Polish J. of Environ. Stud. Vol. 18, No. 5 (2009), 949-955

Original Research

Effect of Habitat and Historical Factors on the Distribution of Meadow Plant Species in the Radziejowa Range (Beskid Sądecki Mountains)

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Received: 10 September 2008
Accepted: 12 January 2009

Abstract

The main objective of our study was to quantify the effect of habitat factors and methods of land use in the mid-19th century and in the 1980s on the distribution of meadow plants. Based on canonical correspondence analysis (CCA), it was found that altitude, solar radiation and the duration of meadow use had the greatest effect on the species composition of grasslands. Because these factors are often correlated with one another, it is difficult to identify the decisive factor. Many species were limited to areas characterized by long duration of meadow use and unfavourable conditions for agricultural production. For these species to be preserved, an incentive system that gives preference to marginal land is required.

Keywords: mountain grasslands, biological diversity, history of land use

Introduction

Grasslands, which form a major part of the seminatural cultural landscape in mountains, are important for preserving the diversity of plant communities and species. As a result, agri-environmental programmes that promote grassland use have been introduced in many European countries, including Poland. However, these efforts were often found to be of low efficiency [1-4], which is probably due to very general recommendations and the fact that grassland use is not adjusted to individual communities and species. For this reason, it is necessary to identify factors affecting grassland distribution and species composition before detailed projects are made.

Many authors hold that the main factor affecting species diversity are soil parameters, in particular the abundance of nitrogen and phosphorus in the soil, and pH value [5-7]. In the mountain areas, considerable differences in vegetation result from the topographic factor [8], i.e. altitude and slope exposure. The prevalence of plants is also affected by human activities such as current use (cutting, grazing) [9-13] and land use history [5, 14].

The objective of the study was to quantify the effect of different habitat factors and history of past land use on the prevalence of some meadow plant species in a topographically diverse area subjected to different utilization methods in the past.

Material and Methods

The Radziejowa range belongs to the Beskid Sądecki Mountains, which are part of the Beskid Wysoki Mountains. Grasslands are found at altitudes ranging from 340 m to almost 1000 m above sea level. Brown soils proper (leached and gleyed) occupy the largest area. The mean annual air temperature ranges from 3ºC on the northern outskirts of Beskid Sądecki to approx. 1.5ºC in the flat-topped parts of the mountains. The annual precipitation ranges from 800 mm in Poprad and Dunajec River valleys to 1,100 mm in the highest parts.

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A total of 350 phytosociological relevés of the Radziejowa range grasslands were done using the Braun-Blanquet method [15]. The basic topographic parameters (altitude, slope and exposure) were determined and a soil sample was taken from the root zone. These samples were analyzed for KCl pH and available forms of phosphorus and potassium using the method of Egner as modified by Riehm [16]. Solar radiation, which varied according to exposure and slope, was calculated assuming horizontal surface solar radiation to be 100%. In the 19th century, land use method in the study area was based on Austrian cadastral maps with a scale of 1:2880, while data on land use in the early 1980s were based on topographic maps with a scale of 1:10,000.

Where a large number of phytosociological relevés involve tens of species and numerous factors that affect them, simultaneous analysis of all the relationships is not possible and in spite of some statistical constraints [17] multivariate analysis is used [18, 19]. In the present study, the effect of individual factors on species composition was analyzed using Canonical Correspondence Analysis (CCA), which enables the most important gradients in a data set to be identified. Figures show species that are best adapted to individual environmental factors. Because nominal variables cannot be used directly in multidimensional analysis, the use of a point in the past was noted as dummy variables; they assume 1 if a point belongs to a certain category, and 0 if it does not. We created four variables to illustrate the use of the points in the past:

GG – grassland in the 19th century and in the 1980s;
AA – arable land in the 19th century and in the 1980s;
GA – grassland in the 19th century and arable land in the 1980s;
AG – arable land in the 19th century and grassland in the 1980s.

