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# Impact of shrub cover and wild ungulate browsing on the vegetation of restored mountain hay meadows

## Einfluss der Strauchdeckung und der Beweidung durch Schalenwild auf die Vegetation renaturierter Bergwiesen

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**Abstract**

Grasslands of middle mountain regions are among the most diverse habitats of the Carpathian Basin, but they are threatened by spontaneous succession leading to woody encroachment. It is a high priority of nature conservation to preserve these diverse habitats by suppressing the woody encroachment and to create new open habitat patches by scrub removal. The main goal of this study was to investigate the effect of shrub cover on plant species composition and vegetation in terms of relative ecological indicator values in semi-natural grassland patches. We also aimed at studying the wild browsers' preference for woody species, which potentially plays a role in shrub encroachment. The study was conducted in the Mátra mountains, North-Hungary, where three study sites were selected within the *Fagetalia* belt: two sites recently restored by scrub removal with different post-restoration management and a semi-natural grassland as a control site. All of the sites were available for wild ungulate grazing. At each study site, vegetation and browsing data were recorded at 50 sampling points for which we used circular plots with a radius of 1.13 m (4 $m^2$). The highest shrub cover was found in the clearing that was grazed only by wild ungulates. The linear regression analysis showed that shrub cover significantly increased the abundance-weighted nutrient (NB) and water (WB) scores and decreased the naturalness value (SBT). Moreover, we found that an increase of shrub cover significantly decreased cover and species richness of grassland specialists, but increased weed cover. Most of the woody species were browsed in relation to their abundance except *Rubus* and *Acer* species, which were non-preferred. Our results highlight that shrub encroachment has a negative effect on semi-natural grasslands and that beside wild ungulate browsing additional management is needed to preserve these diverse habitats.

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**Erweiterte deutsche Zusammenfassung am Ende des Artikels**

## 1. Introduction

Natural and semi-natural grasslands are among the most diverse habitats in Central Europe (DENGLER et al. 2014, VALKÓ et al. 2016). However, many of these habitats have become endangered because of the social and economic changes during the last few decades (TÄLLE et al. 2016). One of the main reasons for their degradation is abandonment, which often led to a considerable level of shrub encroachment (VALKÓ et al. 2012, ERDŐS et al. 2013, HUDJETZ et al. 2014). An increasing shrub cover threatens grasslands in several ways: Shrubs overshadow short herbaceous plants (FACELLI & PICKETT 1991) and might mechanically inhibit their growth, resulting in a decreased biodiversity (TÄLLE et al. 2016). Litter of shrub species can suppress the establishment of herbaceous species by limiting the availability of establishment gaps and may also have allelopathic effects (BONANOMI et al. 2006, MIGLÉCZ et al. 2013, DEÁK et al. 2018, 2020). Moreover, shrubs can hinder the nutrient uptake of herbaceous species (SALA et al. 1989). An increasing shrub biomass can also lead to a greater risk of fire (VALKÓ et al. 2014).

The effect of wild ungulate grazing and browsing on vegetation has been in the focus of ecological research in the past decades (HARMER 2002, KRAMER et al. 2006, KATONA et al. 2013, SANKARAN et al. 2013). Most of the studies deal with wild ungulate browsing in woodlands and mainly focus on the economic aspects as the effects of wild ungulates on timber production have still not been clarified sufficiently (SCHELLER & MLADENOFF 2007, PRETZSCH et al. 2008, BERNES et al. 2016, ÅNÖSTAM 2017). However, only few studies have explored the effects of wild ungulates on the biodiversity of temperate grasslands (DA SILVEIRA-PONTES et al. 2016, ARGENTI et al. 2017, RIESCH et al. 2019). DU TOIT & OLFF (2014) stated that the effect of grazing and browsing are functionally similar in grasslands. Thus, in several countries the concept of maintaining grasslands by wild ungulate grazing as a replacement for traditional farming has been considered an alternative option (FERNÁNDEZ-OLALLA et al. 2016, LÓPEZ-SÁNCHEZ et al. 2016). Because of their browsing habits, wild ungulates can be effective in the suppression of woody plants in grasslands as they prefer younger sprouts of the arboreal vegetation (DA SILVEIRA-PONTES et al. 2016). However, more information is needed to evaluate whether and under which circumstances wild ungulate browsing can be used as a tool for mitigating shrub encroachment in semi-natural grasslands.

