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Impact of Climate on Vegetation Change in a Mountain Grassland – Succession and Fluctuation

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Abstract

Traditionally managed Central European mountain grasslands have high nature conservation value because of their high species diversity. Whether these grasslands and their diversity can be preserved will depend on many factors, including how plant species composition responds to changes in climate conditions. To differentiate between fluctuations and directional succession in the herbaceous layer composition of a Romanian *Festuca rubra* L. and *Agrostis capillaris* L. grassland in Apuseni and whether any compositional changes can be related to climate. The vegetation of permanent plots was recorded annually between 2004 and 2012. Temperature and precipitation were measured by an automatic weather station at the study site. Cluster analysis, Indicator Species Analysis and the co-dominance ratio between *F. rubra* L. - *A. capillaris* were analysed. The compositional data was related to the climate variables. Thresholds of relevant climate variables differentiating between clusters of plots with similar vegetation composition were determined using classification tree methods. The vegetation composition in our plots within the years 2004, 2005 and 2008 were different from each other. From 2004 to 2006 directional succession could be identified; however the major patterns to emerge were fluctuations which occurred over the whole study period. Compositional shifts included *A. capillaris* L. and *F. rubra* L exchanging co-dominance with each other. The most important variables differentiating clusters were temperature during the dormant and vegetation periods and water balance during the vegetation period. It can be concluded that compositional shifts among years were largely a consequence of year to year climatic fluctuations; however, there is some evidence for a directional shift during the early years of the study.

Keywords: climate fluctuation, vegetation dynamic, *Festuca rubra* L. - *Agrostis capillaris* L. meadow, Romania

Introduction

Habitats with a long history have reached an equilibrium which is not static and fluctuates permanently by undirected changes of lesser magnitude (Frelich, 2002). Climate fluctuations also generate floristic, structural and functional changes in plant communities including grassland (Petrychenko *et al.*, 2012). These climate introduced fluctuations were shown to occur in grasslands of North America (Collins *et al.*, 1987), the Czech Republic (Dostálek and Frantík, 2011), Poland (Zarzycki and Szewczyk, 2013) and other areas (Cui, 2009; Egan and Crandall, 2008; Ihm *et al.*, 2007; Lal, 2012, Miller, 2008; Schmer *et al.*, 2010).

Successional trends are difficult to separate from fluctuations (Kasperek 1998, Matesanz *et al.*, 2009). Changes of temperature and precipitation have caused well documented shifts in species composition, community structure and turnover of grassland vegetation (Deutsch *et al.*, 2011; Heisler-White *et al.*, 2009; Niu and Wan, 2008). The duration of these changes and their impact at the ecosystem level are still largely unknown (Zurek 2011, 2012). The existing knowledge is based on phytosociological studies (Brito *et al.*, 2014; Leonard, 2014; Worthington, 2014), but experimental studies are lacking.

In an experimental approach site factors can be quantified and management can be simulated. The climate effect on the behaviour of plant species is less known (Niu and Wan, 2008). Understanding and quantifying the impacts of climate remains a key-challenge for ecologists (Heisler-White *et al.*, 2009). Knowledge about the relationships between climate and vegetation is essential for planning land-use, retaining and enhancing biodiversity, and climatic change modelling (Morecroft *et al.*, 2004;

Plantureux *et al.*, 2012; Sala *et al.*, 2000; Schneider *et al.*, 2009; Schaumberger, 2012; Trnka 2011).

Only long-term monitoring in multifactorial experiments exploring the interacting effects of land use change and climatic fluctuations can provide the necessary data to distinguish these processes, e.g., the impact of changing precipitation patterns (Morecroft *et al.*, 2004). Only few studies exist and they are largely confined to systems with a capacity for rapid compositional change (e.g. Grime *et al.*, 2008).

Mountain grasslands contain some of the most important high nature conservation value areas in Europe (Veen *et al.*, 2009). Highly diverse mountain farmlands can increase tourism incomes and provide a potential seed source for local biodiversity restoration (Hopkins, 2011).

The interactions between climate and management in grasslands dominated by *Festuca rubra* L. and *Agrostis capillaris* L. seem to produce fluctuations in species abundance and cause changes in succession affecting the species composition, diversity and biomass production (Pleșa, 2012). Phytosociological studies rarely define robust community dynamics (Cristea *et al.*, 2004).

The objectives of this study were to distinguish the successional trends and fluctuations in a *Festuca rubra* L. - *Agrostis capillaris* L. grassland in the Apuseni Mountains, Romania in an experimental approach. Permanent sample plot data from Romanian mountain grassland were measured annually over nine years. Our aim was: (1) to quantify the long-term directional successional floristic changes under the impact of climate and management through mowing (2) to identify the most relevant climatic parameters affecting the species composition in the short-term; (3) to develop a model of the grassland community response on the species-level, including the changes in *F. rubra* L. and *A. capillaris* L. co-dominance patterns.

Materials and methods

Study area and experimental design

The research was conducted near the village of Ghețari, Gîrda de Sus commune, situated in the central part of Apuseni Mountains, Romania (coordinates: latitude 46°29'24.88" and longitude 022°48'52.40"). The regional geology is dominated by limestone (Orășeanu, 2005). The area has a mountainous climate with an average temperature of 5.2 °C and an average annual precipitation of 1122.65 mm (Pleșa, 2012). The experiment was established in 2001 in a *F. rubra* L. – *A. capillaris* L. grassland, at 1130 m elevation on a red preluvosol soil with an average nitrogen content (0,212 %) but poor in phosphorus (3 ppm) and potassium (25 ppm) (Parichi and Stănilă, 2005). The vegetation was recorded on 16 plots, placed on a uniform phytocoenosis with a total area of 3000 m^2, each plot having a size of 10 m^2. Starting from 2001 plots were mowed each year when the grasses were in bloom. As a historical management, land surface was used in a mixed farming system during 1990-2000, through mowing and occasionally autumn grazing with cattle and horses. Therefore, the mowing regime was slightly adjusted as grazing did not occur every year.

