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The Effects of Different Management Methods on Restored Grasslands in Potential Temperate Forest Zones

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Abstract: The European temperate forest zone has great importance, in terms of maintaining the habitats of not only forests but also anthropogenous grasslands, which were formed as a result of habitat reconstruction. These habitats have great importance, by means of nature conservation, landscape use, economy, and forest and grassland use. The mosaic-like habitat complexes that consist of these grasslands and forest patches help to increase biodiversity and supply the habitat for forest game. In this survey, changes in the vegetation of the temperate forests (Fagetum) of the Mátra Mountains of Hungary were investigated after reconstruction. In 2012, shrub cutting was carried out in the area of Parádóhuta, and then three different management methods (abandoning, mowing, and grazing) were utilized. Our goals were the following: to perform a vegetation survey of the sample areas (i); surveying the natural regeneration of the grassland and analyzing its biodiversity, nature conservation, and economical value (ii); and analyzing the vegetation in terms of nature conservation and valuing its life form spectrum, economy values, and livestock-feeding ability (iii). According to our results, systematic mowing and a less-intensive grazing had a significantly positive effect on biodiversity and the coverage of species, thus increasing the naturalness of the studied grassland habitats, while wild game were able to act as ecological engineers.

Keywords: fagetum; grassland management; nature conservation restoration; coenology; species diversity

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1. Introduction

In the temperate zone of Europe, where the natural vegetation types are forests, anthropogenous grasslands can serve as important biodiversity hotspots, as they can increase the natural conservational and economical value of the area [1–3]. Mountain grasslands can possess high nature conservation value at the local level [4,5]. Human efforts have had a main role in their emergence; hence, they are endangered by many factors, among which, the increasing cover of shrub is the most important, as it causes the total transformation and closing of grasslands [6–10]. It usually requires human intervention to stop this process, with the most common nature conservation management practices, such as systematic shrub cutting, mowing, or grazing, being applied [11].

Habitats with more shrub or tree cover can act as ecotones between grasslands and forests. One must examine their influence on the habitat because it can be useful to maintain smaller patches of arboreal flora [12]. Thus, the aim of grassland restoration management is often to maintain a balance between open grasslands and shrubs [13,14]. This entails the need for shrub cutting, as these grasslands have significant nature conservational and economical values. Marriott et al. summed up the topic in an extensive review [15].

Once woody plants invaded the grasslands, they can create positive feedback by enlightening the invasion by other arboreal plants, making the whole process irreversible after reaching a certain level of tree cover [16–19]. Michielsen et al. pointed out that one of the main factors in increasing shrub cover are woody individuals' age and the fact that younger plants have weaker resprouting availability, independent of the managing method [20]. In the life cycle of shrub species, belowground biomass takes priority over aboveground biomass, and in this way, woody plants can persist in frequently disturbed grasslands [21].

The present survey was carried out on one of these habitats in the northern part of the Mátra mountain range, near Parádóhuta. These grasslands were covered by forests, which were cut until 1850, in order to obtain timber for heating the glass furnaces that were operated here. In the place of woodlands, meadows and pastures have been formed [22,23].

In the past few decades, many surveys have proven the importance of natural disturbances in different forms of vegetation [24], as well as their presence in ecosystems [25–32].

The cessation of natural conservation management can lead to declining diversity, by means of increasing coverage of some species with a broad tolerance spectrum [33–36]. The opposite effect of mowing and pasturing has been proven by many surveys [29,37–48]. This verifies the importance of small-scale disturbances in the composition of vegetation through positive effects on biodiversity [49,50]—they help to spread propagules, maintain ecosystem services, and suppress invasive species. In this way, they help to maintain natural conditions on a longer timescale [51–54]. One of the biggest issues of declining biodiversity, following the cessation of mowing or pasturing, is the increasing coverage of shrubs [6–8,55–59]. Management helps the germination of plants through decreasing the amount of living phytomass and dead leaves; thus, new species can be introduced into the vegetation [43,44,60–67].

