

Article

Impact of Land Use Changes on the Diversity and Conservation Status of the Vegetation of Mountain Grasslands (Polish Carpathians)

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Abstract: In recent decades, in the Polish Carpathians, agriculture has undergone major changes. Our goal was to investigate whether the former management (plowing or mowing and grazing) had an impact on the current species composition, diversity and conservation status of the vegetation of grazing areas. We carried out vegetation studies on 45 grazing sites with traditional methods of grazing (transhumant pastoralism). The survey covered both old (continuous) grasslands and grasslands on former arable land. The most widespread were *Cynosurion* pastures and mesic *Arrhenatherion* grasslands. Wet *Calthion* meadows occurred at more than a half of grazing sites, while nutrient-poor *Nardetalia* grasslands were only recorded at several grazing sites. For each grazing site, we used soil maps from the 1960s to read land use in the past. We mapped present grassland and arable land area. Compared with the 1960s, there was a significant decrease in the area of arable land and an increase in grasslands. Species diversity was greater in grazing sites where grasslands developed on former arable land. However, this diversity was associated mainly with the occurrence of common grassland species. *Cynosurion* pastures and wet *Calthion* meadows had the best conservation status, while nutrient-poor *Nardetalia* grasslands were the worst preserved. We concluded that the conservation status of mesic grasslands and pastures is dependent on the present diversity of land use within a grazing site, rather than the land use history 60 years ago. This is the first study of the natural, not economic, value of pasture vegetation in the Polish part of the Carpathians.

Keywords: grazing management; biodiversity; high-nature-value farming; old field grassland



Citation: Zarzycki, J.; Korzeniak, J.; Perzanowska, J. Impact of Land Use Changes on the Diversity and Conservation Status of the Vegetation of Mountain Grasslands (Polish Carpathians). *Land* **2022**, *11*, 252. <https://doi.org/10.3390/land11020252>

Academic Editor:
Alexandru-Ionuț Petrișor

Received: 13 December 2021

Accepted: 1 February 2022

Published: 8 February 2022

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1. Introduction

Grasslands provide a variety of ecosystem services, such as cultural landscape and environmental values [1]. They are significant reservoirs of biodiversity and belong to the most species-rich plant communities in Europe [2]. Apart from an abundance of plant species, they are also the habitat for a multitude of animal species from different taxonomic groups, such as insects, arachnids, and snails [3]. The biodiversity of grassland is also related to the time since the transformation of arable land into grassland.

The majority of grasslands in Europe originated as a result of the interaction of environmental conditions and farming by grazing and mowing [4]. However, social and economic transformations in the 20th century provoked changes in land use and management practices in agriculture. In Western Europe, this process particularly accelerated in the 1950s/1960s [5], while in Eastern Europe after the political transformation at the beginning of the 1990s [6]. As a result, the area covered by grasslands has been decreasing. On the one hand, wherever land is suitable for agricultural use, grasslands are transformed into arable fields or the intensity of such use increases [7,8], which results in the development of highly productive but species-poor communities [9]. On the other hand, in marginal

areas less suitable for agriculture, land use is abandoned, which promotes secondary forest succession and the disappearance of grassland communities [10–12]. It is particularly disadvantageous because grassland communities in infertile habitats are characterized by the highest natural value and diversity [9,13]. In the Carpathians, the expansion of forest cover has been progressing for over a century and has especially hastened in recent decades [14]. Despite a significant increase in forest cover, the area of grasslands is not only not reduced but even grows [15], as former arable fields are transformed into meadows and pastures. Similar processes were also observed in other montane regions, e.g., in the Caucasus [16], in Slovakia [17] and in the Apennine mountains [18]. As a consequence, a large portion of grasslands in the Carpathians is situated at present on the former arable fields. They are usually located at lower altitudes and on more fertile soils. The species composition of such communities also formed over a short period. For this reason, these plant communities are usually species-poor and are characterized by a lack of many specialist grassland species [19,20].

A number of studies indicate that the species composition of communities, their diversity and the occurrence of rare species are related not only to the current management but also to the habitat history [21,22]. The historical land use and land use sequences shaped the vegetation of Swedish semi-natural grassland more so than the current management. The highest diversities of grassland plants have been found in pastures continuously grazed since the 18th century [21]. The continuity of extensive mowing and grazing has a positive effect on the occurrence of grassland and forest edge specialist species [22]. The spatial context is also important: the present and historical habitat connectivity influences fine-scale plant species diversity in grazed temperate semi-natural grasslands [23].

