	0.303	ns	0.420	*
<i>Veratrum album</i> L.	0.485	**	0.324	ns	-0.013	ns
<i>Veronica chamaedrys</i> L.	0.638	***	-0.180	ns	0.276	ns

r - Pearson correlation coefficient, Significance

4. Conclusion

Treatments, lasting at least 6 years, with mulching and mulching combined with organic fertilization in different quantities did not cause profound changes in the general cover of the dominating grasses, i.e., leaving the vegetation defined as grassland type unchanged. However, there were changes with respect to the herbs. Legumes were promoted by almost all treatments. Forbs were negatively affected by annual mulching + 5 t/ha manure yearly. Mulching and mulching combined with organic fertilization influenced certain species, either positively or negatively. The treatments conserve phytodiversity in all variants. The species number has increased in the case of annual mulching + 10 t/ha manure triennially (V6). For the maintenance of oligotrophic grasslands and biodiversity in the Apuseni Mountains any of our treatments can be applied, especially annual mulching + 10 t/ha manure triennially. We recommend alternating mowing (and biomass removal) and mulching as the best management practice to avoid succession and to maintain biodiversity in a feasible, inexpensive way, for example conservation of *Arnica montana*.

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References

1. BAKKER, J. P., ELZINGA, J. A. & DE VRIES, Y. Effects of long-term cutting in a grassland system: perspectives for restoration of plant communities on nutrient-poor soils, *Appl. Veg. Sci.* 5, 107-120 (2002)
2. BARBARO, L., DUTOIT, T., ANTHELME, F. & CORCKET, E. Respective influence of habitat conditions and management regimes on prealpine calcareous grasslands, *Journal of Environmental Management* 72, 261-275 (2004)
3. BRIEMLE, G. Wie viel Düngung verträgt" ein artenreicher Kalkmagerrasen der Schwäbischen Alb, *Veröff. Naturschutz Landschaftspflege Baden-Württ* 71, 1-1 (1997)
4. BRINKMANN, K., PĂCURAR, F., ROTAR, I., RUȘDEA, E., AUCH, E. & REIF, A. The grasslands of the Apuseni Mountains, Romania, *Grasslands in Europe of high nature value*, 226-237 (2009)
5. CARBONI, M., DE BELLO, F., JANEČEK, Š., DOLEŽAL, J., HORNÍK, J., LEPŠ, J., REITALU, T. & KLIMEŠOVÁ, J. Changes in trait divergence and convergence along a productivity gradient in wet meadows, *Agriculture, Ecosystems & Environment* 182, 96-105 (2014)
6. CHALMANDRIER, L., ALBOUY, C. & PELLISSIER, L. Species pool distributions along functional trade-offs shape plant productivity--diversity relationships, *Sci. Rep.* 7, 15405-15405 (2017)
7. CHIDOVEȚ, S., VÎNTU, V., SÂRBU, C., TARCĂU, D., STAVARACHE, M. & SAMUIL, C. CERCETĂRI PRIVIND ÎMBUNĂTĂȚIREA PAJIȘTILODIN DIN BAZINUL SUPERIOR AL SUCEVEI PRIN FERTILIZARE ORGANICĂ, *Lucrări Științifice – Seria Zootehnie* 60, (2013)
8. CLERGUE, B., AMIAUD, B., PERVANÇON, F., LASSERRE-JOULIN, F. & PLANTUREUX, S. Biodiversity: function and assessment in agricultural areas. A review, *Agronomy for sustainable development* 25, 1-15 (2005)
9. COUSINS, S. A. O. & ERIKSSON, O. The influence of management history and habitat on plant species richness in a rural hemiboreal landscape, Sweden, *Landscape Ecol.* 17, 517-529 (2002)
10. DAHLSTRÖM, A., ANA-MARIA, I. U. G. A. & LENNARTSSON, T. Managing biodiversity rich hay meadows in the EU: a comparison of Swedish and Romanian grasslands, *Environ. Conserv.* 40, 194-205 (2013)