Several surveys [68,69] have analyzed the effects of game browsing, comparing the natural and cut areas. In this work, we compared three cut areas in the Mátra Mountains that have been managed by different methods.

The study area of this research was a complex pasture forest that had been terminated 30 years ago. Through landscape rehabilitation, grasslands that had been shaped among forest patches are important, not only by means of mosaic-like landscape structure but also by virtue of nature conservation and biodiversity; they serve as a starting point for human resources and grassland-based animal farming [70].

Our aim was to monitor and analyze the processes of landscape reconstruction of the former grassland–forest mosaics.

Our goals were as follows: to disclose the vegetation of the sample areas (i), surveying the natural regeneration of the grassland and analyzing and valuing the effects of mowing and foraging on grasslands (ii), and analyzing the vegetation, in terms of nature conservation and valuing its life-forming spectrum (iii).

Further questions related to the study are as follows:

1. How close are the grasslands developed in the shrub-cut areas to natural habitats?
2. Is mowing or grazing more effective in reducing shrubs?
3. Which is the best management method resulting in greater biodiversity? On what level are they useful for grassland management, and how much livestock can they keep?

2. Materials and Methods

The Mátra Mountains are the highest mountain range of Hungary. They emerged from andesite volcanic activity in the Miocene. Their precipitation (600–750 mm per year) comes with the winds from the southwest, south, northwest, and north, and their peak values are measurable in the summer. Solar radiation relations are diverse, which helps in forming a diverse biosphere, but the southern slopes are usually warmer. The main temperatures drop to 0.3 °C at every 100 m, which makes the vertical changes of the vegetation clearly visible. According to the geological features, our studied area is a part of the Kékes-stump moving southwards, which consists of andesite, andesite tufa, and breccia [71]. It has a main altitude of 390 m. The area has been inhabited by forest until the late 18th century and was deforestated by the 1850s, in order to make place for glasshouses. The original zonal climactic vegetation was beech forest (Melittio-Fagetum Soó 1962 em. Soó 1971) [72]; since the 19th century, it was covered mainly by very species-rich meadows and pastures, which were maintained through human landscape use.

In 2012, shrub cutting was conducted in the area, forming different vegetation patches. Afterwards, four different management methods could be followed:

- I Systematic mowing until 2013. Mosaic-like vegetation, in which Festuco ovinae-Nardetum Dostál 1933 and *Festucetum rubrae-Cynosuretum* Tx. 1940 patches are the most common.
- II Shrub was cut. *Festucetum rubrae-Cynosuretum* Tx. 1940 typicum patches are the most common, but *Helictotron pubescens* facies is also present. After shrub cutting, the area was abandoned.
- III Shrub was cut. *Festucetum rubrae-Cynosuretum* Tx. 1940 is the most common taxa. In 2013, the area was divided to two parts (IIIa and IIIb).
  - IIIa Intensive grazing (3–4 animals per hectare or stocking density, which was 1.3 animal unit (AU)/ha) was conducted with Carpatian Braunvieh (Borzderes) cattle and Ratzka sheep.
  - IIIb The grazing was in extensive utilization, but stocking density was 0.5 AU/ha less intensive, due to periodic, less frequent use of the area.

The wild game in the area are mainly roe and red deer [73]. On the basis of shot game and wildlife management analysis [68,74–76], it is possible to find out whether game is over- or undermaintained. In this case, Pápay et al. [67] have stated that, in relation to the amount of food, game is over-maintained in this area.

We recorded six randomly generated 2 × 2 m plots in each sample area using the method of Braun-Blanquet [76], giving coverage values of species in June in every odd year during the survey. The names of species follow the nomenclature of Plants of the World Online [77]. Nature conservation categories [78] and social behavior types [79] were also compared. Data were valued through lifeforms, according to Raunkiaer [80]. We also calculated Shannon diversity.

Non-metric dimensional scaling (NMDS) of sites (with the Bray–Curtis distance as the dissimilarity measure) was used to analyze the data structure of the coenological surveys. Statistical analysis was carried out using the R software package. Subsequent analyses and data visualization were completed using the R packages vegan (ver. 2.5–3) [81] and ggplot2 (ver. 3.1.0) [82].