The aim of this study was to investigate the effect of shrub cover on the plant species composition of semi-natural grassland patches embedded in *Fagus* forests. To achieve this goal three study sites were selected in the Mátra Mountains, Northern Hungary. The control site was a semi-natural grassland where edaphic conditions prevented forest growth. We also designated two sites where the semi-natural grassland had been overgrown by shrubs. In these sites the scrub had been cut 5 years before the survey. All of the sites were available for wild ungulate grazing, but one of the scrub-cut sites was also temporarily managed by low-intensity cattle grazing. In this study we aimed to answer the following questions: (1) How does the shrub cover affect the grassland vegetation in terms of relative ecological indicator values? (2) Does the shrub cover influence the plant species richness and the cover

of grassland specialists and weeds? (3) Which woody species are consumed by wild browsers in grassland patches located in the *Fagetalia* belt? We hypothesise that a low shrub cover results in an increased richness and cover of grassland specialists as well as an increased naturalness of the vegetation. We also expect increasing mean ecological indicator values for temperature, nutrients, water and light with decreasing shrub cover.

## 2. Methods

### 2.1 Study sites

The survey was conducted between April and August 2016 in three mountain grasslands (*Festucetum rubrae-Cynosuretum* Tx. 1940, Soó 1957; BORHIDI et al. 2012) in the Mátra Mountains, Northern Hungary (Fig. 1). The potential natural vegetation of the study sites is *Fagus* forest (*Fagetalia sylvaticae* Pawlowski in Pawl. et al. 1928; BORHIDI et al. 2012); however, wood pastures and meadows were traditionally created in the area centuries ago (ELLENBERG 1996, BORHIDI et al. 2012). The mean annual temperature is 9 °C, the mean annual precipitation 600–750 mm (FICK & HIJMANS 2017, SZABÓ et al. 2019). We selected three study sites according to the followings: There was (1) a control site, Sombokor (0.6 ha), a semi-natural grassland formed within the *Fagetalia* belt, where edaphic conditions did not allow forest growth. There were two young clearings formerly covered by semi-natural grassland vegetation where the scrub had been cut 5 years before the survey: (2) Fallóskút site (1.6 ha), where the grassland restored by scrub removal was grazed only by wild ungulates, and (3) Parádóhuta site (1.5 ha), where after the scrub removal the majority of the grassland area had been grazed by a small herd (4 individuals) of a native cattle breed (Carpathian Brown Cattle) for two years, and since

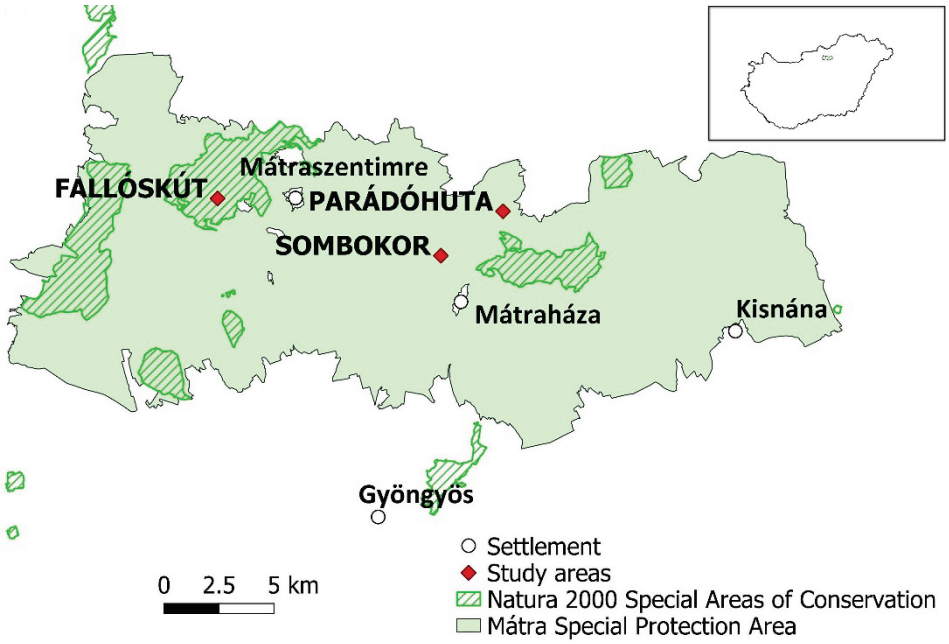


**Fig. 1.** Map of the study region. White circles denote settlements, red diamonds the three study sites.

**Abb. 1.** Karte der Studienregion im Mátra-Gebirge in Nordungarn. Weiße Kreise kennzeichnen Siedlungen, rote Rauten die drei Untersuchungsgebiete.