Ordination analyses were performed using CANOCO for Windows ver. 4.5, and the resulting figures were made using CanoDraw for Windows.

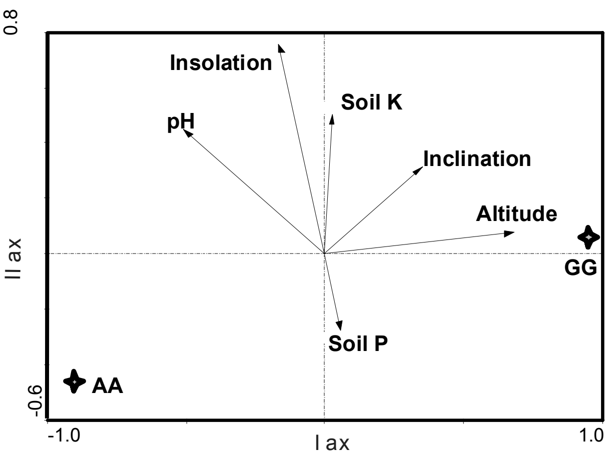

Fig. 1. Ordination diagram of selected variables with axes I. and II. of a Detrended Correspondence Analysis (DCA). Environmental factors are represented by arrows. Land use in the past is represented by stars.

Table 1. Impact of selected variables on botanical composition.

Variable	Eigenvalues	%	F	P
Altogether	0.388	13.99	5.0	0.01
Altitude	0.09	3.3	11.95	0.01
GG	0.09	3.3	11.15	0.01
AA	0.08	2.9	9.84	0.01
pH	0.07	2.7	9.59	0.01
Insolation	0.07	2.5	9.1	0.01
Inclination	0.04	1.6	5.45	0.01
Soil K	0.03	1.1	3.82	0.01
Soil P	0.02	0.7	2.58	0.01

Eigenvalues – measure for explanatory power of the explanatory variables (total inertia = 2.725);
% – percentage of explained variance;
F – F ratio for the test of significance of all canonical axes;
P – corresponding probability value obtained by the Monte-Carlo-permutation test.

Results

Using the forward selection procedure of CCA analysis and the Monte Carlo permutation test, exposure and two variables illustrating past use (AG, GA) were rejected as they did not significantly increase the percentage of variation explained. CCA analysis showed that selected habitat factors account for 13.99% of total variation in species composition. The effect of particular factors, after eliminating the effect of others, is shown in Table 1, and the relationships between factors are illustrated in Fig. 1.

Altitude had the greatest effect on species composition. The greatest correlation with altitude was shown by bilberry (*Vaccinium myrtillus*), mat-grass (*Nardus stricta*) and broad-leaved meadow-grass (*Poa chaixii*) in the higher parts of the massif, and by soft brome (*Bromus hordeaceus*), field bindweed (*Convolvulus arvensis*) and corn speedwell (*Veronica arvensis*) in the lower parts of the massif (Fig. 2). Sickle alfalfa (*Medicago falcata*), fairy flax (*Linum catharticum*) and agrimony (*Agrimonia eupatoria*) were found in the areas with higher soil pH, while common hawkweed (*Hieracium lachenalii*), mat-grass, heath speedwell (*Veronica officinalis*) and oakforest woodrush (*Luzula luzuloides*) were associated with higher soil acidity (Fig. 2).

Higher solar radiation values favoured the prevalence of greater knapweed (*Centaurea scabiosa*), hoary plantain (*Plantago media*) and heath sedge (*Carex flacca*). True oxlip (*Primula elatior*) and spiked rampion (*Phyteuma spicatum*) were found in areas with the lowest solar radiation. The species associated with high slope inclination were mountain clover (*Trifolium montanum*), heath grass (*Danthonia decumbens*) and woodland strawberry (*Fragaria vesca*). Flat areas were typified by species associated with lowland communities such as dandelion (*Taraxacum officinalis*), rough bluegrass (*Poa trivialis*), common mouse-ear (*Cerastium holosteoides*) and bush vetch (*Vicia sepium*) (Fig. 3).