To reveal the correlation between number of years passed since 2013, intensity of management, species number, Shannon diversity, and total cover with cover of Raunkiaer life forms and social behavior type environmental parameters, we used the linear r (Pearson) correlation method of the PAST (Paleontological Statistics Version 4.07) statistical software package. To visualize our results, we used the R, PAST, MS Excel, and MS PowerPoint software packages [83].

3. Results

As a result of our survey, 17 tree-shrub species were described in our study area, of which, only *Robinia pseudoacia* is an invasive alien, while the rest are native species, such as *Carpinus betulus, Crataegus monogyna, Prunus spinosa*, or *Acer campestre* These taxons were spread significantly in only two of our study plots, i.e., II and IIIb. In plot II, there was game damage, while in plot IIIb, the less intensive grazing controlled the spread of shrub and tree species.

In the mowed plot I, the number of shrub species was less (12), and the coverage of shrubs was lower, as well, at only 1–2%, on average.

Grazing was found to be suitable, in terms of reducing the number and coverage of shrub species, as well. The decline of shrubs was significantly higher (by almost half) in the intensively grazed plot (IIIa), while, in the less intensively grazed IIIb plot, the coverage of woody plants increased significantly, from 1% to 8% in 2 years.

Among the natural taxa of these habitats, grasses are the most important. During the taxonomic examinations, the genus *Festuca* was proven to be difficult to ascertain. This genus plays a significant part in the coenology of these grasslands. Five members of it were found on the area: the wide-leafed species *F. pratensis*; *F. ovina,* which is a characteristic narrow-leafed species of the natural vegetation type of the area; *F. rubra,* which has transitional leaf characteristics but is a natural habitant; *F. rupicola;* and the disturbance-tolerant *F. pseudovina.*

In sample area I, the distribution of the SBT categories did not change drastically (Figure 1). The generalist species *Carpinus betulus* and *Crataegus monogyna* appeared, and the cover of the competitor species *Festuca rupicola* and *Nardus stricta* increased by 8%; however, they dropped then under 13 and 15%, respectively.

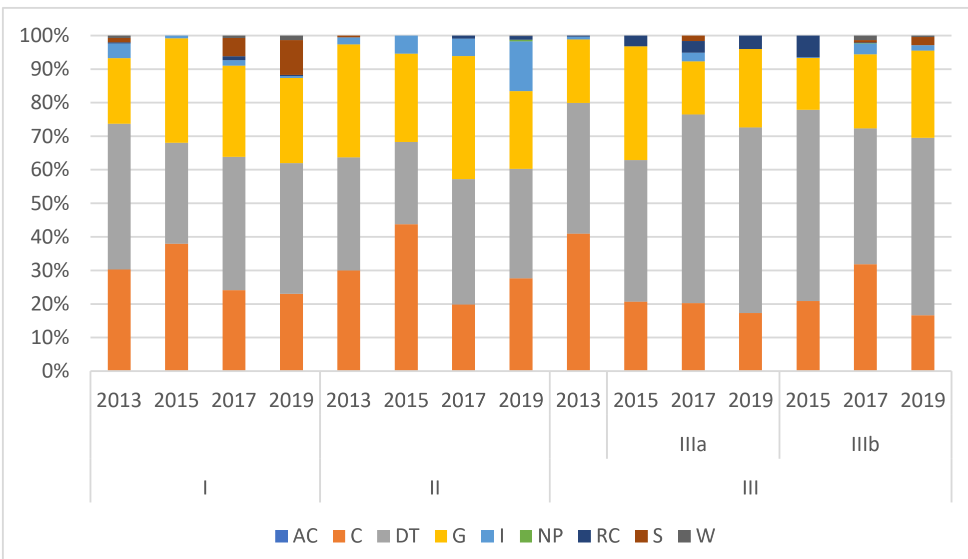


Figure 1. Distribution of social behavior types (SBT) of the taxa in the areas. AC: adventive competitors; C: competitors; DT: disturbance-tolerants; G: generalists; I: invasives; NP: natural pioneers; RC: ruderal competitors; S: specialists; W: weed.