11. DOLEŽAL, J., MAŠKOVÁ, Z., LEPŠ, J., STEINBACHOVÁ, D., DE BELLO, F., KLIMEŠOVÁ, J., TACKENBERG, O., ZEMEK, F. & KVĚT, J. Positive long-term effect of mulching on species and functional trait diversity in a nutrient-poor mountain meadow in Central Europe, *Agriculture, Ecosystems & Environment* 145, 10-28 (2011)
12. DZWONKO, Z. Effect of changes in land use during the 20th century on woodland and calcareous grassland vegetation in southern Poland, *Folia Biologica et Oecologica* 7, 27-48 (2011)
13. EMANUELSSON, U. The rural landscapes of Europe: how man has shaped European nature, , - (2009)
14. FIGUEIREDO, J. & PEREIRA, H. M. Regime shifts in a socio-ecological model of farmland abandonment, *Landscape Ecol.* 26, 737-749 (2011)
15. GAISLER, J., HEJCMAN, M. & PAVLU, V. Effect of different management on the botanical composition of permanent grassland., , 849-851 (2004)
16. GARDA, N. Studiul unor elemente de landsaft montan (cu privire specială asupra ecosistemelor de pajisti din comuna Gârda de Sus, Muntii Apuseni), *Teză de doctorat, USAMV Cluj-Napoca* , 160-224 (2010)
17. GIBON, A. Managing grassland for production, the environment and the landscape. Challenges at the farm and the landscape level, *Livestock Production Science* 96, 11-31 (2005)
18. IORAS, F. Trends in Romanian biodiversity conservation policy, *Biodiversity & Conservation* 12, 9-23 (2003)
19. IORDAN, I. & FRĂSINEANU, D. Bevölkerungsentwicklung im transekt Gârda de sus - Ghețari – Călineasa, *Perspektiven für eine traditionelle Kulturlandschaft in Osteuropa: Ergebnisse eines inter- und transdisziplinären, partizipativen Forschungsprojekts im Apuseni-Gebirge in Rumänien, Culterra* 34, 133-137 (2005)
20. ISSELSTEIN, J., JEANGROS, B. & PAVLU, V. Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe-a review, *Agronomy Research* 3, 139-151 (2005)
21. JUNG, L. S., WINTER, S., KRIECHBAUM, M., ECK-STEIN, R. L., DONATH, T. W. & OTTE, A. Regulation of meadow saffron (*Colchicum autumnale* L.) in extensively managed grasslands, *Grassland Science in Europe (15)* , 660-662 (2010)
22. KAMPMANN, D., HERZOG, F., JEANNERET, P., KONOLD, W., PETER, M., WALTER, T., WILDI, O. & LÜSCHER, A. Mountain grassland biodiversity: Impact of site conditions versus management type, *Journal for Nature Conservation* 16, 12-25 (2008)
23. KARADAVUT, U., PALTA, C. & ÇARKACI, D. A. Effects of varying nitrogen fertilizer application rates on chemical composition of permanent grassland in Turkey, *Romanian Biotechnological Letters* 22, 12785--12785 (2017)
24. MARINI, L., KLIMEK, S. & BATTISTI, A. Mitigating the impacts of the decline of traditional farming on mountain landscapes and biodiversity: a case study in the European Alps, *Environ. Sci. Policy* 14, 258-267 (2011)
25. MAŠKOVÁ, Z., DOLEŽAL, J., KVĚT, J. & ZEMEK, F. Long-term functioning of a species-rich mountain meadow under different management regimes, *Agriculture, Ecosystems & Environment* 132, 192-202 (2009)
26. MCCUNE, B. & MEFFORD, M. PC-ORD: Multivariate analysis of ecological data. Version 6, *MjM Software, Gleneden Beach, Oregon* (2011)
27. MCKINNEY, M. L. Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems, *BioScience* 52, 883-890 (2002)
28. MICHLER, B., ROTAR, I., PACURAR, F. & STOIE, A. *Arnica montana*, an endangered species and a traditional medicinal plant: the biodiversity and productivity of its typical grasslands habitats, *Grassland Science in Europe* 10, 336-339 (2005)
29. MILAN, C., MICHAL, H., HENNEKENS STEPHAN, M. & JÜRGEN, S. Changes in vegetation types and Ellenberg indicator values after 65 years of fertilizer application in the Rengen Grassland Experiment, Germany, *Appl. Veg. Sci.* 12, 167-176 (2018)
30. PĂCURAR, F. & ROTAR, I. *Metode de studiu și interpretare a vegetației pajștilor*, Risoprint (2014)
31. PACURAR, F., ROTAR, I., BOGDAN, A. D., VIDICAN, R. M. & DALE, L. The influence of mineral and organic long-term fertilization upon the floristic composition of *Festuca rubra* L.-*Agrostis capillaris* L. grassland in Apuseni mountains, Romania, *Journal of Food, Agriculture & Environment* 10, 866-879 (2012)