Assessment of climatic variables and calculation of indices

An automatic weather station was set up in the research area, which recorded temperature and rainfall every 15 minutes. The climatic data was split into two periods: the vegetation period (May – October) and the dormant period between 20 of November and April (outside of vegetation period). For each period the monthly maximum and minimum temperatures were determined and the monthly precipitation totals were calculated. The combined effect of temperature and precipitation was incorporated into water balance and humidity indices. The soil water balance index was calculated as the difference between rainfall and evapotranspiration on a monthly basis (Vicente-Serrano *et al.*, 2010). The potential evapotranspiration was estimated based on the simplified model proposed by Thornthwaite (1948) using R (R Core Team 2013) package “spei” (Begueria and Vicente-Serrano, 2013). The humidity index is a simplified expression of the ratio between monthly precipitation and potential evapotranspiration (Samaras, 2012).

Additionally, the climate conditions of the three previous years were analyzed regarding their impact on the vegetation composition change. In the following the climate variables were coded as follows: t – mean temperature °C, p – rainfall sum, w – water balance, h – humidity index, m – minimum value in a month, M – maximum value in a month, v – vegetation period, o – outside the vegetation period or dormant period, 1, 2, 3 – the number of years ago.

Vegetation data collection

Vegetation data were collected through floristic relevés based on the cover abundance of each species using the Braun-Blanquét scale (Braun-Blanquet, 1964). For greater precision, the scale’s intermediate values were used (Gârda, 2010; Pleșa *et al.*, 2010). Vegetation data from the permanent plots was collected from 2004 to 2012; on the period when the grasses were flowering. Therefore, for a better understanding, plots were placed in 2001, and vegetation data were collected annually from 2004.

Statistical analysis

In the first step of the analysis sequence the plots were classified based on their species composition in order to understand and describe their similarity within and between the years. The hierarchical classification was performed using Soerensen index and the group average algorithm (agnes in the R “cluster” package, 1.14.4, Maechler *et al.*, 2013) recommended by several authors (McCune *et al.*, 2002; McCune and Mefford, 2011; Peck, 2010). Additionally, different dissimilarity indices and several algorithms were applied to ensure that the final solution was stable (Legendre and Legendre, 1998). The optimum number of clusters was confirmed by a multi-response permutation procedure (MRPP). This analysis (performed with PC-ORD ver. 6, McCune and Mefford, 2011) confirmed that there was a significant difference in species composition between the clusters.

In the next step the Indicator Species Analysis was used (Dufrêne and Legendre, 1997) to assess the degree to which a species indicates a compositional group based on its constancy and abundance (Tremp, 2005; Peck, 2010; Leyer and Wesche, 2007; Kent, 2012). This analysis was performed based on Soerensen index - using PC-ORD. For the interpretation, the Ellenberg indicator values adapted by Kovacs (1979) for Romania were used.

Additionally, the turnover between the two dominant species (*F. rubra* L. and *A. capillaris* L.) was analysed with the co-dominance ratio (using Statistica 8.0, Statsoft, 2012). To analyse in detail the effect of the different climate variables on the abundance of the dominant species a comparative Post-hoc Fisher LSD type analysis was performed. This test emphasizes the significant differences among groups (Pleşa, 2012).

To examine variation in species composition we used unconstrained ordination (non-metric multidimensional scaling (NMDS) based on Soerensen index using *metaMDS* function ("vegan" package, Oksanen *et al.*, 2013) and PC ORD. The latter was used to visualize vectors between the clusters in order to find out if a fluctuation or a succession happened and to determine the directional change in vegetation (McCune and Mefford, 2011). To quantify the general influence of the climatic variables (basic and synthetic) on the vegetation they were included in the non-metric multidimensional scaling (NMDS). The corresponding aligning of climatic factors to the ordination was performed using the function *envfit* ("*vegan*" package). Pearson-type correlations among species and climate variables, that were found amongst the climatic variables were analysed ("*ecodist*" package, Goslee and Urban, 2007). Prior to the NMDS, from each pair of strongly correlated climate variables, one was removed (r>0.80, Chan, 2003) to reduce collinearity in the following analysis (Peralta *et al.*, 2012).

To identify the climate thresholds between the different vegetation clusters the dataset was subdivided recursively into subsets using classification tree methods. These were increasingly homogeneous with respect to the defined groups, providing a tree-like classification and an associated dichotomous key to classify unknown samples into groups (Urban 2002). The calculations were performed using the "*rpart*" package (Therneau *et al.*, 2013).

Results and discussions

Vegetation classification

The vegetation plots were divided into five clusters (Fig. 1). The results over nine years show that some years were floristically very homogenous while others were quite different. Especially the first and second year – 2004 (cluster 1) and 2005 (cluster 2) were different. Within the remaining large group, 2008 (cluster 4) forms another floristically different group while the other two comprise data from several years (clusters 3 and 5). This shows that the vegetation plots in some years were compositionally very similar to the same plots measured in other years, like 2006 to 2007 and 2010 (cluster 3) and 2009 to 2011 and 2012 (cluster 5).

During the nine year study period the sample plots fell into one of five distinctive composition (clusters) which largely represent temporal changes in the *Festuca rubra* L. - *Agrostis capillaris* L. grassland. The NMDS ordination showed that the five compositional groups formed through time are related to variability in temperature and precipitation as well as water balance and humidity indices.

The co-dominance ratio between *F. rubra* L. and *A. capillaris* L. changed during the nine years (Tab. 1). The cover of *Agrostis capillaris* L. decreased significantly during the study period from 24.27% (2004) to 10.47% (2009, 2011 and 2012). Contrariwise *F. rubra* L. showed an increasing trend from 15.72% cover (2004) to 23.17% (2009, 2011 and 2012).