In sample area II, after the shrub cutting, competitors, generalists, and disturbance-tolerants had approximately the same cover values, i.e., around 30%. The relations had changed by the end of the survey. While these categories remained approximately on the same cover value, invasive species increased their cover by 100% for the last year.

In sample area III, competitors and disturbance-tolerants covered the ground to approximately the same degree (40%); the remaining parts were covered mainly by generalists. In the following years, on the less intensively grazed part, generalists' cover increased by over 50% (e.g., *Holcus lanatus, Carex tomentosa*); on the intensively grazed part, ruderal competitors and disturbance-tolerants spread.

On the basis of the distribution of the Pignatti lifeforms of the vegetation (Figure 2), in area I, in 2013, the cover of the arboreal species was over 20% after a 10-year mowing period. The remaining soil was inhabited by perennial herbs; chamaephytes were also present, to a lesser extent (Figure 2). By 2015, grazing had also started in the area. Despite this, phanerophytes' cover did not decrease and plants with a trunk (P scap), even doubled. Relations of the perennial herbs also changed: reptants (H rept) had disappeared and rosette (H ros) cover were cut by half, giving their place to caespitose (P caesp) grasses. By 2017, relations had become similar to 2013. In the last year of the survey, with the ceasing grazing, restarting, and mowing, phanerophytes' cover began to decrease again.

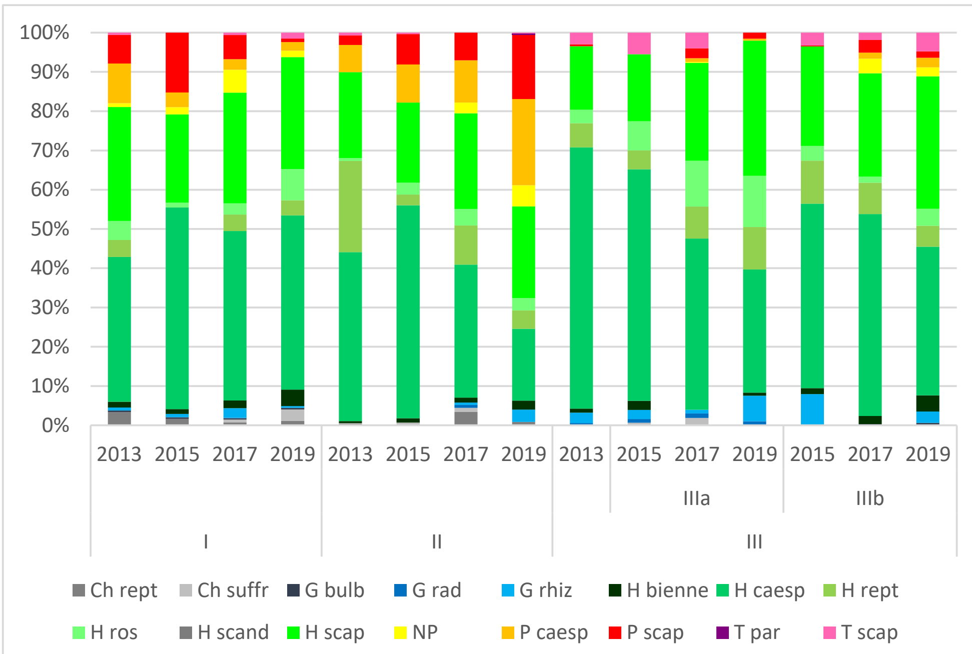


Figure 2. Distribution of Pignatti lifeforms of the taxa in the areas I-III. Ch: chamaephyte; G: geophyte; H: hemicriptophyte; NP: nanophanerophyte; P: phanerophyte; T: therophyte. rept: reptant; suffr; suffruticose; bulb: bulbose; rad: radose; rhiz: rhizomes; bienne: biennial; caesp: caespitose; ros: rosette; scand: scandose; par: parasitic.

