Grasslands restoration opportunities in different habitats, with different grazing animals. Overview case studies II: Goat pastures

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ABSTRACT

In this summary overview, we present the findings of phytosociological surveys conducted in vegetation types subjected to goat grazing –excluding the control meadows – across seven different study sites in addition to four settlements located in Transdanubia and the North Hungarian Mountains. The areas are also evaluated from a grassland management perspective. Furthermore, we explored the potential use of two invasive species (Solidago gigantea and Calamagrostis epigeios) as goat fodder, and we included a mown meadow as a control. The primary aim was to assess the species richness and ecological value of these areas under varying levels of grazing pressure and grassland management strategies, particularly in terms of conservation and pasture use.

The most degraded plant communities were observed in Nagyréde and Kaposdada, where overgrazing had occurred. This was evident in species composition, as these areas were the least species-rich and showed significant infestation by ruderal species. In contrast, the most favorable outcomes – both for conservation and for grassland management – were found in sites that were initially mown and subsequently grazed by goats. The results suggest that vegetation types developed under light grazing pressure were more beneficial from a grazing perspective. Overall, the study indicates that a combination of light grazing and mowing is the most suitable management approach for maintaining and utilizing these semi-dry grasslands sustainably.

Additionally, both invasive species may have potential for use as fodder when harvested at appropriate phenological stages and supplemented with additional feed, although not for meat production purposes.

***Keywords**: productivity of the grassland; Festuca species, forage value*

Human activity has played a pivotal role in the formation and maintenance of Pannonian grasslands. In particular, management practices that support the long-term persistence of these habitats – most notably grazing – are of critical importance (Bartha et al., 2022). At the same time, the control of invasive species remains a key concern (Kárpáti, 2001; Házi et al., 2009, 2011, 2012, 2022; Szentes et al., 2012).

Within the Pannonian region, goat grazing has a relatively limited role and is typically practiced alongside sheep grazing (Jávor, 1999; Jávor et al., 1999; Stilling et al., 2022). Nevertheless, from a conservation perspective, this grazing type may offer distinct advantages. Goat grazing tends to promote the development of a mosaic-like vegetation structure (Hajnáczki et al., 2021; Póti et al., 2007), as goats – especially under conditions of ample forage – exhibit highly selective feeding behaviour (Hajnáczki et al., 2021). Goats may contribute to both biodiversity conservation and grassland maintenance (Mancilla-Leytón et al., 2012; Rosa García et al., 2012), although their primary significance lies in their economic utility (Yayota and Doi, 2020; Fernández-Lugo et al., 2013). Additionally, they can play a role in controlling shrub encroachment (Krehl, 1997; Haumann, 1998; Kukovics and Németh, 2007). Goats also consume approximately 30% of conditionally undesirable (ruderal) plant species in their diet (Tasi, 2007, 2011), making them potentially effective agents in the suppression of invasive species. However, grazing must be managed with great caution, as goats may also pose a threat to native plant species (Burney, 1993; Anderson and Hoffman, 2007; Baraza and Valiente-Benuet, 2008; Ramirez, 1999).

In this study, we examined and compared the vegetation of grasslands with varying grazing pressures that had been converted from arable fields and subjected to long-term goat grazing for 24-25 years under different grazing intensities and grassland management regimes. Additionally, as a

control, we analyzed data from a site managed exclusively by mowing, and from another area initially used as a hayfield but later subjected to grazing. The central research question was how various grazing pressures and grassland management practices – grazing alone, mowing alone, or a combination of both – affect species composition in the grasslands. Furthermore, we aimed to assess species richness and economic value under long-term management.

The study sites were located within the Pannonian biogeographical region of the Carpathian Basin, specifically in the Northern Hungarian Mountains and Southern Transdanubia. The following locations and treatment types were included in the research: Site I was located at Kaposszerdahely, where an abandoned arable field was converted into a goat pasture. Grazing began in 2012, and our observations were conducted 3 to 6 years after abandonment. Site II, at Kaposdada, was characterized by natural dry Pannonian grasslands. Here, two treatment types were studied: II.1, a lightly grazed grassland, and II.2, an overgrazed site. Site III was situated at Nagyréde and comprised two sub-sites: III.1, a 2.5-hectare pasture dominated by *Festuca pseudovina* and *Lolium perenne*, managed with high grazing pressure by 24 mother goats and their offspring continuously since 1999; and III.2, a 1-hectare hayfield dominated by *Lolium perenne*, used only for mowing. Site IV, at Csokvaomány, also included two sub-sites: IV.1, a 2.4-hectare *Festuca pseudovina*-dominated grassland managed with low grazing pressure by 12 mother goats and their offspring since 2000; and IV.2, a 2.4-hectare meadow used as a mixed-use site where the first growth was mown, followed by grazing with the same goat population. Vegetation surveys were conducted using 2×2 m quadrats. In parallel, we carried out aboveground biomass assessments during May and June. To model the impact of goat grazing, a 7 cm stubble height was left in place. Biomass production was estimated using the method of Balázs (1960), as modified by Házi et al. (2022). In evaluating the grasslands from an agricultural perspective, we assessed the proportions of economically valuable versus non-valuable species and species groups. We also analyzed the life-form composition of the vegetation based on Pignatti's (2005) system. Furthermore, sites were assessed according to conservation value, following the classification systems of Borhidi (1995) and Simon (2000). To compare the vegetation patterns across sample areas, we performed multivariate hierarchical cluster analysis (UPGMA – Unweighted Pair Group Method with Arithmetic Mean, Saitou and Nei, 1987), using Euclidean average linkage distance.