Fluctuation and successional trajectory

The successional vectors in the ordination (Fig. 2) show that the plant community was transformed during the nine years due to climatic conditions. It seems that from '2004' (cluster 1) to '2005' (cluster 2) all four plots move along axis 1, with no change on axis 2. Then from '2005' to '2006, 2007 and 2010' (cluster 3) all four plots move to lower scores on axis 1 but to higher scores on axis 2. Then from '2006, 2007 and 2010' to '2008' (cluster 4) plots move to slightly higher scores on axis 1 but barely move on axis 2. The plots of cluster 5

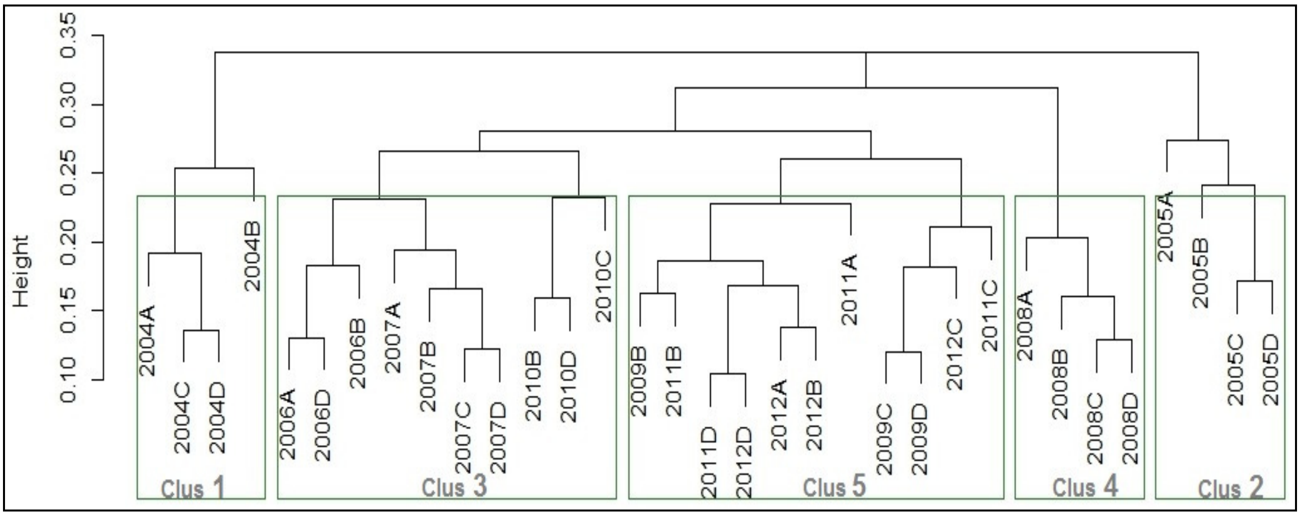

Fig. 1. Dendrogram showing the vegetation classification based on Soerensen index and the group average algorithm. A-D indicate the individual plots and 2004-2012 the year of assessment; Clus – cluster

Tab. 1. Modification of co-dominance relationship between *F. rubra* L. and *A. capillaris* L. during 2004-2012, under the influence of climatic factors

			Agrostis capillaris L.			
Cluster		1	2	3	4	5
	Cover %	24.27	12.99	16.36	11.58	10.47
1	24.27		p<0.001 $^{\circ\circ\circ}$	0.003$^{\circ\circ}$	p<0.001 $^{\circ\circ\circ}$	p<0.001 $^{\circ\circ\circ}$
2	12.99			0.120	0.574	0.197
3	16.36				0.063	0.004$^{\circ\circ}$
4	11.58					0.632
5	10.47					
			Festuca rubra L.			
Cluster		1	2	3	4	5
	Cover %	15.72	16.44	19.67	24.17	23.17
1	15.72		0.859	0.338	0.075	0.043 *
2	16.44			0.358	0.067	0.027*
3	19.67				0.276	0.206
4	24.17					0.905
5	23.17					

Cluster: 1 – 2004; 2 – 2005; 3 – 2006, 2007, 2010; 4 – 2008; 5 – 2009, 2011, 2012

$p < 0.05$ * $^{\circ}$ $p < 0.01$ ** $^{\circ\circ}$ $p < 0.001$ *** $^{\circ\circ\circ}$