Traditional pastoral systems in many mountain areas (Carpathians, Alps, Pyrenees) consisted of transhumance, i.e., grazing livestock at higher altitudes in summer and descending with the herd into valleys for the winter [24]. Such a pastoral system has been used up till now in Romania [25], Ukraine [26], Switzerland, Scandinavia, France and Spain [27]. In Poland, at the end of the 1980s, the period of transition into an open-market economy saw a livestock population crash; for instance, the sheep population was dramatically reduced from 4,837,000 in 1985 to 266,911 in 2018 [28], due to the decreased profitability of agricultural production. However, since the mid-2000s, we have witnessed a revival of transhumant pastoralism in the Polish Carpathians [29] thanks to subsidies under the Common Agricultural Policy (CAP). However, the most common locations of transhumance have changed [29]. New grazing sites are located at lower altitudes and primarily on the site of arable fields (Figure 1). The term grazing sites suggests that they are covered only by pastures. However, in practice, parcels of land used as grazing sites are very diverse and harbor natural and semi-natural types of vegetation, and also arable fields. A sheep herd migrates daily within the grazing sites and in the evening the sheep return to a portable shelter. Biodiversity conservation in rural areas is analyzed in connection with viewing these areas as a patch–corridor matrix, which is a dynamic system linking natural processes with current human impact and its future consequences [30]. This approach, based on a landscape-level perspective, is increasingly often adopted in the conservation of semi-natural grasslands [31,32].

The aim of this work was to characterize the sites used for traditional pastoralism, treated as a kind of functional unit, in terms of (a) the species composition and diversity of plant communities occurring in these areas, (b) the evaluation conservation status of these communities, and (c) the impact of land use in the past and historical and present grassland area to arable land area ratio, on the species diversity and conservation status of grassland.



Figure 1. Grazing on former arable land in the Pieniny Mts.

2. Materials and Methods

2.1. Study Area

The study was carried out at 45 grazing sites located in 7 physico-geographical regions in the Polish part of the Western Carpathians (Figure 2) extending 45 km N–S and 95 km E–W. The extent of the area from the west to the east in combination with a wide range of altitudes (347–1159 m a.s.l.) caused large variations in climatic conditions. The area of grazing sites was diverse and ranged from 15 to 145 hectares (Table 1). All study sites have been extensively grazed by sheep (livestock density did not exceed 0.5 LU/ha) for at least a few years, but most of them have been used in this way for a long time. The survey covered both old (continuous) grasslands and those on former arable land. Vegetation of the grazing sites primarily comprised different types of grasslands with scattered patches of forest, thickets, fields and fallow lands, wetlands covered by fen and marsh vegetation, and sporadic small orchards.

2.2. Methods

Vegetation studies were performed in summer 2017. To analyze the species composition of the main types of grasslands, phytosociological relevés were taken according to the Braun-Blanquet method in 25 m² plots [33]. Since the grazing sites differed in area, we took 1 relevé per 10 ha of grazing site area. In total, in all 45 sites, 420 relevés were performed. The thickness of the litter layer was also measured for each relevé. In order to assess the conservation status of the grassland types within each grazing site, their structure and function were evaluated (a proxy of habitat quality). The assessment was based on the methodology applied in the Monitoring of Natural Habitats in Natura 2000 areas, which is conducted in Poland by the Chief Inspectorate for Environmental Protection [34]. Since many patches of mesic grasslands were of transitional nature between habitat types 6510 (lowland hay meadows) and 6520 (mountain hay meadows), they were analyzed jointly as mesic *Arrhenatherion* grassland. Nutrient-poor *Nardetalia* grasslands were classified as the Natura 2000 habitat 6230. The assessment of the structure and function of *Cynosurion* pastures and wet *Calthion* meadows, not included in Annex I to the Habitats Directive [35], was based on an analogical formula, as for habitats 6230, 6510 and 6520. Habitat structure and function were assessed according to a three-point scale: favorable, unfavorable

inadequate and unfavorable bad. The composite result of the evaluation of indices was defined individually for each habitat. The following indices were assessed: spatial structure of habitat patches, diagnostic species, invasive alien species, expansive species of herbs, and expansion of shrubs and trees [34]. The nomenclature of vascular plant species was adopted according to Mirek et al. [36]. Field work also included mapping the grassland and arable land area.

The variability of the species composition of grassland vegetation was assessed based on phytosociological relevés. To reduce redundancy due to the oversampling of some areas, the set of 420 relevés was subjected to stratified resampling [37] in JUICE 7.0 [38]. We assumed that the mean geographical distance between all pairs of relevés belonging to the same grassland type should be at least 0.5 km, which corresponds to a geographical grid of 0.25 latitude \times 0.4 longitude. The resulting data set used in ordination analyses contained 294 relevés. The unweighted mean Ellenberg Indicator Values (EIV) were calculated for every relevé.

Agricultural soil maps from the 1960s, digitized and georeferenced using QGIS 3.16.7., were used to calculate the area of grassland and arable land at that time in each grazing site. As a quality assessment of grazing sites for agricultural production, indicators of the quality and usefulness of agricultural soils (QUAS) were used [39]. These indicators are the result of calculations made for soil valuation classes and soil-agricultural complexes shown on soil maps. The method of land use (arable vs. grassland) where the relevé was located was also read from the soil maps.