In area II, the cover of nanophanerophytes (NP) and phanerophytes (P) was around 10% in the first year (2013). The remainder were perennial herbs. However, in the next year, the cover of phanerophytes increased by almost 100%, although its change was negligible in 2017. Relations of perennial herbs changed, mostly at reptants (H rept). In 2017, chamephytes (Ch) and geophytes (G) also appeared. By the last year (2019), significant changes occurred. In 2018, the area was heavily cut; therefore, the grazing area of game became twice as large. Game was not able to set back succession on such a large area anymore. By 2019, the species composition of perennial herbs had not changed significantly, but their cover decreased from 71% to 52%, giving their place to shrubs.

The two parts of area III that were separated in 2014 showed differences in the following years. In the more intensively grazed part (IIIa), rosette (H ros) and reptant (H rept) hemicryptophytes increased their cover by 50% by the end of the survey, while, on the less intensively grazed area, they were set back by half, and scapose herbs (H scap) became more dominant. The cover of caespitose hemicryptophytes (H caesp) decreased on both parts; however, in IIIa, this process was faster.

In area II, after the shrub cutting of 2012, there have not been larger human interventions (Figure 3). Despite this, diversity increased by 2017, mainly due to wild game, which had browsed the young saplings of shrub because of the scarcity of young sprouts in the forests nearby. In this way, they helped perennial herbs to grow. However, in the last year of the survey, this value decreased again, to under 3.5, showing that game is not enough in itself to maintain the biodiversity of grasslands.

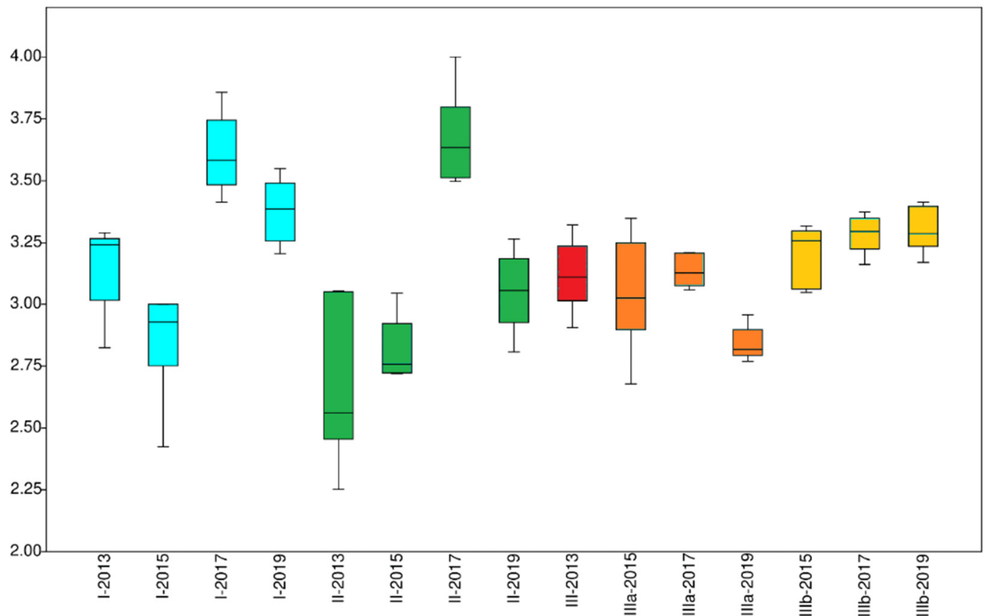
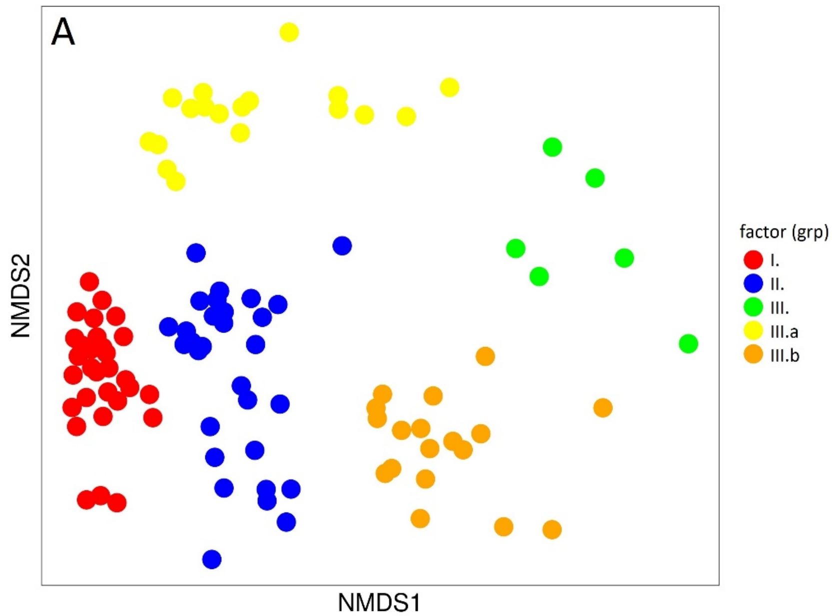