In addition to species diversity and species richness, the proportion of plant species and functional groups within the vegetation also holds significant importance from an agricultural perspective. In this regard, the most relevant groups for grassland management are the grasses (Poaceae) and leguminous species (Fabaceae). Across all grazed sites, the abundance of grasses was generally lower compared to other management types. The highest proportions and biomass of grasses were found in the areas managed as meadows, particularly in site III.2, as well as in the plots subjected to both mowing and grazing, such as IV.1. In contrast, the overgrazed areas (II.2 and III.1) showed significantly different patterns compared to the other sites ($p \leq 0.0001$, $p = 0.003$). In these areas, *Festuca pseudovina* became the dominant species, though several other grass species, such as *Dactylis glomerata*, *Lolium perenne*, and *Poa angustifolia*, also reached high cover values.

Leguminous species were more prevalent in areas exposed to low grazing pressure. Although their proportion was also substantial in mown plots, this did not differ significantly from that of the lightly grazed areas ($p = 0.001$). The abundance of weedy species was highest in the overgrazed vegetation types, where their cover could reach 35-40%. Although some weed species also occurred in notable quantities in the lightly grazed plots, their proportion remained below 10%.

Among the surveyed plots, the proportion of annual, erect-stemmed species became notably higher in the more intensively grazed areas, exceeding 30% cover in some cases within the overgrazed types. Similarly, stoloniferous perennial species reached their highest abundance in these overgrazed plots. The presence of annual stoloniferous species, particularly *Trifolium repens*, was significant only under conditions of excessive grazing pressure. Rosette-forming perennial species also showed a marked presence in the overgrazed sample areas. Across all sites, perennial erect-stemmed species – predominantly dicotyledons – were present in substantial quantities. Over time, the cover of perennial grasses declined, primarily due to overgrazing by livestock, which selectively removed these species from the sward. Nonetheless, their highest coverage was recorded in the meadow plots. Shrub species (*P caesp*) were detected only in negligible amounts.

Based on the Balázs assessment method, which evaluates both green biomass and yield, average grassland productivity steadily increased throughout the study period – from 5.78 t/ha to 9.01 t/ha in green mass – accompanied by a notable rise in forage value (from 0.71 to 2.77). The lowest values were associated with the overgrazed plots, while the most favourable results were observed in areas subjected to both mowing and grazing. This improvement can be attributed to increased total vegetation cover, particularly the rise in species richness and cover of grass species. Notably, the most substantial increases were observed among primary grass species such as *Dactylis glomerata*, *Elymus repens*, *Lolium perenne*, and *Festuca pseudovina*. Alongside grasses, leguminous species also reached approximately 20% cover in these plots, a proportion considered optimal from both a forage production and pasture management perspective. Among them, *Trifolium repens* consistently achieved the highest cover each year, a species well-regarded for its excellent forage quality and tolerance to trampling.

The total abundance of valuable forage species was also greatest in the mown and grazed plot (IV.2), where it reached up to 30-35%.

The forage utilization potential of *Solidago gigantea* and *Calamagrostis epigeios* was evaluated due to their relevance from both agricultural, silvicultural, and conservation perspectives. During the forage value assessment, we determined the chemical composition of both species, including dry matter content, crude protein, crude fat, crude fiber, and nitrogen-free extractable substances, alongside their apparent digestibility coefficients and net energy values for maintenance (NEm), growth (NEg), and lactation (NEl). Based on these chemical analyses, the nutritional values of the two species were compared with those of commonly used forage crops. We also identified the optimal grazing periods, ideal phenological stages, and appropriate regeneration intervals for both species.

The findings suggest that goats are well-suited for the forage use of these two species, particularly in the case of *Calamagrostis epigeios*, which is characterized by a high dry matter content. In terms of energy value – specifically NEm – both species can be classified as moderate when compared to standard forage crops, rendering them suitable primarily for meeting maintenance energy requirements. Additionally, *Solidago gigantea* may also serve as a potential energy source during lactation. However, neither species is recommended as a primary forage for meat-producing livestock. When employed as roughage, both require supplementation with protein-rich feed to meet the animals' nutritional needs. For optimal utilization by goats, *C. epigeios* should be grazed in its four-leaf stage, while *S. gigantea* is best targeted before the budding phase. The regeneration intervals vary depending on the intended purpose of grazing.

Goat grazing can lead to the effective suppression of shrubs, as clearly evidenced by vegetation surveys. Species richness peaked in the meadow plots. From the perspective of species composition and overall forage quality, grasslands under light grazing pressure proved most suitable. Coenological surveys conducted in both natural and sown grasslands confirmed that goats are appropriate agents for grassland conservation and management. The most ecologically and agriculturally valuable plots were those managed with light grazing pressure or combined mowing and grazing regimes. Furthermore, the targeted, cautious use of invasive species such as *Solidago gigantea* and *Calamagrostis epigeios* as forage for goats represents a viable strategy for integrating invasive species control with sustainable livestock feeding practices.