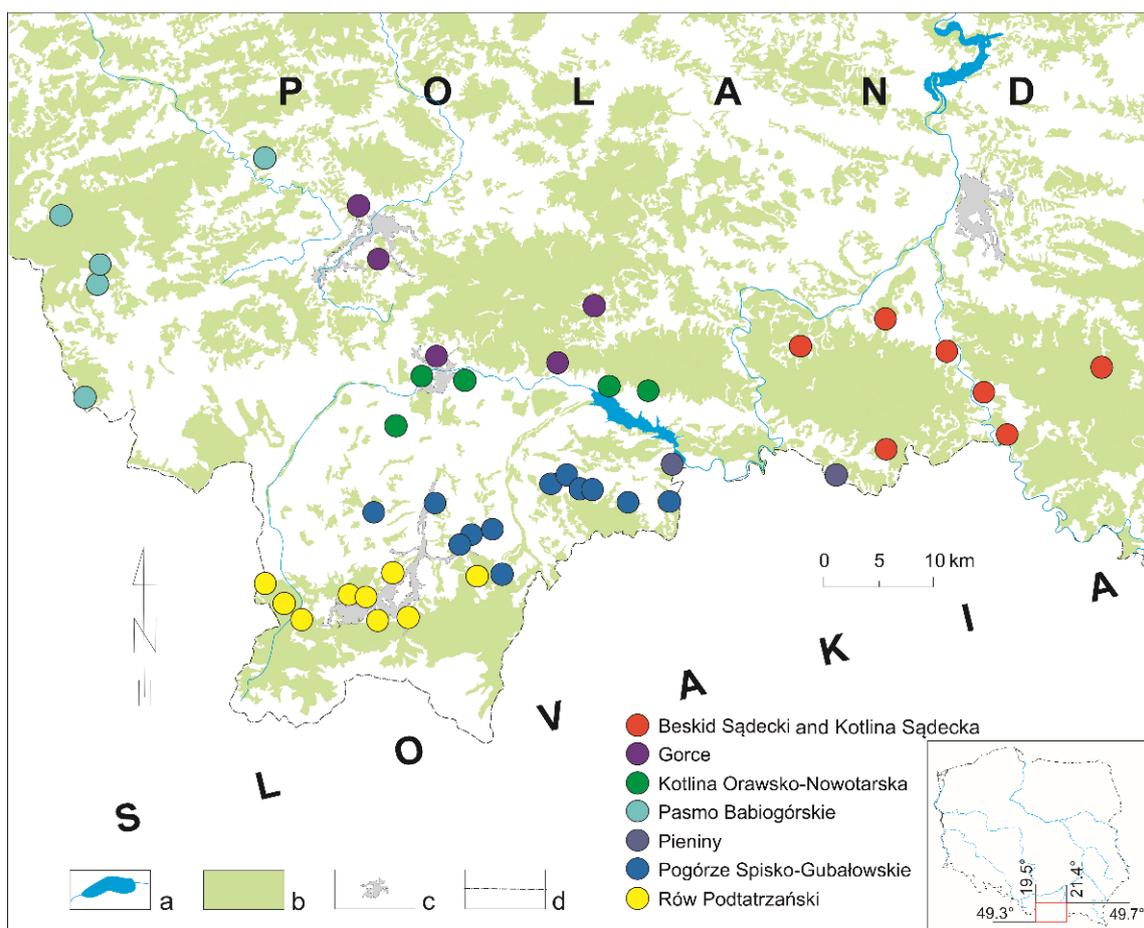


Figure 2. Locations of the grazing sites within regions in the Polish Carpathians. The regions are displayed as colored circles. Explanations: (a) rivers and water bodies, (b) forests, (c) localities, (d) state border.

Table 1. Diversity of grassland types in relation to land use in the past. Land use in the 1960s: G-grassland; A-arable fields.

Region (No of Grazing Sites)	Altitude Range (m a.s.l.)	Mean Slope Angle (deg)	Annual Mean Temperature (°C)	Annual Mean Precipitation (mm)
Pasma Babiogórskie (5)	481–1037	6.5	6–7	830–980
Kotlina Orawsko-Nowotarska (5)	567–807	4.4	6–7	730–850
Pogórze Spisko-Gubałowskie (12)	588–1055	9.2	6–8	540–930
Rów Podtatrzański (9)	794–1159	9.3	4–5	1000–1080
Gorce (5)	518–1012	10.4	4–7	820–1350
Pieniny (2)	490–924	11.5	6–7	730–760
Beskid Sądecki (6) and Kotlina Sądecka (1)	347–908	11.9	5–8	700–850

The diagnostic species [40] for the grassland phytosociological syntaxa (*Calthion*, *Arrhenatherion*, *Polygono-Trisetion*, *Cynosurion*, *Nardetalia*, *Arrhenatheretalia*, *Molinio-Arrhenatheretea*) were distinguished and used to classify relevés into the main types of grassland vegetation. The main diversity measures for sites were determined: average number of vascular plant species in a relevé (α diversity), total number of vascular plant species in all relevés within a grazing site (γ diversity) and the number of diagnostic species for grassland syntaxa.

To explore major gradients in species composition of the main grassland types and their relationship with environmental characteristics and past land use, the Detrended Correspondence Analysis (DCA) was performed using the CANOCO 5.10. For the ordination analysis, species abundance data from 294 plots were square-root transformed with the downweighting of rare species [41]. Because of a lack of normality, the Spearman rank-correlation coefficient for the analyses of relationships between site species diversity, habitat quality and site environmental characteristics was used. Correlations were analyzed using Statistica 13.1.