**Table 1.** Estimated density of wild ungulates and hunting bag data from the study region.

**Tablle 1.** Geschätzte Schalenwild-Dichten und Jagdstreckendaten aus der Untersuchungsregion.

| | Red deer | Fallow deer | Roe deer | Mouflon | Wild boar | Total |
|---|---|---|---|---|---|---|
| Estimated population size | 7,253 | 153 | 10,517 | 2,681 | 5,879 | |
| pcs/100 ha | 1.91 | 0.04 | 2.76 | 0.70 | 1.54 | 6.96 |
| Hunting bag | 3,697 | 49 | 3,913 | 1,143 | 11,185 | |
| pcs/100 ha | 0.97 | 0.01 | 1.03 | 0.30 | 2.94 | 5.25 |

then, wild ungulate species have been the only grazing animals in the area. All sites were accessible for wild ungulate species during the survey in 2016. According to the estimated density and hunting bag data from the study region, red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and mouflon (*Ovis musimon*) are common large herbivore species in all three sites, but fallow deer (*Dama dama*) occurs as well (Table 1). Besides, wild boar (*Sus scrofa*) is also a widespread ungulate species in the Mátra Mountains (Table 1).

### 2.2 Field sampling

On each study site the percentage cover of vascular plants was recorded in 50 circular sampling plots with a radius of 1.13 m (4 $m^2$), distributed randomly over the site. The browsing preference of wild ungulates was also investigated in each sampling plot by recording the number of woody individuals with shoots accessible for the animals (i.e. lower than 2 m height) and the number of browsed individuals. Former and recent browsing damages were not distinguished.

### 2.3 Data processing

For the statistical analyses we categorised the species into two ecological groups: grassland specialists and weeds according to BORHIDI (1995). Using Borhidi's ecological indicator values of the recorded herbaceous species, we calculated cover-weighted scores on a plot level for relative ecological indicator values for temperature (TB), nutrient (NB), water (WB) and light (LB). We also calculated a naturalness score based on the cover-weighted mean scores for social behaviour types (SBT) for the herbaceous species (BORHIDI 1995). One-way ANOVA with Tukey's post-hoc test was used to compare the shrub cover between the study sites. We applied linear regressions to explore the effect of shrub cover (independent variable) on cover-weighted ecological indicator values (TB, NB, WB, LB) and naturalness score (SBT) as well as on the cover and species richness of grassland specialists and weeds (dependent variables). All univariate statistics were calculated in IBM SPSS Statistics v. 20.0 (Armonk, NY: IBM Corp).

To gain quantified values of browsing preference (preferred or non-preferred), Jacobs' preference index was calculated for woody species (JACOBS 1974):

$$D = (r - p)/(r + p - 2rp),$$

where r indicates the proportion of species in consumption and p indicates the proportion of species in supply. The value of D can vary between -1 (absolutely ignored) and 1 (absolutely preferred). Values near 0 indicate consumption corresponding to the proportion in the supply (KATONA et al. 2013).

## 3. Results

The analysis of variance showed that management (grazed by wild ungulates, by wild ungulates and cattle, and control site) had a significant effect on shrub cover ($F_{2.147} = 55.18$, $p < 0.001$). The post hoc HSD Tukey test showed that shrub cover was significantly the highest at Fallóskút ($p < 0.001$), the site only grazed by wild ungulates, and the lowest at the control site (Fig. 2).

Linear regressions were calculated to investigate the relationship between shrub cover and relative ecological indicator values, grassland specialist and weed species' richness and cover. The analyses showed that an increase of shrub cover significantly increased cover-weighted NB scores ($R^2 = 0.262$, $\beta = 0.02 \pm 0.003$, $F = 52.57$, $p < 0.001$) and cover-weighted WB scores ($R^2 = 0.225$, $\beta = 0.007 \pm 0.001$, $F = 40.85$, $p < 0.001$) (Fig. 3). However, cover-weighted TB scores ($R^2 = 0.217$, $\beta = -0.004 \pm 0.001$, $F = 40.98$, $p < 0.001$) and naturalness values (SBT) ($R^2 = 0.26$, $\beta = -0.030 \pm 0.004$, $F = 52.09$, $p < 0.001$) decreased with an increasing shrub cover. We did not find a significant relationship between shrub cover and cover-weighted LB scores ($R^2 = 0.004$, $\beta = -0.001 \pm 0.001$, $p = 0.45$). The analyses also showed that an increase of shrub cover significantly increased weed cover ($R^2 = 0.739$, $\beta = 1.31 \pm 0.064$, $F = 419.7$, $p < 0.001$) and weed species richness ($R^2 = 0.275$, $\beta = 0.062 \pm 0.008$, $F = 56.1$, $p < 0.001$) (Fig. 4). Furthermore, we found that a low shrub cover resulted in an increased cover ($R^2 = 0.351$, $\beta = 0.568 \pm 0.063$, $F = 80.1$, $p < 0.001$) and species richness of grassland specialists ($R^2 = 0.21$, $\beta = -0.136 \pm 0.020$, $F = 39.33$, $p < 0.001$) (Fig 4).