Figure 3. Shannon diversity of the sample areas I–III. ($p < 0.05$).

In area III, the Shannon diversity was around 3.1 at first; after dividing the grassland, it decreased to 2.75 on the more intensively grazed part. On the other part, it began to slowly increase to 3.2.

On the basis of the NMDS approach (Figure 4), all the four studied groups were separated by both study area and time-based analysis. Area I (which had been mowed already before the 2012 intervention) was found to be coherent, with no significant differences between the studied years. Area II was found close by and showed similarities to Area I, but its coenological groups were found to be more separated from each other. In the case of Area III, the results showed great differences between the coenological groups of IIIa and IIIb.



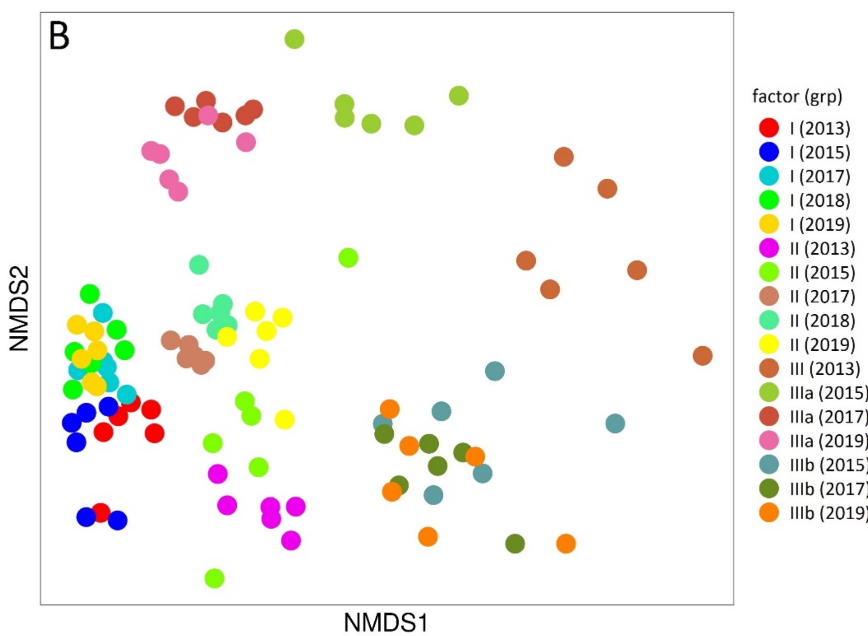


Figure 4. Non-metrical multidimensional ordination (NMDS) of the areas ((**A**) based on management methods, (**B**) based on years); grp = group.

On the basis of the linear (Pearson) correlational analysis (Figure 5), it can be stated that years passed, since the treatment at the beginning of the survey correlated positively with the Shannon diversity (r = 0.6001, p = 0.0066) and total cover (r = 0.4933, p = 0.0319), as well as therophytes (r = 0.5032, p = 0.0281), hemitherophytes (r = 0.6027, p = 0.0063) and disturbance-tolerants (SBT-DT, r = 0.5142, 0.0243).