3. Results

3.1. Changes in Land Use

In the 1960s, arable fields dominated in the areas of analyzed grazing sites, and only 3 sites were entirely without them (Figure 3). In 8 sites, 90% of the area was covered by arable fields. In 2017, the area of arable land was marginal and 22 grazing sites were completely devoid of them, while in 16, the share of arable fields to the total grazing site area was lower than 10%. Only in two grazing sites was the share of arable fields relatively high, amounting to 40%. A QUAS calculated for grazing sites were low and as many as 39 grazing sites did not exceed 35 points (on an 18–100-point scale) (Figure 4).

3.2. Species Composition and Diversity of Four Types of Grasslands

The most widespread vegetation types were pastures of the *Cynosurion* R. Tx. 1947 alliance, mostly *Festuco-Cynosuretum* Bükér 1941, and mown and grazed grasslands of the *Arrhenatherion elatioris* (Br.-Bl. 1925) Koch 1926 alliance. Due to a diverse pattern of land use as hay meadows and pastures, many phytocenoses were of a transitional nature, between a pasture and a hay meadow. Wet eutrophic meadows of the *Calthion palustris* R. Tx. 1936 em. Oberd. 1957 alliance occurred at more than a half of grazing sites. *Cirsietum rivularis* Nowiński 1927 was encountered most often, *Scirpetum sylvatici* Ralski 1931 was rarer while *Epilobio-Juncetum effusi* Oberd. 1957 occurred at intensely grazed places. Nutrient-poor grasslands with *Nardus stricta* of the *Nardetalia* Prsg. 1949 order were only recorded at 18 grazing sites. They usually appeared as small patches, often with a large proportion of species typical of the neighboring meadows.

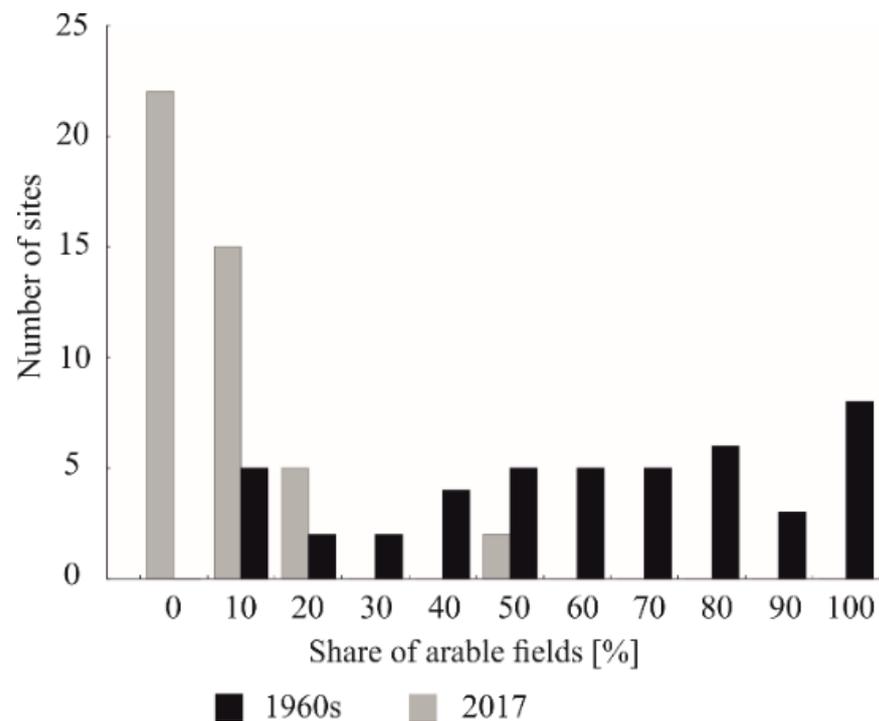


Figure 3. Number of grazing sites in classes of arable field area in the 1960s and in 2017.