The available phosphorus content of soil varied considerably but showed little variation according to species. Broad-leaved meadow-grass and wild angelica (*Angelica sylvestris*) showed the largest correlation with this parameter. Slightly higher species correlations were found for the available potassium content of soil. The highest correlation with elevated potassium levels was shown by thermophilic species such as sickle alfalfa, greater knapweed (*Centaurea scabiosa*) and cypress spurge (*Euphorbia cyparissias*), and by species such as caraway (*Carum carvi*). Species found in areas with the lowest potassium content were broad-leaved dock (*Rumex obtusifolius*) and soft brome (Fig. 4).

Analysis of past land use showed that there were two distinctive groups of species. First associated with continuous meadow use since the mid-19th century and second associated with areas that recently served as arable land. Long-term meadow use is associated to a large extent with wavy hairgrass (*Deschampsia flexuosa*), bilberry and wood betony (*Betonica officinalis*). The species associated with the shortest formation of the meadow community include ruderal species such as broad-leaved dock, broad-leaved chervil (*Chaerophyllum aromaticum*) and wild chervil (*Anthriscus sylvestris*) (Fig. 5).

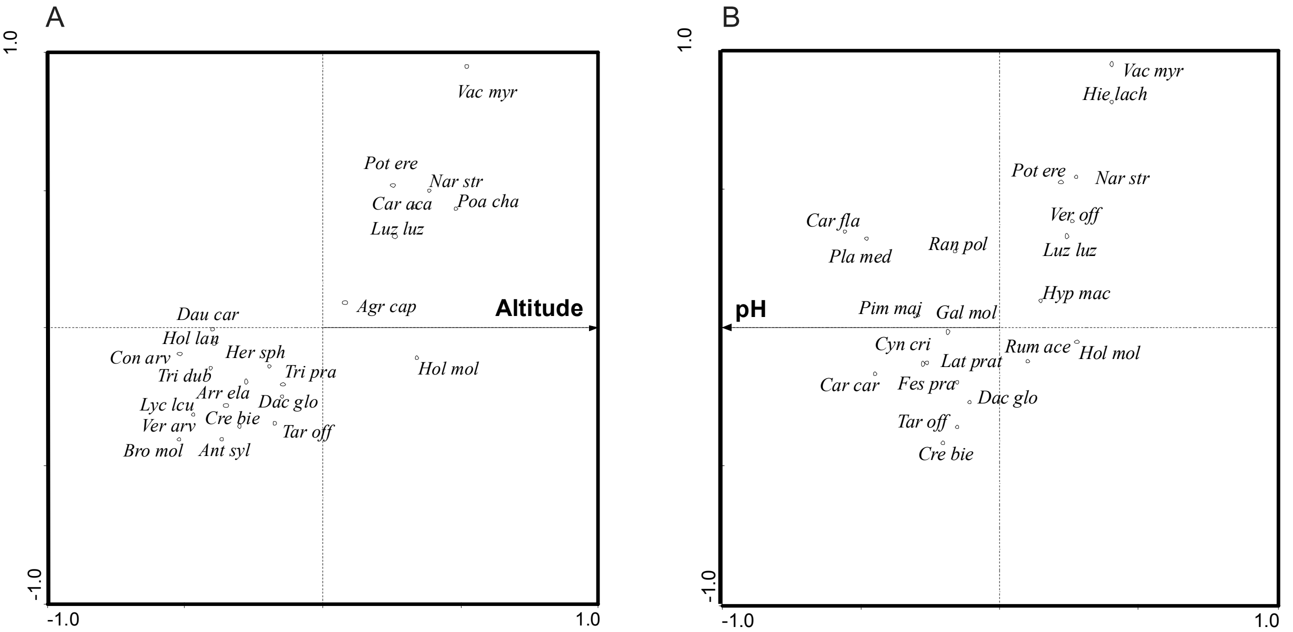

Fig. 2. Ordination diagram (CCA) of best-fitted species to altitude (A) and pH (B).