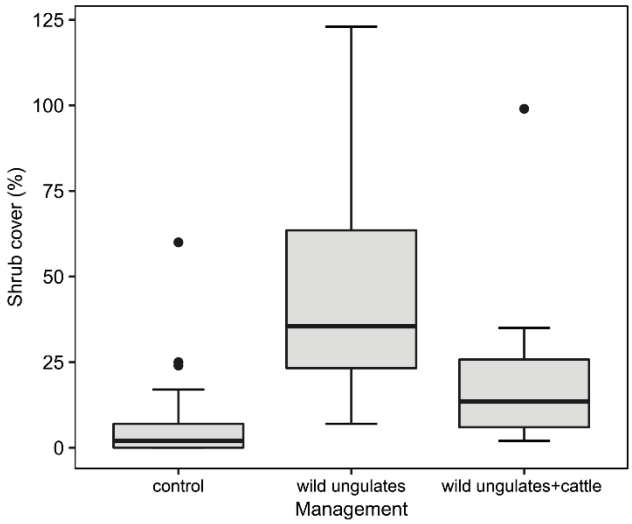


**Fig. 2.** Percentage cover of shrubs in the three study sites. The boxes represent the 25% and 75% quartiles from the median (thick line), the whiskers represent the maximum and minimum values, excluding outliers. Moderate outliers (open points) are values between 1.5 and 3 times the interquartile range and extreme outliers (asterisks) are values above 3 times the interquartile range.

**Abb. 2.** Prozentuale Strauchdeckung in den drei Untersuchungsgebieten. Die Kästchen stellen die 25 %- und 75 %-Quartile vom Median (dicke Linie), die Antennen stellen die Maximal- und Minimalwerte dar, Ausreißer ausgenommen. Moderate Ausreißer (offene Punkte) sind Werte, die zwischen dem 1,5- und 3-fachen des Interquartilsbereichs liegen und extreme Ausreißer (Sternchen) sind Werte, die dem über dem 3-fachen des Interquartilsbereichs liegen.