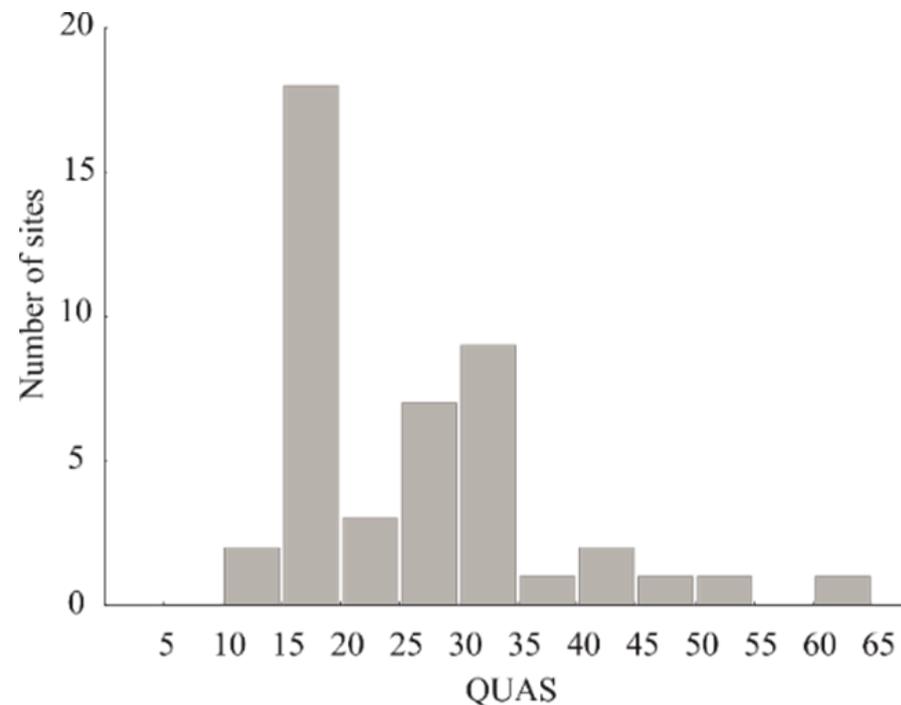


Figure 4. Number of grazing sites in classes of quality and usefulness of agricultural soils index (QUAS).

The main grassland vegetation variability gradient represented by the first DCA axis is associated with soil moisture (Figure 5). The second DCA axis mostly reflects differences in soil fertility, separating nutrient-poor *Nardetalia* grasslands from the remaining grassland types. The occurrence of nutrient-poor grasslands is positively correlated with slope and litter thickness, which suggests a lack of agricultural use. Wet *Calthion* meadows are associated with “old” grasslands. For the remaining types of grasslands, historical land use either as arable fields or grassland is not important. The diagram shows a large

degree of similarity between the species composition of *Cynosurion* pastures and mesic *Arrhenatherion* grasslands, and dissimilarity with wet meadows and, to a lesser extent, also *Nardetalia* grasslands. Wet *Caltion* meadows were observed to include a lower proportion of the relevés located on former arable fields compared with the remaining grassland types (Table 2). On the other hand, relevés classified as mesic *Arrhenatherion* grasslands occur more often on former arable fields than on “old” grasslands. In pastures and nutrient-poor *Nardetalia* grasslands, the number of relevés taken on former fields and “old” grasslands is almost equal.