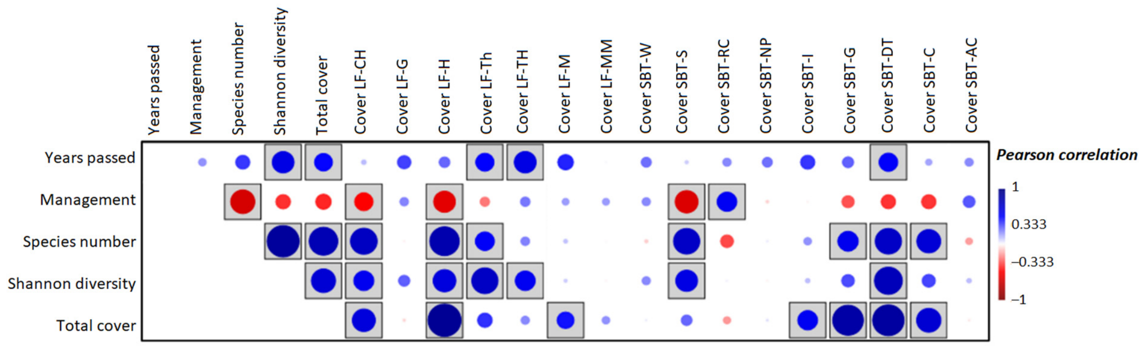


Figure 5. Linear (Pearson) correlation of years passed, management, species number, Shannon diversity, and total cover with cover of different life forms (LF) and social behavior types (SBT) (blue: positive, red: negative correlation, boxed: $p < 0.05$ significance). Ch: chamaephytes; G: generalists; H: hemicryptophytes; Th: therophytes; TH: hemitherophytes; M: phanerophytes; MM: megaphanerophytes; W: weed; S: specialists; R: ruderal competitors; NP: natural pioneers; I: invasives; G: generalists; DT: disturbance-tolerants; C: competitors; AC: adventive competitors.

The intensity of the management showed a negative correlation with the species number (r = −0.5021, p = 0.0285), chamaephytes (r = −0.5021, p = 0.0285), hemcryptophytes (r = −0.5977, p = 0.0069), and specialists (r = −0.6293, p = 0.0039). However, it correlated positively with ruderal competitors (r = 0.5416, p = 0.0166).

The species number correlated positively with Shannon diversity (r = 0.8848, p = 0.0000005), total cover (r = 0.7874, p = 0.0001), chamaephytes (r = 0.7874, p = 0.0001), hemicryptophytes (r = 0.8118, p = 0.00002), and therophytes (r = 0.5234, p = 0.0215), as well as with the specialists (r = 0.7216, p = 0.0005), generalists (r = 0.5589, p = 0.0129), disturbance-tolerants (r = 0.7221, p = 0.0005), and competitors (r = 0.6565, p = 0.0023).

Shannon diversity showed a positive correlation with total cover (r = 0.6636, p = 0.0020), chamaepyhtes (r = 0.5517, p = 0.0143), hemicryptophytes (r = 0.6257, p = 0.0042), therophytes (r = 0.7232, p = 0.0005), and hemitherophytes (r = 0.5502, p = 0.0147), as well as with the specialists (r = 0.5997, p = 0.0066) and disturbance-tolerants (r = 0.7666, p = 0.0001).

The total cover positively correlated with the cover of Ch (r = 0.6325, p = 0.0037), H (r = 0.9122, p = 0.0000001), and M (r = 0.4678, p = 0.0434) life form species, as well as with the cover of I (r = 0.5443, p = 0.0160), G (r = 0.8450, p = 0.0000053), DT (r = 0.8683, p = 0.0000014), and C (r = 0.6710, p = 0.0017) social behavior-type species.

4. Discussion

Grazing can play a significant role in maintaining mountain grasslands, as well as in their unfavorable changing [4]. The role of big game can become more important in the absence of grazing livestock. These ungulate game animals maintain a dynamic grassland–shrub complex through their ecosystem-engineering effects; thus, valuable mountain grassland species can spread to more open areas (under the influence of climatic changes) [84].