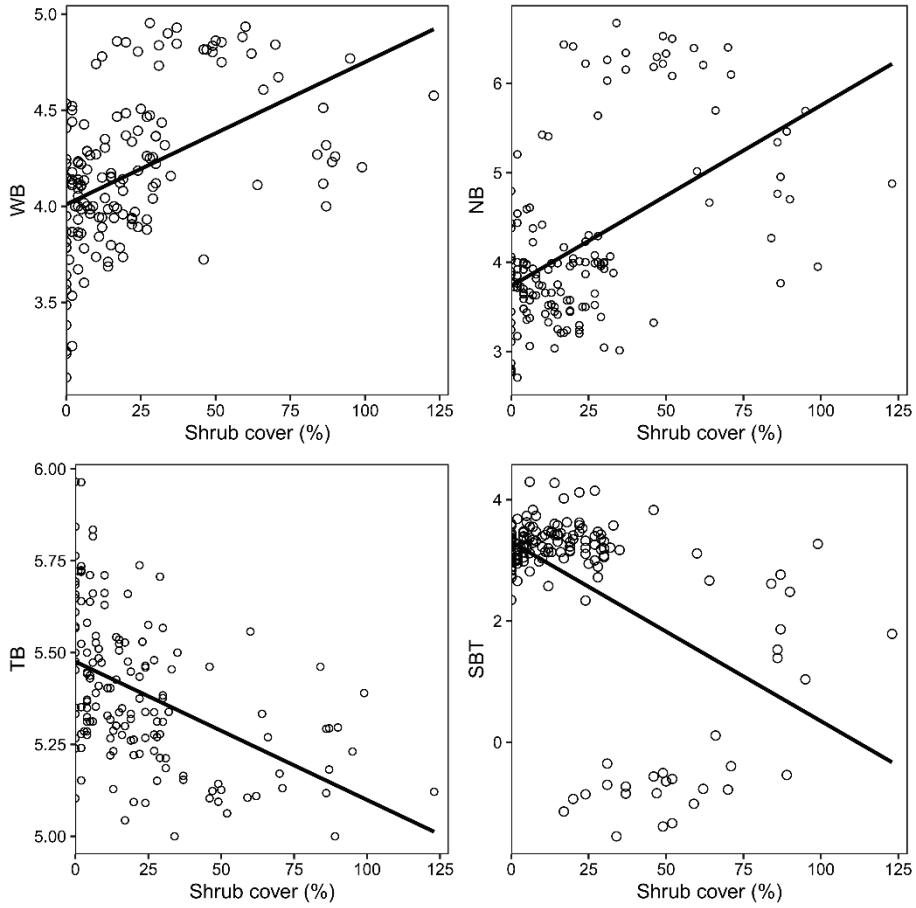


**Fig. 3.** Relationship between shrub cover and cover-weighted mean ecological indicator values (TB, NB, WB) and naturalness scores (SBT).

**Abb. 3.** Beziehung zwischen Strauchdeckung und nach Deckung gewichteten mittleren ökologischen Zeigerwerten (TB – Temperatur, NB – Nährstoffe, WB – Wasser) sowie Natürlichkeitswerten (SBT).

In the control area of Sombokor, browsing occurred in 95% of the sampling points where woody plants were available ($n$ = 41). In average, the proportion of browsed shrub individuals was 69±29% (range: 63–100%). The browsing rate of *Rubus* spp. and *Euonymus europaeus* was between 39% and 49%, while the browsing rate of other species reached 75–100%. We found browsed shrubs in each sampling point in Parádóhuta. The proportion of browsed individuals varied between 14% and 100%, with an average of 64±20%. Every species ($n$ = 12) had a browsing rate above 50% except *Acer platanoides* (12±30%), *Rhamnus cathartica* (20±30%) and *Acer campestre* (33±45%). At the study site in Fallóskút, 98% of the surveyed points ($n$ = 49) had browsed saplings. The mean browsing rate was 51±18% (min.–max.: 19%–82%). Among species, the browsing rate was low for the abundant plants *Rubus* spp. (19%) and *Crataegus* spp. (42%). The browsing rate of other species varied between 29% and 81%. The Jacobs' preference index showed that at the study sites most species had been browsed by wild ungulates in relation to their abundance, except *Rubus* and *Acer* species, *Euonymus europaeus* and *Rhamnus cathartica* (Fig. 5).