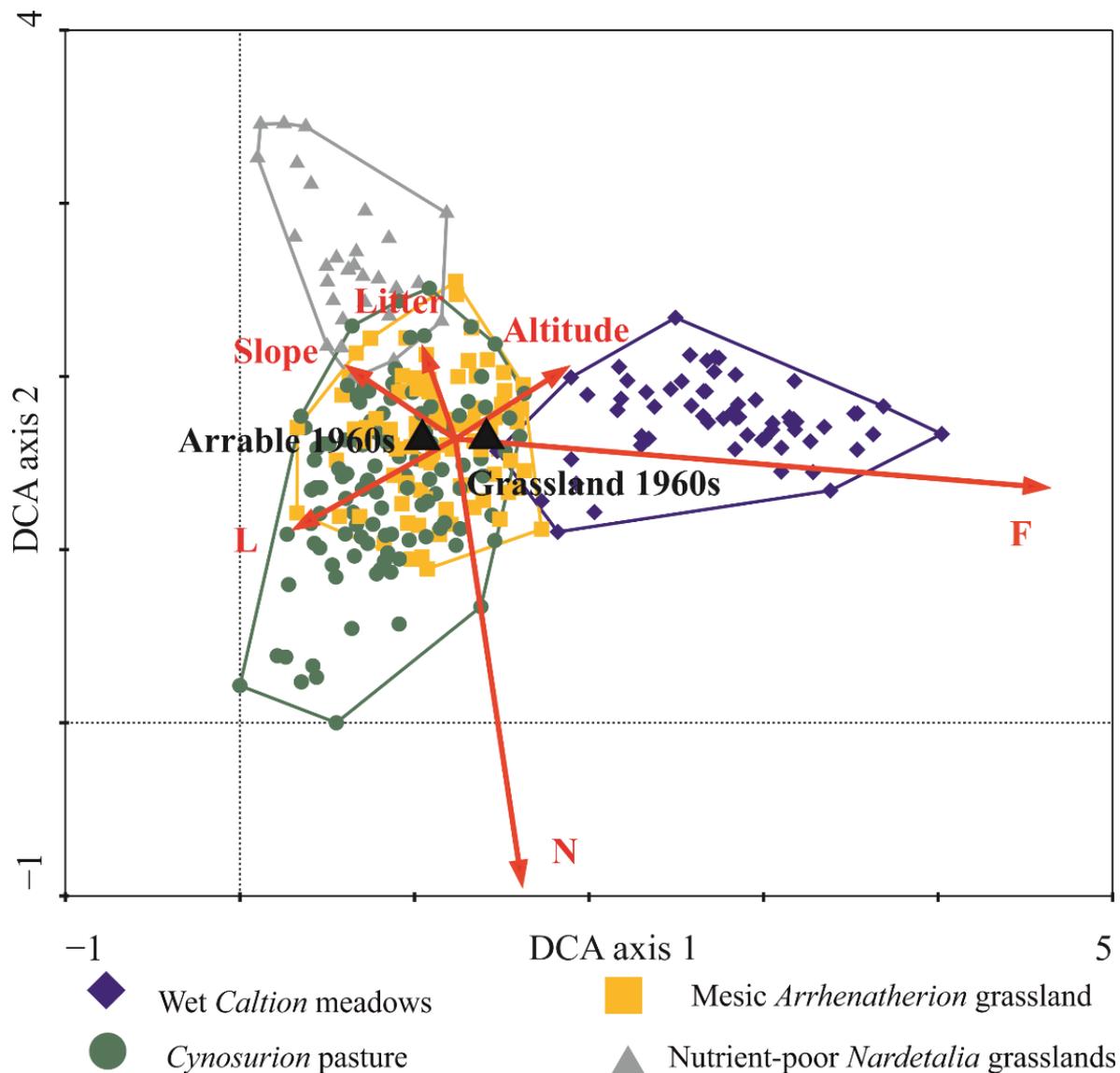


Figure 5. The Detrended Correspondence Analysis (DCA) ordination diagram of 294 plots categorized by grassland type with environmental vectors as overlay. Eigenvalues were 0.506 and 0.276 for the first and second axis, respectively. Cumulative percentage variance of species data for the first and the second axis were 4.9% and 7.5%, respectively. Ellenberg Indicator Values: F-moisture, L-light, N-nutrients.

Table 2. Diversity of grassland types in relation to land use in the past. Land use in the 1960s: G-grassland; A-arable fields.

Grassland Type	Land Use in the 1960s	No. of Relevés	Mean Species Richness (SD)	Mean Shannon Index (SD)
Wet <i>Caltion</i> meadows	G	47	27.5 (6.8)	2.58 (0.39)
	A	14	25.4 (8.0)	2.39 (0.43)
Mesic <i>Arrhenatherion</i> grassland	G	38	28.4 (7.9)	2.70 (0.40)
	A	53	30.0 (5.9)	2.80 (0.30)
<i>Cynosurion</i> pasture	G	55	22.7 (5.5)	2.46 (0.31)
	A	57	23.7 (6.2)	2.41 (0.37)
Nutrient-poor <i>Nardetalia</i> grassland	G	16	26.9 (7.5)	2.59 (0.34)
	A	14	27.4 (7.2)	2.55 (0.42)

The total number of species (gamma diversity) in grasslands situated in grazing sites ranged from 49 to 104, but only three sites were very poor in species (below 60). The average number of species per phytosociological relevé (alpha diversity) was 26.3, ranging from 17.6 to 34.3.

3.3. Conservation Status

The conservation status assessment of grasslands (Figure 6) showed the worst status of nutrient-poor *Nardetalia* grasslands, which were also rare in grazing sites and occupied the smallest surface areas. The conservation status of the wet meadows was assessed as favorable in one third of grazing areas. Mesic grasslands were present in almost all grazing areas; in more than half of grazing sites, their conservation status was evaluated as inadequate, in nine areas as bad and in eight areas as favorable. *Cynosurion* pastures were recorded in all grazing areas and their status was favorable in almost half, and was assessed as bad only at five sites.

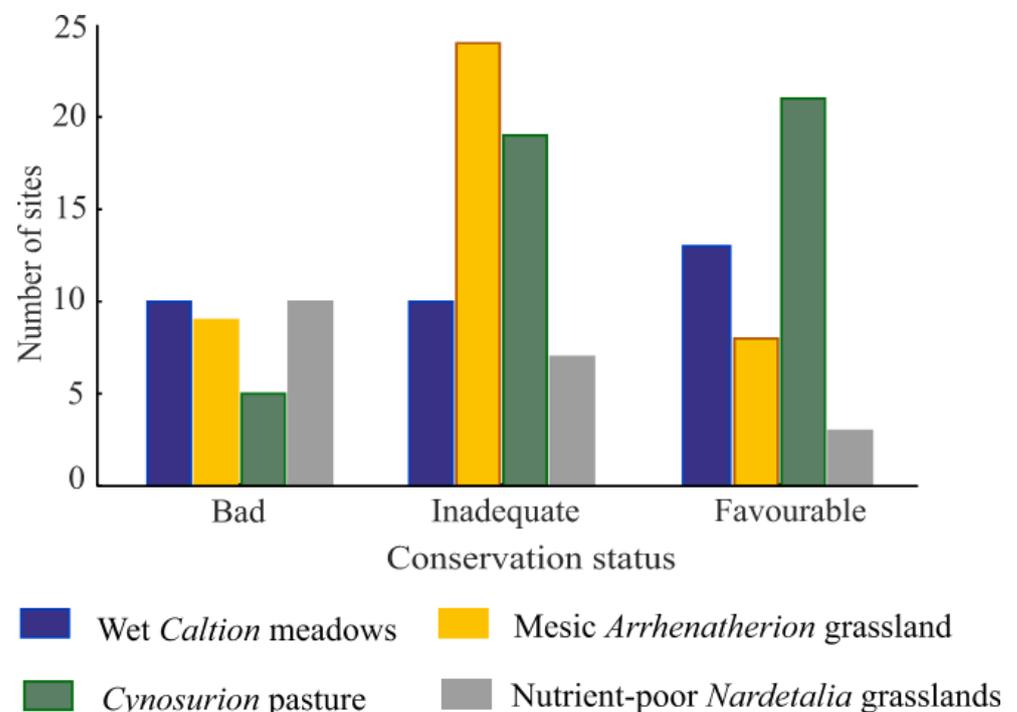


Figure 6. Conservation status of four grassland types evaluated on the basis of an assessment of their structure and function.