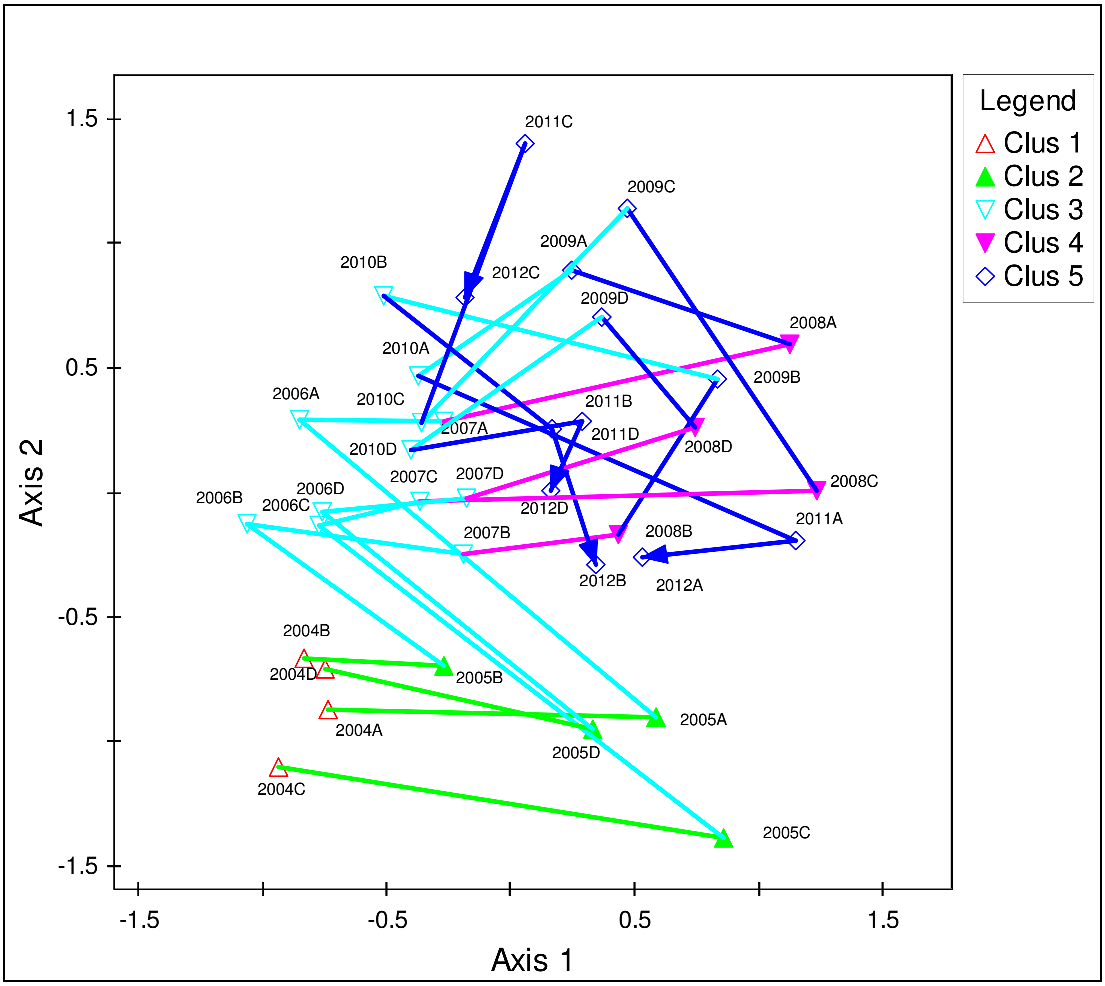

Fig. 2. Succession (trajectory) of the floristic composition during 2004-2012 plotted by succession vectors (clus1 - cluster 1, clus2 – cluster 2, clus3 – cluster 3, clus4 – cluster 4, clus5 – cluster 5)

('2009, 2011 and 2012') are quite scattered in the NMDS ordination space. For this reason we will follow the cluster in segments and can say that from '2008' (cluster 4) to 2009 the plots move to a lower score on axis 1, but to a higher score on axis 2. The majority of the plots of clusters'2009, 2011 and 2012' remain almost at the same position on axis 1 and at a much lower position on axis 2.

Climate caused obvious fluctuations and slight directional succession. During this floristic development the co-dominance ratio between *F. rubra* L. and *A. capillaris* L. often shifted. But the directional succession cannot be explained only by climate. Also, since 2001 (the year that the plots were established) the grassland management consisted in one mown/year. The combination of climate and management