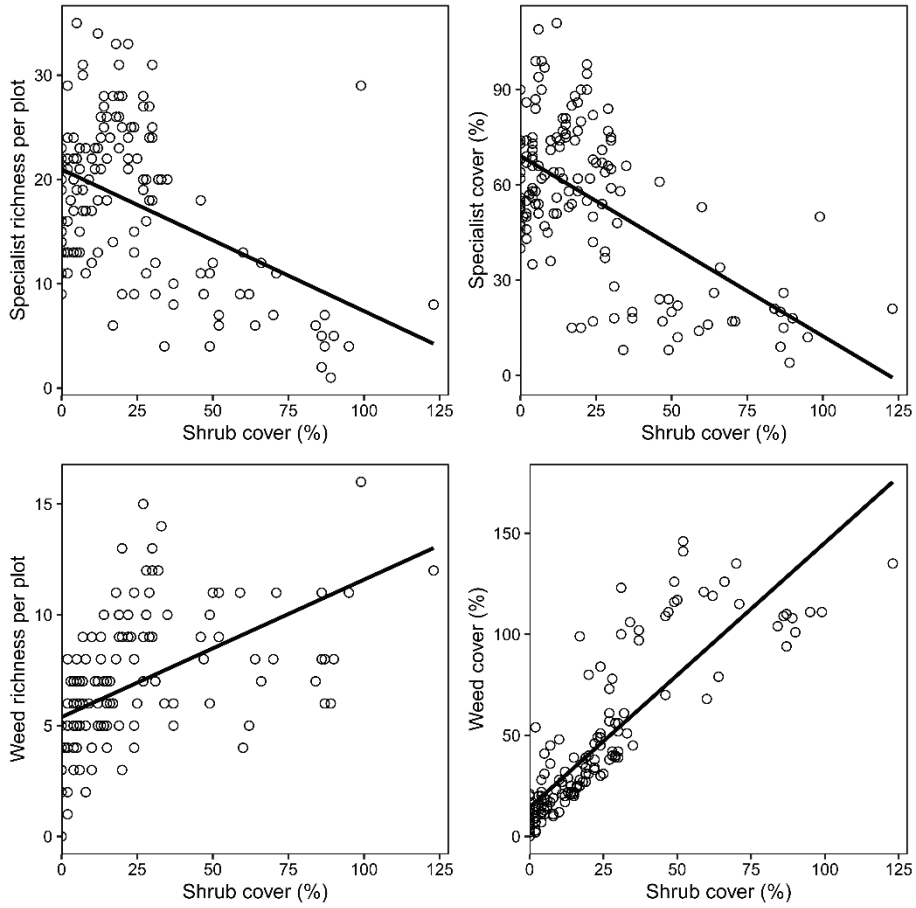


**Fig. 4.** Relationship between shrub cover and richness and cover of grassland specialist and weed species.
**Abb. 4.** Beziehung zwischen Strauchdeckung und dem Artenreichtum und der Deckung von Graslandspezialisten und Unkrautarten.

## 4. Discussion

Our results show that an increased shrub cover may have a deteriorative effect on the vegetation of grassland patches in middle mountain regions. Based on the ecological indicator values, we showed that an increase of shrub cover may favour species with high nutrient and water demand, typically weed species, but provides less suitable conditions for species preferring higher temperatures such as grassland specialists. Moreover, naturalness scores (SBT) as well as cover and species richness of grassland specialists were negatively affected by an increased shrub cover.

All over the world many grasslands are simultaneously affected by wild ungulate browsing and grazing of domestic herbivores (SHORT & KNIGHT 2003). Our results suggest that where edaphic conditions do not prevent forest growth, the use of mixed management could be advantageous. After scrub removal simultaneous grazing of wild ungulates and domestic herbivores resulted in a lower shrub cover than browsing by wild ungulates only. We also

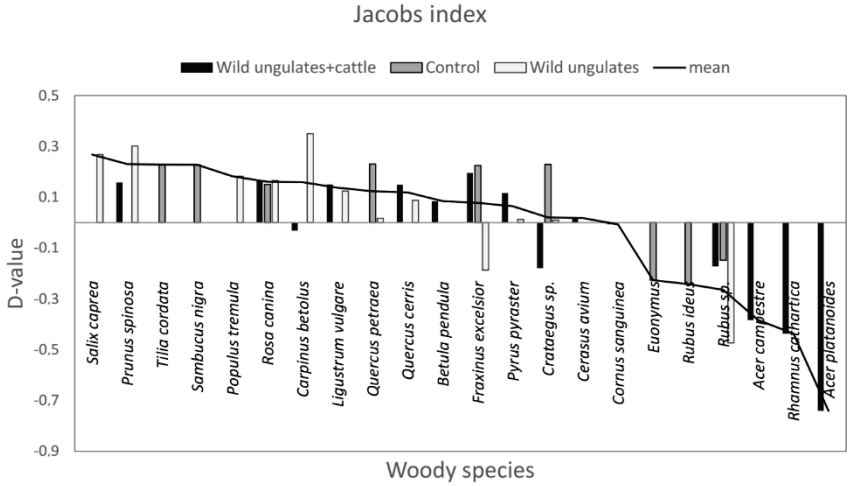


**Fig. 5.** Jacobs' selectivity index calculated for woody species showing the browsing preferences of wild ungulates in the study region.

**Abb. 5.** Mit dem Jacobs-Präferenzindex für die Gehölze errechnete Verbisspräferenz des Schalenwilds in der Studienregion.

showed that woody species were mostly browsed in relation to their abundance. However, there were some shrub and tree species that were significantly non-preferred by wild ungulates such as *Rubus* ssp., *Acer* ssp. and *Rhamnus cathartica*. These species can play a significant role in shrub encroachment (KELEMEN et al. 2017); therefore, additional management actions are needed to remove them. Goat pasturing might be a feasible solution for this problem: ELIAS et al. (2018) found that goat paddock grazing can improve the conservation status of shrub-encroached grasslands.

Our results are in line with former studies that found that the grazing of large wild herbivores usually cannot prevent woodland formation in grasslands, which calls for additional vegetation management solutions (ARCHER 1996, POTT 1998). Wild ungulates might slow down the unfavourable successional processes (KATONA et al. 2013), contribute to the maintenance of open landscapes (TSCHÖPE et al. 2011) and preserve species diversity (VIRTANEN et al. 2002). However, overgrazing by wild ungulates can also lead to unfavourable changes in the vegetation (ARCHER 1996, POTT 1998, KRICSFALUSY 2013). The browsing of deer can set back the resprouting of aspen significantly, especially at high population density (MUEGGLER & BARTOS 1977), and can therefore also be helpful in reducing the cover of invasive woody species (WRIGHT 2017).