3.4. The Effect of Land Use on Species Diversity and Conservation Status of Grasslands

A QUAS index was associated with a greater total number of species in a grazing site and a higher number of species diagnostic of the *Cynosurion*, *Nardetalia*, and other grassland species, but with a lower number of species diagnostic of the *Calthion*. The number of species diagnostic of the *Cynosurion* and species diagnostic for the *Molinio-Arrhenatheretea* class and for the *Arrhenatheretalia* order (*M-A+A*) was positively correlated with the share of arable fields in land use structure in the 1960s, while the number of species diagnostic of the *Calthion* was negatively correlated with this share. The impact of the current share of arable field area in land use structure was much greater and showed a positive correlation with the total number of species in a grazing site, the average number of species in a relevé, and the number of species diagnostic of the *Cynosurion*, grassland species and all other species, but had no effect on the number of species diagnostic of wet meadows (Table 3).

Table 3. Spearman rank-correlation coefficients between grazing site diversity metrics, habitat quality and grazing site characteristics. Abbreviations: *M-A+A*-species diagnostic for the *Molinio-Arrhenatheretea* class and for the *Arrhenatheretalia* order.

	Soil Agriculture Suitability Index	Share of Arable Land Area 1960s	Share of Arable Land Area 2017
Diversity			
γ diversity	0.31 *	0.12	0.50 *
α diversity	0.28	0.06	0.34 *
Number of diagnostic species			
<i>Calthion</i>	−0.31 *	−0.31 *	−0.17
<i>Arrhenatherion</i>	0.19	0.22	0.27
<i>Cynosurion</i>	0.40 *	0.33 *	0.44 *
<i>M-A+A</i>	0.29 *	0.31 *	0.41 *
<i>Nardetalia</i>	0.32 *	−0.09	0.27
Others	0.30 *	0.06	0.48 *
Conservation status			
Wet <i>Calthion</i> meadows	−0.17	−0.30	−0.14
Mesic <i>Arrhenatherion</i> grassland	−0.13	−0.13	−0.15
<i>Cynosurion</i> pastures	0.14	0.02	0.03
Nutrient-poor <i>Nardetalia</i> grassland	−0.23	−0.26	−0.26

* significant $p < 0.05$.

4. Discussion

4.1. Species Composition and Diversity in Relation to Land Use Change

The results of the research indicate a process of increasing similarity in the species composition of grassland in areas where transhumant pastoralism is used. This applies in particular to communities of the alliances *Arrhenatherion* and *Cynosurion* because they can occur in the same environmental conditions, while the management type is a differentiating factor. Grazing caused the species composition of different communities to become similar. This is not the case for wet *Calthion* meadows and nutrient-poor *Nardetalia* grassland. The *Calthion* meadows occur in wet places and usually are only sporadically grazed. They are most often found in grazing sites with poor-quality soils at higher altitudes and with a slight proportion of arable fields in the past. Nutrient-poor *Nardetalia* grasslands in the Polish Carpathians are rare [42]. They most often cover small patches in habitat conditions differing from the surrounding grasslands. Thus, they can appear as enclaves in grazing areas among generally more fertile soils.

The highest biodiversity, as measured by the average number of all vascular species, pasture species and, generally, grassland species, was characteristic of grazing sites comprising a large proportion of arable fields. A significant proportion of arable fields in grazing sites in the past and their remains at present resulted in a high heterogeneity of habitats, related to the occurrence of such elements as field boundaries, clearance cairns, and dirt roads with roadsides. They are overgrown by plant species which increase species diversity in the landscape [32] and can easily migrate to grasslands. The heterogeneity of habitats and the related total number of species does not increase the abundance of grassland specialist species, since the latter occur in old grasslands [43,44]. Additionally, in

our studies, in contrast to grassland generalist species ($M-A+A$), no correlation was found between the number of grassland specialist species and the proportion of arable fields in the grazing site.

The large number of pasture species in a grazing site was correlated with a higher soil quality index and with a higher share of arable fields both at present and in the past. It indicates that ex-arable fields create favorable conditions for pasture communities. Grazing enables the dispersion of species by endo- and epizoochory [45], while disturbances caused by trampling and browsing by animals increase the probability of successful recruitments [46]. Similar relationships were observed in the case of grassland generalist species. However, such use may be insufficient for grassland specialist species [47].