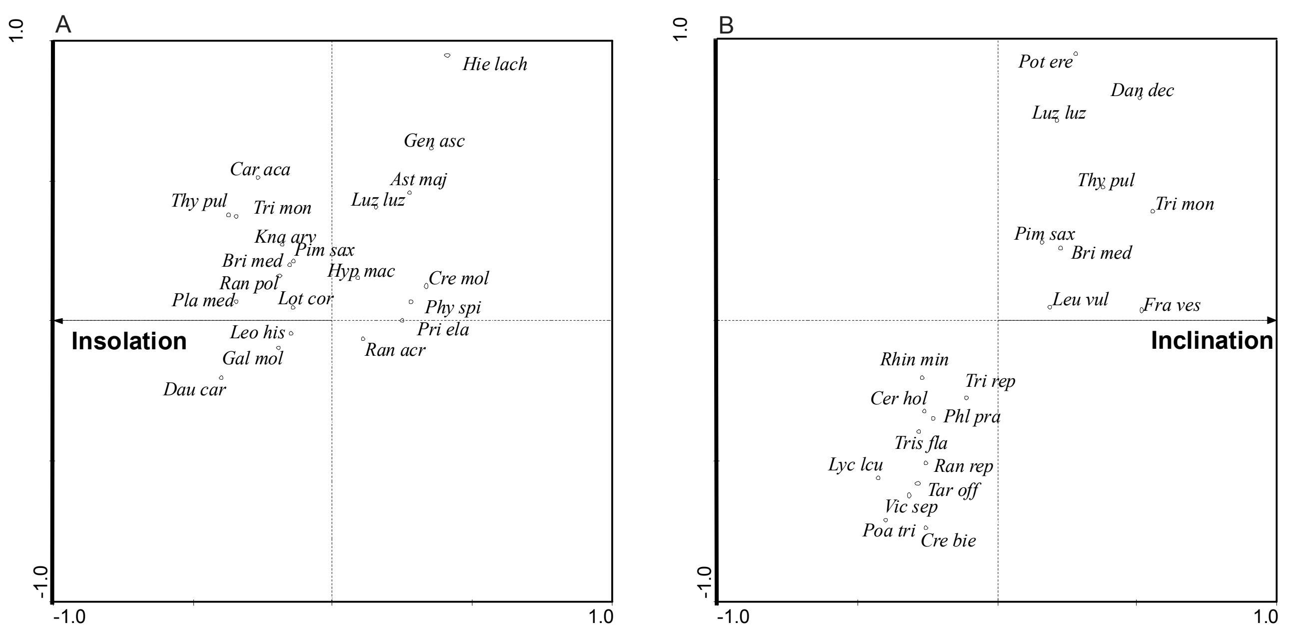

Fig. 3. Ordination diagram (CCA) of best-fitted species to insolation (A) and inclination (B).

Discussion of Results

Because the analyzed factors are often strongly correlated, it is not possible to identify the dominant factor because the species composition of plant communities is the result of habitat factors and method of use [3]. There was no available information about present management of grasslands (e.g. level of fertilization, number of cuts etc.), which is an important factor determining the species composition. In effect, the percent of variation explained is relatively low. Based on the present results, two basic groups of species related to the first DCA axis can be identified, which correspond to the course of largest species variation. The first group includes species found in the highest parts of the range, on highly inclined slopes with strongly acidified soils. These conditions also involve the long-term use of land as grasslands. Similar relationships between the duration of meadow use and altitude and soil pH were obtained in Norway [5] and in Germany [13]. Such areas comprise species typical of sparse mat-grass swards (*Nardo-Calunetea*): mat-grass and tormentil (*Potentilla erecta*); and spruce forests (*Vaccinio-Picetea*): bilberry and wavy hairgrass.