During recent years a new concept has been developed to describe the connections between wild herbivores and vegetation. This „New Wilderness Concept" claims that wild herbivores can create open habitats (VERA 2000, SVENNING 2002). However, besides the important role of wild ungulates, many studies emphasised the crucial role of traditional farming such as mowing in sustaining these open habitats (ELLENBERG 1996, POTT 1998, DIERKING et al. 2000, HÁZI et al. 2011). Although there is no consensus regarding the role of disturbance in grasslands, many studies proved the importance of natural disturbances in ecological systems (WHITTAKER & LEVIN 1977, PICKETT & THOMPSON 1978, WHITE 1979, DEÁK et al. 2014).

## 5. Conclusions

Our findings show that woody encroachment has a significant effect on the species composition of grassland patches in the *Fagetalia* belt. An increased shrub cover creates less suitable ecological conditions for grassland specialists and eventually results in the loss of specialist species richness and an increase of the weed species cover. Our results also highlight that after creating new open patches e.g. by scrub removal, direct conservation management actions are required to maintain high diversity grassland patches because wild ungulate browsing alone may fail to suppress shrub encroachment, especially by *Rubus* and *Acer* species.

## Erweiterte deutsche Zusammenfassung

**Einleitung** – Natürliches und halb-natürliches Grasland gehört zu den vielfältigsten Lebensräumen Mitteleuropas. Sie sind jedoch von der Verbuschung im Zuge der spontanen Sukzession bedroht (VALKÓ et al. 2012). Die zunehmende Strauchdeckung kann krautige Pflanzen überschatten (FACELLI & PICKETT 1991, DEÁK et al. 2020) und die Streu von Sträuchern kann die Etablierung von krautigen Arten unterdrücken und auch allelopathische Effekte haben (BONANOMI et al. 2006). Dies kann zu einem Verlust der Graslandvegetation und Diversität führen. Schalenwild kann aufgrund seiner Verbissgewohnheiten wirksam zur Unterdrückung von Gehölzen im Grasland beitragen (DA SILVEIRA-PONTES et al. 2016). Die Auswirkungen des Weidens und Verbisses von Schalenwild auf die Vegetation wurde in den letzten Jahrzehnten zunehmend erforscht (KATONA et al. 2013, SANKARAN et al. 2013) und das Konzept der Erhaltung von Grasland durch die Beweidung mit Schalenwild als Ersatz für die traditionelle Landwirtschaft als eine alternative Option betrachtet (FERNÁNDEZ-OLALLA et al. 2016, LÓPEZ-SÁNCHEZ et al. 2016). Ob und unter welchen Umständen der Verbiss von Schalenwild als Mittel zur Eindämmung der Verbuschung eingesetzt werden kann, blieb jedoch weitgehend ungeklärt.

**Ziele der Studie** – Ziel dieser Studie war es, den Einfluss der Strauchdeckung auf die Pflanzenartenzusammensetzung von halb-natürlichem Grasland innerhalb des Buchenwaldgürtels zu untersuchen. Um dieses Ziel zu erreichen, wurden drei Untersuchungsgebiete im Mátra-Gebirge in Nordungarn ausgewählt. Wir untersuchten folgende Fragen: (1) Wie wirkt sich Strauchdeckung auf die mittleren ökologischen Zeigerwerte der Vegetation aus? (2) Beeinflusst die Strauchdeckung den Pflanzenartenreichtum und die Deckung von Graslandspezialisten und Unkräutern? (3) Welche Gehölzarten werden von Schalenwild im Grasland des Buchenwaldgürtels verzehrt?