The relationship between present species composition and land use type in the 1960s is not strong. The land use data for that period allow only for the conclusion that grasslands on ex-arable fields do not exist for longer than 60 years. However, this period can be much shorter. Transformations occur gradually; thus, grasslands differ in age, which results in a variable species composition because the migration of propagules depends on time [47]. Öster et al. [48] indicated that over a 50-year period, only 50% of species occurring on neighboring semi-natural grasslands migrated to ex-arable fields. Additionally, investigations on dry grasslands demonstrated a significant role of former land use in terms of species distribution [49].

4.2. Conservation Status and Transhumant Pastoralism as a Protective Measure

Conservation status expressed by structure and function assessment index for all grassland types was not statistically significantly correlated with soil suitability for agriculture or present or past land-use type. Nevertheless, these are dynamic ecosystems in which land use-dependent vegetation changes are relatively fast. In another study [50], significant vegetation changes were found in abandoned mountain meadows only 6 years after the reinstatement of grazing, and after 9 years the proportion of species typical of floristically rich grasslands was increased. The interval of time analyzed by us (ca. 60 years) is probably too long to sustain a statistically significant impact of land use type at that time.

Evaluation of the restoration efficacy of semi-natural grasslands on former croplands should take into account the similarity of the species composition of created communities to the species composition of communities typical of local habitat conditions (referenced community), because it is a better indicator of success than species diversity (number of species) [51]. If no local reference communities have been preserved or the study areas are widely diverse, as in our case, it is necessary to strive for the achievement of conservation status, described as favorable for grassland communities, following the criteria formulated by State Environmental Monitoring [52–54].

The transformation of former arable fields into permanent grasslands is not currently a common practice in Europe, which is related to the extensification of land use, e.g., in protected areas, especially in the mountains [7], or the implementation of agri-environmental programs [55]. The restoration of multispecies communities on formerly intensively used arable fields is difficult and long lasting, and requires the application of diverse measures [56,57]. However, under favorable conditions, this process can be much faster [58]. In the Polish Carpathians, this process proceeds spontaneously through the migration of grassland species from neighboring areas to ex-arable fields. A majority of grazing sites are characterized by a mosaic of small patches of different land use types and by diverse vegetation; thus, an easily accessible source of propagules is available, which is crucial for grassland restoration [57,58]. High doses of fertilizer have never been used in the Polish Carpathians, while high-fertility soils are a significant obstacle to the restoration of species-rich grasslands [56]. A similar mechanism of preservation of high diversity was suggested by Janišová et al. [59] based on studies of semi-natural grasslands in Slovakia.

Traditional transhumance is practiced in the Carpathians, which involves livestock grazing in summer and the migration of herds within a large area covered by a mosaic of semi-natural grasslands, arable fields, ex-arable fields, trees and other small landscape

features, allows species diversity to be preserved [59,60] because it supports natural processes, according to the metacommunity theory [61]. Extensive grazing can also produce negative effects from a nature conservation perspective if it is used in communities created by different management types. Grazing is considered to be more advantageous for species diversity than mowing [62]. However, many types of grasslands with high natural value, such as the mesic grasslands occurring in the study area, have developed and currently exist due to a proper mowing regime [63]. Plant diversity and conservation status largely depend on diversified land use, as revealed by the studies of Kun et al. [64] carried out in the Romanian Carpathians and Tölgyesi et al. [65] in Hungary. Hence, the preservation of the mosaic spatial structure of natural and semi-natural features and extensive farming practices in connection with diverse forms of human impact, such as grazing and mowing, is the optimal solution to preserve diversity at the levels of species, community, and landscape in mountain areas.

5. Conclusions

The transformation of extensively used arable fields into grasslands is relatively fast, but the species composition of communities formed in this way is dominated by less specialized species.

The biodiversity of analyzed grazing sites is dependent on the recent grassland area to arable land area ratio, rather than on the 60-year land use history. Nevertheless, detailed knowledge of past land use should be an integral part of analyses of the current state of vegetation and its dynamics. The spatial context (landscape connectivity, habitat fragmentation) is also worth considering.

Traditional transhumance can have a beneficial effect on the species diversity of grassland communities that have developed on former arable fields. Extensive open grazing over vast areas provides a real opportunity to maintain this type of ecosystem in good condition and should be subsidized by the state.

Author Contributions: Conceptualization, J.Z., J.K. and J.P.; methodology, J.Z., J.K. and J.P.; software, J.Z.; investigation, J.Z., J.K. and J.P.; writing—original draft preparation, J.Z., J.K. and J.P.; writing—review and editing, J.Z. and J.K.; visualization, J.K. and J.P.; project administration, J.P. All authors have read and agreed to the published version of the manuscript.

Funding: This manuscript is not funded by a specific project grant.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The study was conducted in the framework of the statutory activity of the Institute of Nature Conservation, Polish Academy of Sciences and with a subsidy of the Ministry of Science and Higher Education for the University of Agriculture in Kraków in 2022. The results from field work carried out for the project “Maintenance of biological diversity of mountain meadows and pastures through pastoral management” were used. The project was realized by the Landscape Parks of the Malopolska Voivodship, co-financed by the European Regional Development Fund (ERDF) under the Regional Operational Program of the Malopolska Voivodship for the years 2014–2020.

Conflicts of Interest: The authors declare no conflict of interest.

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