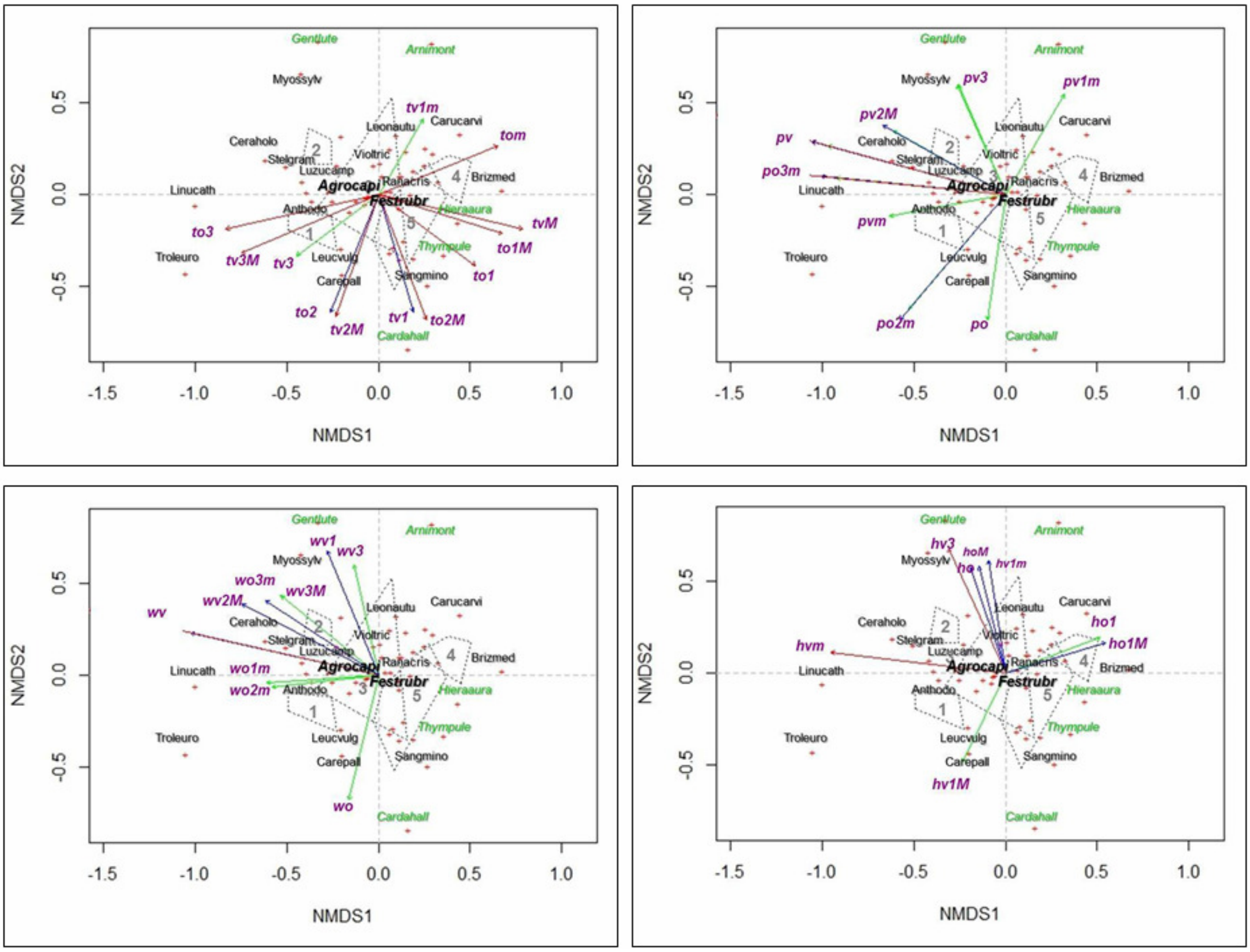

Fig. 3 (a - upper left; b - upper right; c - bottom left; d - bottom right). Clusters ordination and influence of climatic parameters on vegetation: a) mean temperature - t, b) sum of precipitations - p, c) water balance - w, d) humidity index - h (m - minimum value in a month, M - maximum value in a month, v - vegetation period, o - outside the vegetation period, 1, 2, 3 - the number of previous years (their names' combinations codify the climate variables in the figure). The variables drawn in green show the $p<0.05$, in blue $p<0.01$, in red $p<0.001$. The clusters are designed by figures from 1 to 5 drawn in grey. Dominant species: Agrocapi - *Agrostis capillaris* L., Festrubr - *Festuca rubra* L. Indicator species: Anthodo - *Anthoxanthum odoratum* L., Brizmed - *Briza media* L., Carepall - *Carex pallescens* L., Carucarvi - *Carum carvi* L., Ceraholo - *Cerastium holesteoides* Fr.em.Hyl., Leonautu - *Leontodon autumnalis* L., Leucvulg - *Leucanthemum vulgare* Lam., Linucath - *Linum catharticum* L., Luzucamp - *Luzula campestris* L., Myossylv - *Myosotis sylvatica* Ehrh., Ranacris - *Ranunculus acris* L., Sangmino - *Sanguisorba minor* Scop., Stelgram - *Stellaria graminea* L., Troleuro - *Trollius europaeus* L., Violtric - *Viola tricolor* L. Margin species: Arnimont - *Arnica montana* L., Cardahall - *Cardaminopsis halleri* L, Gentlute - *Gentianella lutescens* Velen, Hieraaura - *Hieracium aurantiacum* L., Thympule - *Thymus pulegioides L.*

could have produced a change in vegetation or perhaps it was only one strong factor. In order to separate the effect of these factors, additional data are required which will be analyzed and discussed in a following paper. Collins *et al.* (1987) showed that stopping intensive grazing by goats can lead to an obvious successional trend. Based on our data from 2004-2012, a "dynamic equilibrium" (Cristea *et al.*, 2004) in the *F. rubra* L. – *A. capillaris* L. grassland appears to develop around the '2006-2007-2010' cluster (3) and the '2009-2011-2012'- cluster (5, except 2009). In these periods *F. rubra* L. occur as dominant and *A. capillaris* L. as subordinate. Coldea *et al.* (2012) and Frink (2010) have described the instability of the co-dominance of *F. rubra* L. and *A. capillaris* L. and our study confirms this. Coldea *et al.* (2012) concluded that the instability of the system is mainly due to the high nutrient content of the soil when *A. capillaris* L. prevails. Our study suggests these changes might be driven by climate fluctuations.

The influence of climatic factors on the vegetation change

The species composition of '2004' was positively related to higher temperatures occurring three years earlier (NMDS, Fig. 3a) while '2005' was influenced by higher water availability (Fig. 3bcd). '2008' is positioned opposite to the first two years and therefore also negatively related to their prevailing conditions.

We could not identify species which had a specific ecological indicator value for 'temperature' or 'humidity', this suggests that the constancy and abundance of species reflects the complex action of the different climatic factors. For example, it is the combination of temperature and rainfall that is important for plant species' spreading (Wittig, 2012). In the mountains, differences among plant communities are the result of a complex of factors called "elevation complex" (Dierschke and Briemle (2002) and *Höhenkomplex* by Klapp (1971) . This complex includes low temperature, long term snow cover, a short vegetative period, high precipitation, massive leaching through the soil profile, pronounced soil erosion, low biological activity in the soil and humus bioaccumulation (Dierschke and Briemle, 2002).

The first classification tree (Fig. 4) suggests that temperature variables play the main role in the floristic differentiation of the vegetation. An average temperature of less than -1.3 °C two years earlier during the dormant period (to2) separates the vegetation composition of cluster 1 and cluster 5 from the other vegetation clusters. On the next split (right side of the diagram) is indicated that if the minimum temperature during the vegetation period is less than 5.49°C, the same probability exists to maintain the vegetation of cluster 1 or cluster 5. On the left side, if the minimum temperature during the vegetation period in the previous year (tv1m) was less than 5.49°C, the vegetation as observed in the years '2006, 2007 and 2010' (cluster 3) occurred by taking into account the temperature during the growing season of less than 4.6 the vegetation of clusters 2 or 4 will occur.

Influential for '2004' were the temperatures three years before as well as the precipitation in the current and the previous year which were higher than average. A high influence had also the temperature outside the vegetation period (recorded three years earlier; winter 2001/2002) which was much higher than the average during the rest of the study period. Niu and Shiqiang (2008), studying the effect of global warming on natural meadows in the temperate steppe of China, found that *A. capillaris* L. became dominant under higher temperatures. The current year's minimum rainfall during the study period also plays an important role, and was almost twice the average in 2001-2012 (Annex 1). The findings of the present study are partly consistent with those presented by Stampfli and Zeiter (2004), who found that in wet years *A. capillaris* L. and *Anthoxanthum odoratum* L. abundance increased in similar grassland types. The minimum water balance's influence in the dormant period was two years before 2004, and it had a value in 2002 (wv2M) that was similar to the average during the study period, unlike the value registered in 2003 (wv2M) which was almost double the average for vegetation type observed in 2005. Maximum humidity during the vegetative period in '2003' influenced '2004' when it was almost triple than the average of 2001-2012 (Annex 1). Vegetation responses to extremes in the moisture regime are rapid and independent of annual rainfall (Heisler-White *et al.*, 2009).