In Area II, which was cut and then abandoned, biodiversity decreased and disturbance-tolerant and competitor taxa increased their cover slightly, although not drastically. Wild game was largely responsible for the relatively stable state of the vegetation through its continuous browsing of the saplings [69].

Area I was very diverse in 2013, wherein we observed well-differentiated patches of *Nardus stricta*. In 2015, the mosaic-like nature of the grassland became more articulate because the Carpatian Braunvieh (Borzderes) cattle and Ratzka sheep grazed the arboreal plants and Nardus with lesser intensity; however, diversity dropped, and the coverage of shrub did not decline. In the last years of the survey, foraging ceased, and mowing was reintroduced. The coverage of phanerophytes and perennial herbs, thus, increased, approaching the values of 2013. According to our results, systematic mowing had a significantly higher positive impact on biodiversity and the coverage of species, indicating naturalness, rather than exclusive grazing [38,40]. Here, the most obvious solution would be restarting mowing [38,40,58] and grazing [85–87]. During the last decades, nature conservation management was extended to grasslands that were more diverse in the past than they are today, in order to stop and turn back the decreasing of diversity [24–26,88,89]. Mowing is often used as an additional management method besides sodding practices, in order to set back weeds occurring during the infancy of the process and help accompanying species to germinate [88].

Mowing, as a nature conservation treatment, can slow afforesting and spreading of shrub. It can help grassland species to germinate, thus leading to more diverse grassland communities [90]. In some cases, the changes of species composition can be detected already in the second year of mowing [91]. Mowing plays a large role in restoring abandoned meadows [40,58].

On the basis of the results, it was confirmed that continuous management (mowing) stabilizes the vegetation of grasslands, while ceasing can lead to the spreading of arboreal species and shrub, which, as a result, decreases biodiversity, as well. Thus, small-scale disturbances are necessary because these interventions can have a positive impact on species diversity [49,75]. Their setting back of competitor species helps propagules to spread, granting the continuity of ecosystem services [51,52,54], and meadows and wood pastures are, thus, among the most diverse habitats of Central Europe [58,92]. The ceasing of mowing or grazing can lead to increasing cover of shrub and afforestation [55,93,94]; thus, an evident solution can be the restoring of these methods [29,58].

Grasslands formed on the place of forests are threatened by the increasing cover of forests, mainly *Crataegus monogyna, Carpinus betulus, Acer campestre, Rosa canina, Rubus spp.*, and *Prunus spinosa*, which can be observed in several European countries. Because of the anthropogenous origin of the grasslands, management is inevitable, in order to maintain their diversity [95–98]. Based on our results, shrub can double its cover in 3–5 years.

Browsing can play an important role in preserving mountain grasslands, but overgrazing leads to an unfavorable state of vegetation [4,66]. In the absence of grazing animals, the role of large wild herbivores increases. The grazing of large herbivores cannot, in itself, preserve grasslands from afforestation, which calls for additional vegetation management solutions [99,100]. Wild ungulate communities can maintain dynamic spatial grassland–shrub complexes as ecosystem engineers. On these patches, besides the effects of climatic changes, valuable mountain grassland species can appear and be maintained on the open areas [84].

5. Conclusions

We can conclude that, in the studied temperate deciduous woodland zone, the applied nature conservation practices resulted in different grassland habitat types [98]. The spreading of shrubs was defined as the most threatening factor to biodiversity of these grasslands. We found grazing a suitable method to reduce the number and coverage of shrub species; however, we must consider that overgrazing can result in lower species diversity and the spreading of weeds [101]. On the basis of our results, the best management practice to maintain the studied anthropogenous grasslands with high biodiversity, favorable species composition (including dominant grassland species, such as *Festuca rubra, Cynosurus cristatus, Nardus stricta,* or *Festuca ovina*), and low shrub cover is mowing.

Wild ungulates as ecosystem engineers play an important role in the natural nutrition of European forest ungulates [101], and browsing can play an important role in preserving mountain grasslands [102,103].

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