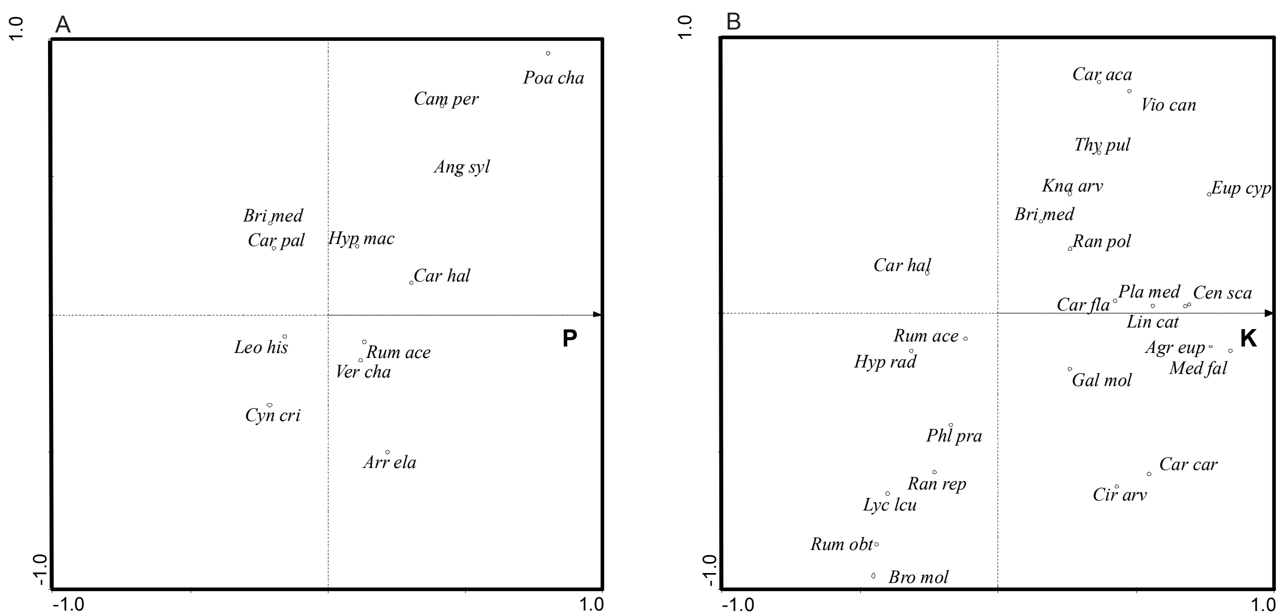

Fig. 4. Ordination diagram (CCA) of best-fitted species to available soil P content (A) and K content (B).