Considering the ecological indicator value for temperature and humidity (Tab. 2) only *Trollius europaeus* L. (according to the indicator value of Ellenberg et al., 1992) and *Linum catharticum* L. to a lesser degree showed the expected ecological indication in the present study. The presence of a generalist could be explained by climatic fluctuations which happened in the past. However, the ecological indication value might have to be adjusted based on measurements. For example, *Leucanthemum vulgare* L. prefers flooded conditions (Hölzel and Otte, 2003) and is diminished by cold winters (Nissinen, 2004). The vegetation composition in '2005' was influenced by rainfall during the vegetation period (pv = 791.9 mm), which was 20% higher than the average during 2001-2012. Dostalek and Frantik (2011) recorded that the abundance of dicotyledonous species increased with rainfall in the Salabka Natural Reservation, Czech Republic. This result is consistent with our results for the Apuseni Mountains. Additionally, important for '2005' was the water balance during the vegetation period (wv) which was 80% higher than the average of the study period maximum water balance during the vegetation period in 2003 (wv2M), 62% higher than the average during 2001-2012 (Annex 1). The minimum value of the humidity index during the vegetation period in 2005 (hvm) was double the average during 2001-2012, and the humidity index during the vegetation period in 2003 was 20% higher than average and had an important influence on the vegetation composition in cluster 2 (Annex 1).

Tab. 2. Groups' indicator species (x – indifferent species)

Species	*Indicator Value*	*Significance*	*Temperature Index*	*Moisture Index*
		Cluster 1 (2004)		
Anthoxanthum odoratum L.	49.3	0.0002 ***	x	x
Carex pallescens L.	45.0	0.0002 ***	4	x (6)*
Leucanthemum vulgare L.	58.5	0.0004 ***	x	4
Linum catharticum L.	44.9	0.0168 *	x	x
Trollius europaeus L.	75.0	0.0020 **	3	7
		Cluster 2 (2005)		
Luzula campestris L.	43.4	0.0004 ***	x	4
Cerastium holosteoides Fr. em. Hyl.	56.6	0.0106 *	x	5
Myosotis sylvatica Ehrh. ex Hoffm	81.0	0.0008 ***	x	5
Stellaria graminea L.	58.2	0.0006 ***	x	4
Viola tricolor L.	45.3	0.0260 *	5	x
		Cluster 3 (2006, 2007, 2010)		
Leontodon autumnalis L.	57.6	0.0004 ***	x	5
		Cluster 4 (2008)		
Briza media L.	44.5	0.0272 *	x	x
Carum carvi L.	60.1	0.0120 *	4	5
Ranunculus acris L.	81.0	0.0394 *	x	x (6)*
		Cluster 5 (2009, 2011, 2012)		
Sanguisorba minor Scop.	41.7	0.0176 *	6	4

* x – by Kovacz, 1979 and 6 – by Ellenberg, 1997

Based only on the synthetic climatic factors the second classification tree (Fig. 5) reveals that when the water balance was higher or equal to 135.2 mm during the vegetation period in the current year (WV) it was the most important factor, dividing roughly cluster 4 and 5 from the rest of clusters.

The minimum temperature during the dormant period (tom) had a strong influence for cluster 4 (2008), which was lower than the average obtained for 2001-2012 (Annex 1). The minimum rainfall in 2007 (pv1m) was particularly important as it was almost double the average (Annex 1). The value of the humidity index in the dormant period of 2007 (ho1) had a strong influence and was 410.3% higher than the average during 2001-2012 while the maximum value of the humidity index during the dormant period in 2007 (ho1M) was 418.9% times higher than the average (Annex 1). Nowak and Sculz (2002) considered that *F. rubra* L. increased markedly after several rainy years, a result similar to our own. The preferences of the indicator species for temperature and rainfall do not correspond to the described situation and it can be asserted that the species' presence is determined mostly by the interaction between the previous year's temperature and humidity (humidity index). Stampfli and Zeiter (2004) have found that *F. rubra* L. increased in abundance with plentiful rainfall in previous years but average or even lower than average rainfall fell in the study year. They also found that *Briza media* L. decreased during drought, a result similar to the present study.

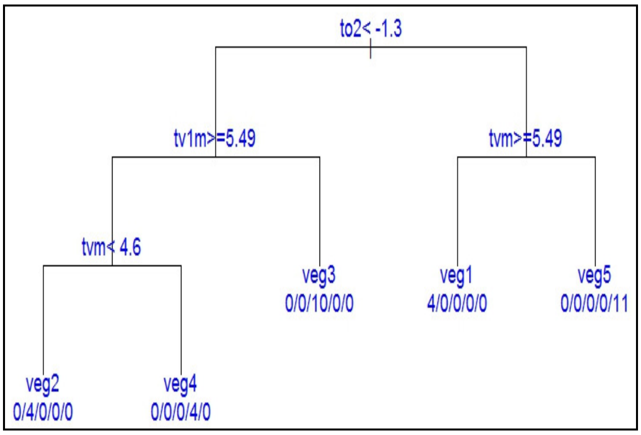

Fig. 4. Climatic factors with major importance to herbaceous layer changes (to2 - temperature of the vegetation period two years before, tvm - the temperature during the vegetation period in the current year, tv1m - the temperature during the vegetation period one year before, veg1 - cluster 1 (2004), veg2 - cluster 2 (2005), veg3 - cluster 3 (2006, 2007, 2010), veg4 - cluster 4 (2008), veg5 - cluster 5 (2009, 2011, 2012)