**Materialien und Methoden** – Wir wählten drei Untersuchungsgebiete aus: (1) ein Kontrollstandort, Sombokor (0,6 ha), ein naturnahes Grasland, das sich innerhalb des Buchenwaldgürtels gebildet hat, und zwei junge Lichtungen, auf denen die Gehölze fünf Jahre vor der Erhebung entfernt wurden: (2) Fallóskút (1,6 ha), wo das durch die Entbuschung entstandene Grasland nur von Schalenwild beweidet wurde, und (3) Parádóhuta (1,5 ha), wo nach der Entbuschung der Großteil der Graslandfläche vorübergehend von einer kleinen Rinderherde beweidet wurde. In jedem Untersuchungsgebiet wurde die Vegetation in 50 kreisförmigen Untersuchungsflächen mit einem Radius von 1,13 m (4 $m^2$), die gleichmäßig über das Gelände verteilt waren, erfasst. Die Verbisspräferenz des Schalenwilds wurde ebenfalls untersucht, indem die Anzahl der Gehölze mit für die Tiere zugänglichen Trieben und die Anzahl der verbissenen Individuen erfasst wurde. Für jede Untersuchungsfläche berechneten wir für krautige Pflanzenarten die deckungsgewichteten mittleren Zeigerwerte (nach BORHIDI 1995) für Temperatur (TB), Nährstoffe (NB), Feuchtigkeit (WB) und Licht (LB). Wir berechneten außerdem den Natürlichkeitswert auf der Grundlage der deckungsgewichteten phytosoziologischen Zugehörigkeit (SBT) (BORHIDI 1995). Zum Vergleich der Untersuchungsgebiete hinsichtlich ihrer Strauchdeckung verwendeten wir eine einfache Varianzanalyse (ANOVA) mit Tukey Signifikanztest. Um den Einfluss der Strauchdeckung auf die mittleren Zeigerwerte und den Natürlichkeitswert sowie auf die Deckung

und den Artenreichtum von Graslandspezialisten und Unkräutern (abhängige Variablen) zu untersuchen, verwendeten wir lineare Regressionen. Zudem berechneten wir den Jacobs-Präferenzindex für Gehölzarten (JACOBS 1974), um quantifizierte Werte der Verbisspräferenz zu erhalten.

**Ergebnisse** – Die Bewirtschaftung hatte einen signifikanten Einfluss auf die Strauchdeckung. Diese war am nur von Schalenwild beweideten Standort am höchsten und am Kontrollstandort am niedrigsten. Die Strauchdeckung war zudem signifikant positiv mit den NB- und WB-Werten, sowie negativ mit den TB- und SBT-Werten korreliert. Wir fanden jedoch keine signifikante Beziehung zwischen der Strauchdeckung und dem LB-Wert. Mit zunehmender Strauchdeckung nahm die Unkrautdeckung und der Unkrautartenreichtum signifikant zu, während Deckung und Artenreichtum der Graslandspezialisten am höchsten bei geringer Strauchdeckung war. Der Jacobs-Präferenzindex zeigte, dass die meisten Arten im Verhältnis zu ihrer Häufigkeit von Schalenwild verbissen wurden, mit Ausnahme von *Rubus*- und *Acer*-Arten, sowie *Euonymus europaeus* and *Rhamnus cathartica*.

**Diskussion** – Die Ergebnisse zeigen, dass sich Verbuschung signifikant negativ auf die Pflanzenartenzusammensetzung der Graslandflächen im Buchenwaldgürtel auswirkt. Eine Zunahme der Strauchdeckung begünstigte Arten mit hohem Nährstoff- und Wasserbedarf, typischerweise Unkrautarten, verschlechterte aber die Bedingungen für Graslandspezialisten, und verringerte den Natürlichkeitswert. Nach der Entbuschung führte die gleichzeitige Beweidung durch Schalenwild und domestizierte Pflanzenfressern zu einer geringeren Strauchdeckung als auf Flächen, die nur durch Schalenwild beweidet wurden. Dies deutet darauf hin, dass eine gemischte Bewirtschaftung vorteilhafter sein könnte als der reine Verbiss von Schalenwild, um Graslandflächen offen zu halten (siehe auch LÓPEZ-SÁNCHEZ et al. 2016). Die meisten Gehölzarten wurden im Verhältnis zu ihrer Häufigkeit verbissen. Es gab jedoch einige Strauch- und Baumarten, wie *Rubus* ssp., *Acer* ssp. und *Rhamnus cathartica*, die von Schalenwild verschmäht wurden. Diese Arten könnten bei der Verbuschung eine bedeutende Rolle spielen und somit zusätzliche Maßnahmen, wie manuelle Entbuschungen, erfordern (ELIAS et al. 2018). Unsere Ergebnisse machen deutlich, dass nach Auflichtungen zusätzliche Erhaltungsmaßnahmen erforderlich sind, um Graslandflächen in ihrer typischen Artenzusammensetzung und -diversität zu erhalten, da der Verbiss von Schalenwild allein die Verbuschung nicht unterdrücken kann.

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## Author contribution

K.P. and G.P. conceived the ideas of the study. A.F., G.S., Z.Z., E.S.-F., I.J., D.S., L.S., and P.C. participated in the fieldwork. G.P., O.K., K.K. and K.P carried out the statistical analyses. G.P., O.K. and K.P. prepared illustrations. G.P., O.K. and P.K. wrote the manuscript, and all authors commented on the drafts. The first two authors contributed equally to the manuscript.

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