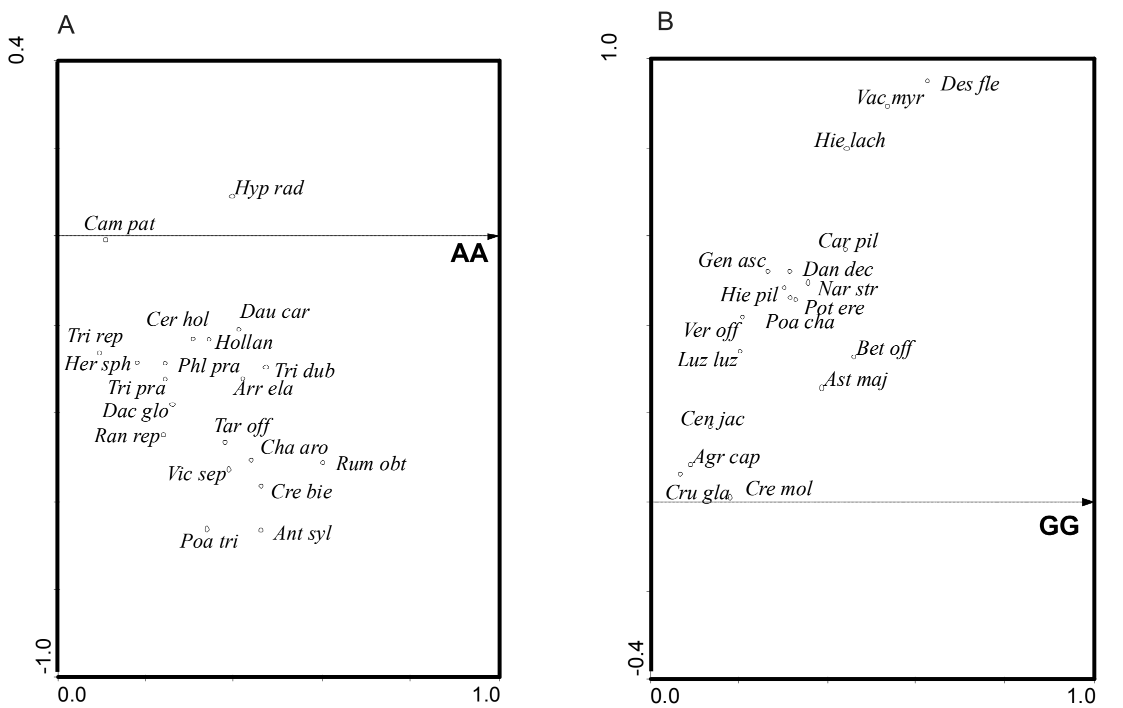

Fig. 5. Ordination diagram (CCA) of best-fitted species to short grassland use (A) and long grassland use (B).

Table 2. Abbreviations of species names used in Figures.

Agi eup	*Agimonia eupatoria*	*Dan dec*	*Dantonia decumbens*	*Phy spi*	*Phyteuma spicatum*
Ang syl	*Angelica sylvestris*	*Dau car*	*Daucus carota*	*Pim maj*	*Pimpinella major*
Ant syl	*Anthriscus sylvestris*	*Des fle*	*Deschampsia flexuosa*	*Pim sax*	*Pimpinella saxifraga*
Arr ela	*Arrhenatherum elatius*	*Eup cyp*	*Eupatoria cyparisias*	*Pla med*	*Plantago media*
Ast maj	*Astrantia major*	*Fes pra*	*Festuca pratensis*	*Poa cha*	*Poa chaixi*
Bet off	*Betonica officinalis*	*Fra ves*	*Fragaria vesca*	*Poa tri*	*Poa trivialis*
Bri med.	*Briza media*	*Gal mol*	*Galium mollugo*	*Pot ere*	*Potentilla erecta*
Bro mol	*Bromus mollis*	*Gen asc*	*Gentiana asclepiadea*	*Pri ela*	*Primula elatior*
Cam per	*Campanula persicifolia*	*Her sph*	*Heracleum sphondylium*	*Ran rep*	*Ranuculs repens*
Car hal	*Cardaminopsis halleri*	*Hie lac*	*Hieracium lachenali*	*Ran acr*	*Ranuculus acris*
Car fla	*Carex flava*	*Hie pil*	*Hieracium pilosella*	*Ran pol*	*Ranunculus polyanthemos*
Car pil	*Carex pilulifera*	*Hol lan*	*Holcus lanatus*	*Rhi min*	*Rhinanthus minor*
Car aca	*Carlina acaulis*	*Hol mol*	*Holcus mollis*	*Rum ace*	*Rumex acetosa*
Car car	*Carum carvi*	*Hyp mac*	*Hypericum maculatum*	*Rum obt*	*Rumex obtusifolius*
Cen jac	*Centaurea jacea*	*Hyp rad*	*Hypochoeris radicata*	*Thy pul*	*Thymus pulegiodes*
Cen sca	*Centaurea scabiosa*	*Kna arv*	*Knautia arvensis*	*Tri mon*	*Trifolim montanum*
Cer hol	*Cerastium holosteoides*	*Lat pra*	*Lathyrus pratensis*	*Tri dub*	*Trifolium dubium*
Cha aro	*Chaerophyllum aromaticum*	*Leu vul*	*Leucanthemum vulgare*	*Tri pra*	*Trifolium pratense*
Cir arv	*Cirsium arvense*	*Lin cat*	*Linum catharticum*	*Tri fla*	*Trisetum flavescens*
Con arv	*Convolvulus arvensis*	*Lot cor*	*Lotus corniculatus*	*Vac myr*	*Vaccinium myrtillus*
Cre bie	*Crepis bienis*	*Luz luz*	*Luzula luzuloides*	*Ver arv*	*Veronica arvensis*
Cre mol	*Crepis mollis*	*Lyc lcu*	*Lychnis flos-cuculi*	*Ver cha*	*Veronica chamaedrys*
Cru gla	*Cruciata glabra*	*Med fal*	*Medicago falcata*	*Ver off*	*Veronica officinalis*
Cyn cri	*Cynosurus cristatus*	*Nar str*	*Nardus stricta*	*Vic sep*	*Vicia sepium*
Dac glo	*Dactylis glomerata*	*Phl pra*	*Phleum pratense*	*Vio can*	*Viola canina*