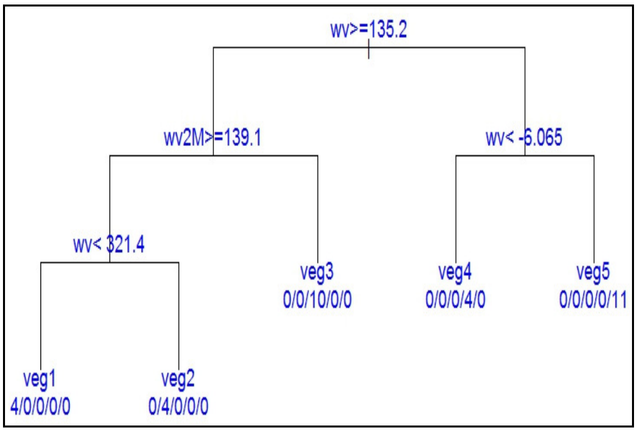

Fig. 5. The synthetic climatic indexes with major importance in herbaceous layer changes (wv - water balance in the current year, wv2M - maximum water balance two years before, veg1 - cluster 1 (2004), veg2 - cluster 2 (2005), veg3 - cluster 3 (2006, 2007, 2010), veg4 - cluster 4 (2008), veg5 - cluster 5 (2009, 2011, 2012)

Cluster 5 (2009, 2011, 2012) was influenced by the maximum temperatures during the vegetation period (tvM) and the maximum temperatures in the dormant period one year before (to1M) and two years before (to2M, Annex 1). Rainfall in the dormant period (po) which, in general, was lower than the average during 2001-2012 also had an influence (Annex 1). Water balance in the dormant period, especially the current year's (wo) balance, which was generally lower than the average during the study period and had a similar influence (Annex 1). Overall, it is *F. rubra* L. as the dominant, *A. capillaris* L. as the co-dominant and *Sanguisorba minor* Scop. as an indicator that were determined first of all by the maximum temperatures both in the current year as well as in previous years and by lower rainfall in the dormant period of the current year. Our results are consistent with Stampfli and Zeiter (2004) who showed that *F. rubra* L. increased its abundance in drought years when compared with *A. capillaris* L. which decreased in abundance. Those authors did not identify changes in *Sanguisorba minor* Scop. abundance after alternating periods of drought and rain.

The classification tree results emphasized that temperature in the dormant period two years before (to2) had the highest influence on changing the herbaceous layer when it was lower than −1.3 °C. This, combined with the minimum temperature during the vegetation period one year before (higher or equal to 5.49 °C), resulted in a specific species composition.

Dostalek and Frantik (2011) studying the dry meadows in the Czech Republic stated that temperature had a lower effect on species abundance and richness compared to precipitation. It is somehow incongruous considering that the limiting factor in their study area is water. However, they found that the annual average temperature in the previous year had no effect upon the species abundance and species richness and only the temperature variation from one year to another played a significant role in the grass canopy changes. Similar to the findings of the present study they reported that the winter temperature considerably influenced the vegetation composition.

Discussion

The impact of climate during 12 years on the *F. rubra* L. – *A. capillaris* L. grassland has led to several alterations in the herbaceous composition which have occurred due to fluctuations and minimal succession. The co-dominance ratio between *F. rubra* L. and *A. capillaris* L. changes towards the dominance of *F. rubra* L at the end of the study period. The high amount of precipitation in the current year and the years before led to the dominance of *A. capillaris* L., whereas high temperatures and lower rainfall caused *F. rubra* L. to become the dominant species.

These results emphasize that precipitation and temperature during the last three years play an even greater role than the current year's precipitation and temperature regarding the grassland vegetation compositional changes. Extreme temperatures affect the herbaceous vegetation not only during the vegetation period but also in the dormant period.

The classification tree result has emphasized that the most important factor in fluctuations and succession on the herbaceous species composition was the temperature. The second most important factor in the fluctuations and succession of *F. rubra* L. – *A. capillaris* L. plant community is the water balance during the current year. Experiments like ours, with long-term observations and equipped with weather stations can provide new information regarding the individual reactions of plant species as well as plant communities' responses to climatic fluctuations or climate changes. Furthermore, it is recommend to verify and to readapt the Ellenberg indicator values (originally adapted by Kovacs (1979) to the Romanian conditions) using up-to-date technologies.