32. PĂCURAR, F., ROTAR, I., PLEȘA, A., VIDICAN, R. & STOIAN, V. The Influence of Organic Fertilization Combined with Mulching on Meadows Phytodiversity, *ProEnvironment Promediu* 6 (2013)
33. PAVLŪ, L., PAVLŪ, V., GAISLER, J., HEJCMAN, M. & MIKULKA, J. Effect of long-term cutting versus abandonment on the vegetation of a mountain hay meadow (Polygono-Trisetion) in Central Europe, *Flora-Morphology, Distribution, Functional Ecology of Plants* 206, 1020-1029 (2011)
34. PECK, J. E. Multivariate analysis for community ecologists (2010)
35. PEYRAUD, J. L. & PEETERS, A. The role of grassland based production system in the protein security., *The multiple roles of grassland in the European bioeconomy. Proceedings of the 26th General Meeting of the European Grassland Federation, Trondheim, Norway, 4-8 September 2016* , 29-43 (2016)
36. PLEȘA, A., ROTAR, I., PĂCURAR, F. & VIDICAN, R. THE SEMI-NATURAL GRASSLANDS IN DIFFERENT SUCCESSIONAL STAGES OF ABANDONMENT., *Agronomy Series of Scientific Research/Lucrari Stiintifice Seria Agronomie* 57 (2014)
37. PLIENINGER, T., HARTEL, T., MARTÍN-LÓPEZ, B., BEAUFOY, G., BERGMEIER, E., KIRBY, K., MONTERO, M. J., MORENO, G., OTEROS-ROZAS, E. & VAN UYTVANCK, J. Wood-pastures of Europe: Geographic coverage, social-ecological values, conservation management, and policy implications, *Biol. Conserv.* 190, 70-79 (2015)
38. REITALU, T., PURSCHKE, O., JOHANSSON, L. J., HALL, K., SYKES, M. T. & PRENTICE, H. C. Responses of grassland species richness to local and landscape factors depend on spatial scale and habitat specialization, *Journal of Vegetation Science* 23, 41-51 (2012)
39. SAMUIL, C., STAVARACHE, M., SIRBU, C. & VINTU, V. Influence of Sustainable Fertilization on Yield and Quality Food of Mountain Grassland, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 46, 410-417 (2018)
40. SAMUIL, C., VINTU, V., SIRBU, C. & STAVARACHE, M. Influence of Fertilizers on the Biodiversity of Semi-natural Grassland in the Eastern Carpathians, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 41, 195-195 (2013)
41. SAMUIL, C., VÎNTU, V., IACOB, T., POPOVICI, I. C., STAVARACHE, M. & MUNTEANU, I. Possibilities to improve the Festuca Valesiaca l. permanent grasslands from NE of Romania, *Lucrări Științifice, Universitatea de Științe Agricole Și Medicină Veterinară " Ion Ionescu de la Brad" Iași, Seria Agronomie* 53, 239-242 (2010)
42. SANDERSON, M. A., GOSLEE, S. C., SODER, K. J., SKINNER, R. H., TRACY, B. F. & DEAK, A. Plant species diversity, ecosystem function, and pasture management--a perspective, *Can. J. Plant. Sci.* 87, 479-487 (2007)
43. SIMA, N. Cercetări privind productia sustenabilă (durabilă) de furaje pe pajiști montane de, *Festuca Rubra* (2003)
44. STOATE, C., BÁLDI, A., BEJA, P., BOATMAN, N. D., HERZON, I., VAN DOORN, A., DE SNOO, G. R., RAKOSY, L. & RAMWELL, C. Ecological impacts of early 21st century agricultural change in Europe - A review, *J. Environ. Manage.* 91, 22-46 (2009)
45. STOIE, A., PĂCURAR, F. & ROTAR, I. Cercetări privind pajiștile cu Arnica montana din zona centrală a Munților Apuseni, *Lucrări științifice agricultură* 39, 265-270 (2007)
46. TILMAN, D. & DOWNING, J. A. Biodiversity and stability in grasslands, *Nature* 367, 363-363 (1994)
47. TOKARCZYK, N. CHALLENGES FOR THE CONSERVATION OF SEMI-NATURAL GRASSLANDS IN MOUNTAINOUS NATIONAL PARKS-CASE STUDIES FROM THE POLISH CARPATHIANS, *Carpathian Journal of Earth and Environmental Sciences* 13, 187-198 (2018)
48. TONN, B., BRIEMLE, G., SCHNYDER, H., ISSELSTEIN, J., TAUBE, F., AUERSWALD, K. & HOPKINS, A. Minimum management intensity for maintaining and improving biodiversity of a mesotrophic semi-natural grassland, , 747-749 (2010)
49. VÎNTU VASILE, IONEL ADRIAN, I. T. Contribuții la îmbunătățirea pajiștilor permanente situate pe terenuri în pantă din silvostepa Moldovei, *Lucr. șt. Inst. Agronomic Iași* 33, 124-130 (1991)
50. VÎNTU, V., SAMUIL, C., ROTAR, I., MOISUC, A. & RAZEC, I. Influence of the management on the phytocoenotic biodiversity of some Romanian representative grassland types, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 39, 119 (2011)
51. VON GLASENAPP, M. & THORNTON, T. F. Traditional ecological knowledge of Swiss alpine farmers and their resilience to socioecological change, *Human ecology* 39, 769-781 (2011)

52. WALLISDEVRIES, M. F., POSCHLOD, P. & WILLEMS, J. H. Challenges for the conservation of calcareous grasslands in northwestern Europe: integrating the requirements of flora and fauna, *Biol. Conserv.* 104, 265-273 (2002)
53. WILSON, J. B., PEET, R. K., DENGLER, J. & PÄRTEL, M. Plant species richness: the world records, *Journal of vegetation Science* 23, 796-802 (2012)
54. * MADR, Măsuri de mediu și climă finanțate prin PNDR 2014-2020 Campania 2018. (2018, June 28). Retrieved from <http://www.apia.org.ro/ro/masuri-de-mediu-si-clima-finantate-prin-pndr-2014-2020-campania-2018>