Lower altitudes are dominated by habitats with low inclination and higher soil pH. These habitats are characterized by relatively good productive properties, which is why they were recently used as arable land. They were changed into grassland by sowing meadow mixtures or through spontaneous revegetation. In most cases, these are unstabilized communities. The species found under these conditions include plants typical of lower communities of the order Arrhenatheretalia: cocksfoot (*Dactylis glomerata*), meadow fescue (*Festuca pratensis*), tall oat-grass (*Arrhenatherum elatius*), and Queen Anne's lace (*Daucus carota*). Ruderal species such as field bindweed, broad-leaved dock and wild chervil are also found. Differences in habitat fertility also vary according to the main gradient of plant variation. In many cases, this factor is considered decisive for the occurrence of meadow species [6, 20].

The second DCA axis is correlated with the content of available phosphorus and potassium and solar radiation. Only the group of thermophilic species occurs on soils with a higher potassium content. These include agrimony, sickle alfalfa and dodder (*Cuscuta epithymum*), which are common on the meadows of the neighbouring Pieniny Mountains. Unlike the results of many meadow vegetation studies in Western Europe, where high phosphorus content is considered an important factor reducing species diversity [20-23], influence of this factor on botanical composition of grassland sward in Radziejowa Range is low. One possible explanation is the presence of phosphorus-deficient soils in the Beskid Sądecki and the low level of phosphorus fertilization. It is in accordance with results obtained by many authors [11, 20, 23, 24]. They found a significant effect of available phosphorus content on botanical composition of grassland but only in the case of high phosphorus content. The analysis revealed a few species connected with the naturally most interesting mountain meadow community (*Gladiolo-Agrostietum*). The main reason is that they occur when the analyzed factors were at a medium level. Only brown knapweed (*Centaurea jacea*), colonial bentgrass (*Agrostis capillaris*) and Northern Hawk's-beard (*Crepis mollis*) were associated with long-term meadow use.

Conclusions

A large number of meadow species are only found in communities that are marginal from the agricultural point of view (high altitude, low pH, steep slope) and have long been used as meadows and pastures. A similar relationship that the high nature quality species are found mainly in undisturbed natural or semi-natural habitats has been reported by other authors [24, 25]. The socio-economic processes result in such areas being abandoned or afforested, which takes place in Poland and other European countries [26-29]. Feed production in the Beskidy Mountains is now carried out mainly on old arable land characterized by better production conditions, but the plants that grow there usually represent common species. For many species that have adapted to specific habitat conditions and show low ecological amplitude to be preserved, it is necessary to use a system of payments that gives preference to the use of meadows and pastures at higher altitudes and on poorer soils, even at the cost of reducing subsidies on grasslands on old arable land of low natural value. Result-orientated subsidies in grasslands should be created and the farmers are to be paid for keeping up a high plant species richness [4, 13]. In case of well prepared, prescriptions the results can be satisfactory [30].

Acknowledgements

This article was prepared as a part of research project No. 2P06S 01228 financed by the State Committee for Scientific Research.

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