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Annex 1

Individual and combined effect of climatic factors on grasslands phytocoenosys

Cluster		Year	tvm	tvM	tv1	tv1m	tv2m	tv2M	tv3	tv3M	tom	to1	to1M	to2	to2M	to3	to3M
Temperature	1	2004	5.58	14.7	12.83	4.1	6.5	17.1	11.93	15.6	-10.5	-2.12	3.1	0.63	4.6	-0.08	4.1
	2	2005	3.6	14.8	10.59	5.58	4.1	16.3	12.33	17.1	-9.4	-1.63	4.7	-2.12	3.1	0.63	4.6
	3	2006	5.3	15.5	11.03	3.6	5.58	14.7	12.83	16.3	-9.5	-3.88	2.9	-1.63	4.7	-2.12	3.1
		2007	5.9	15.9	11.03	5.3	3.6	14.8	10.59	14.7	-2	-3.72	4	-3.88	2.9	-1.63	4.7
		2010	3.4	16.3	12.2	5.4	5.6	17.4	12.05	15.9	-6	-1.15	6.7	-1.45	8.2	0.32	5.8
	4	2008	5.6	17.4	12.05	5.9	5.3	15.5	11.03	14.8	-5.1	0.32	5.8	-3.72	4	-3.88	2.9
	5	2009	5.4	16.6	12.33	5.6	5.9	15.9	11.03	15.5	-4.8	-1.45	8.2	0.32	5.8	-3.72	4
		2011	4.3	15.4	11.55	3.4	5.4	16.6	12.33	17.4	-4.9	-0.77	4.8	-1.15	6.7	-1.45	8.2
		2012	5.32	17.6	11.77	4.3	3.4	16.3	12.2	16.6	-8.6	-0.77	5.3	-0.77	4.8	-1.15	6.7
		Mean	*4.93*	*16.02*	*11.71*	*4.80*	*5.04*	*16.07*	*11.81*	*15.99*	*-6.76*	*-1.69*	*5.06*	*-1.53*	*4.98*	*-1.45*	*4.90*
Cluster		Year	pv	pvm	pvM	pv1	pv1m	pv1M	pv2m	pv2M	pv3	pv3m	po	po1m	po2m	po3m	
Precipitations	1	2004	720.8	70.9	144.8	637.1	1.8	211.3	64	239	756.4	35.4	668.7	40.6	41.3	60.1	
	2	2005	791.9	25	223.6	720.8	70.9	144.8	1.8	211.3	828.6	64	246.5	55.2	40.6	41.3	
	3	2006	750.6	40.3	185.9	791.9	25	223.6	70.9	144.8	637.1	1.8	256.2	0	55.2	40.6	
		2007	669.2	79	158	750.6	40.3	185.9	25	223.6	720.8	70.9	372.4	5.4	0	55.2	
		2010	803	70.9	194.5	564.4	31.6	152.4	7.2	130.4	669.2	79	658.6	27.2	52.2	3.3	
	4	2008	476.6	7.2	130.4	669.2	79	158	40.3	185.9	791.9	25	432.6	3.3	5.4	0	
	5	2009	564.4	31.6	152.4	476.6	7.2	130.4	79	158	750.6	40.3	433	52.2	3.3	5.4	
		2011	468.6	14	235.6	803	70.9	194.5	31.6	152.4	476.6	7.2	271	72.8	27.2	52.2	
		2012	515.87	35.2	118.8	468.6	14	235.6	70.9	194.5	564.4	31.6	353.94	0.6	72.8	27.2	
		Mean	*640.11*	*41.57*	*171.56*	*653.58*	*37.86*	*181.83*	*43.41*	*182.21*	*688.40*	*39.47*	*410.33*	*28.59*	*33.11*	*31.70*	
Cluster		Year	wv	wvM	wv1	wv2m	wv2M	wv3	wv3M	wo	wo1m	wo2m	wo3m				
Water balance	1	2004	294.94	80.14	127.74	-36.59	146.52	287.14	139.21	607.14	33.21	15.06	60.1				
	2	2005	347.94	131.59	294.94	-103.37	180.63	339.01	146.52	266.27	45.1	33.21	15.06				
	3	2006	308.43	95.92	347.94	12.12	80.14	127.74	180.63	258.35	0	45.1	33.21				
		2007	188.6	92.79	308.43	3.99	131.59	294.94	80.14	222.23	5.4	0	45.1				
		2010	339.89	142.44	81.77	-111.78	57.71	188.6	92.79	531.53	-16.97	20.15	-35.57				
	4	2008	-13.76	57.71	188.6	-19.57	95.92	347.94	131.59	408.45	-35.57	5.4	0				
	5	2009	81.77	81.11	-13.76	-32.41	92.79	308.43	95.92	292.72	20.15	-35.57	5.4				
		2011	1.63	131.69	339.89	-49.09	81.11	-13.76	57.71	427.86	57.24	-16.97	20.15				
		2012	23.59	58.67	1.63	-18.92	142.44	81.77	81.11	263.75	-4.48	57.24	-16.97				
		Mean	*174.78*	*96.90*	*186.35*	*-39.51*	*112.09*	*217.98*	*111.74*	*364.26*	*11.56*	*13.74*	*14.05*				
Cluster		Year	hvm	hvM	hv1m	hv1M	hv2m	hv2M	hv3	hv3m	hv3M	ho	hoM	ho1	ho1M	ho2	ho2M
Humidity index	1	2004	1.13	2.46	0.02	8.67	0.64	3.37	1.56	0.69	2.9	1.84	6.22	1.38	5.76	2.47	10.94
	2	2005	1.05	2.44	1.13	2.46	0.02	8.67	1.97	0.64	3.37	6.64	34.13	1.84	6.22	1.38	5.76
	3	2006	0.67	2.42	1.05	2.44	1.13	2.46	2.19	0.02	8.67	0.58	3.48	6.64	34.13	1.84	6.22
		2007	0.71	2.82	0.67	2.42	1.05	2.44	1.86	1.13	2.46	15.8	83.24	0.58	3.48	6.64	34.13
		2010	0.81	8.14	0.46	3.7	0.06	2.82	1.67	0.71	2.82	2.07	9.66	4.35	25.51	0.23	1.38
	4	2008	0.06	2.82	0.71	2.82	0.67	2.42	1.66	1.05	2.44	0.23	1.38	15.8	83.24	0.58	3.48
	5	2009	0.46	3.7	0.06	2.82	0.71	2.82	1.74	0.67	2.42	4.35	25.51	0.23	1.38	15.8	83.24
		2011	0.19	2.27	0.81	8.14	0.46	3.7	1.33	0.06	2.82	1.72	9.45	2.07	9.66	4.35	25.51
		2012	0.34	2.98	0.19	2.27	0.81	8.14	1.43	0.46	3.7	0.57	3.42	1.72	9.45	2.07	9.66
		Mean	*0.60*	*3.34*	*0.57*	*3.97*	*0.62*	*4.09*	*1.71*	*0.60*	*3.51*	*3.76*	*19.61*	*3.85*	*19.87*	*3.93*	*20.04*
Influence		***		**		*		ns.		°		°°		°°°		*Combined effect*	

Legend: t – average temperature °C ; p – sum of precipitation; w – water balance; h – humidity index; m – minimum value from a month; M-maximal value from a month; v – vegetation period; o – outside vegetation period; 1, 2, 3 – number of years prior.