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REFERENCES

Anderson, P. M. L.-Hoffman, M. T. (2007): The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa J. Arid. Environ. 70: 686-700. https://doi.org/10.1016/j.jaridenv.2006.05.017

Animut, G.-Goetsch, A. L. (2008): Co-grazing of sheep and goats: Benefits and constraints. Small Ruminant Research 77: 127-145. https://doi.org/10.1016/j.smallrumres.2008.03.012

Balázs F. (1960): A gyepek botanikai és gazdasági értékelése [Botanical and Economic Assessment of Grasslands]. Mezőgazdasági Kiadó, Budapest

Baraza, E.-Valiente-Benuet, A. (2008): Seed dispersal by domestic goats in a semiarid thornscrub of Mexico. J. Arid. Environ., 72: 1973-1976. https://doi.org/10.1016/j.jaridenv.2008.04.004

Bartha, S.-Szabó, G.-Csete, S.-Purger, D.-Házi, J.-Csathó, A. I.-Campetella, G.-Canullo, R.-Chelli, S.-Tsakalos, J. L.-Ónodi, G.-Kröel-Dulay, Gy.-Zimmermann, Z. (2022): High-Resolution Transect Sampling and Multiple Scale Diversity Analyses for Evaluating Grassland Resilience to Climatic Extremes. Land 11: 378. https://doi.org/10.3390/land11030378

Borhidi, A. (1995): Social behavior types, the naturalness and relative ecological indicator values of the higher plants in the Hungarian Flora. Acta Bot. Acad. Sci. Hung., 39(1-2): 97-181.

Burney, D. A. (1993): Late Holocene environmental change in arid southwestern Madagascar. Quat. Res. 40: 98-106.

Fernández-Lugo, S.-Ramón Areévalo, J.-de Nascimento, L.-Mata, J.-Bermejo, L. A. (2013): Long-term vegetation responses to different goat grazing regimes in semi-natural ecosystems: a casestudy in Tenerife (Canary Islands). Applied Vegetation Science 16: 74-83. https://doi.org/10.1111/j.1654-109X.2012.01211.x

Haumann, P. (1998): Biotope conservation with ruminants in Germany: the example of goats on shrub-infested slopes. In: 2nd LSIRD Conference on Livestock production in the European LFAs, Bray, Ireland, 186-196.

Hajnáczki S.-Pajor F. P. N.-Bodnár Á.-Penksza K.-Póti P. (2021): Solidago gigantea Ait. and Calamagrostis epigejos (L) Roth invasive plants as potential forage for goats. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 49(1): 12197.

Házi J.-Nagy A.-Szentes Sz.-Tamás J.-Penksza K. (2009): Adatok a siska nádtippan (*Calamagrostis epigeios*) (L.) Roth. Cönológiai viszonyaihoz Dél-tiszántúli gyepekben. Tájökológiai Lapok 7(2): 1-13.

Házi, J.-Bartha, S.-Szentes, S.-Wichmann, B.-Penksza, K. (2011): Seminatural grassland management by mowing of Calamagrostis epigejos in Hungary. Plant Biosystems 145(3): 699-707. https://doi.org/10.1080/11263504.2011.601339

Házi, J.-Penksza, K.-Bartha, S.-Hufnagel, L.-Tóth, A.-Gyuricza, Cs.-Szentes, Sz. (2012): Cut mowing and grazing effects with grey cattle on plant species composition in case of Pannon wet grasslands. Applied Ecology and Environmental Research 10(3): 223-231.

Házi, J.-Penksza, K.-Barczi, A.-Szentes, S.-Pápay, G. (2022): Effects of Long-Term Mowing on Biomass Composition in Pannonian Dry Grasslands. Agronomy 12: 1107. https://doi.org/10.3390/agronomy12051107

Jávor A. (1999): Juhok és legeltetés. DGYN 15: 173-176.

Jávor A.-Molnár Gy.-Kukovics S. (1999): Juhtartás összehangolása a legelővel. In: Nagy G.-Vinczeffy I. (szerk.): Agroökológia – Gyep – Vidékfejlesztés. 169-172.

Kárpáti L. (2001): A gyepek természetvédelmi jelentősége. Debreceni Gyepgazdálkodási Napok 17. Gyepgazdálkodásunk helyzete és kilátásai, MTA Állatteny. Biz., Debrecen, 57-60.

Krehl, A. (1997): Verhaltan von Ziegen und Schafen in der Weidehaltung. Diplomarbeit, FG Int. Nutztierzucht u. –haltung, Univesitat Gesamthochschule Kasel, Witzenhausen

Kukovics S.-Németh T. (2007): A kecsketartásban alkalmazott gyephasználat. A magyar gyepgazdálkodás 50 éve – tanulságai a mai gyakorlat számára. Gyepgazdálkodási ankét SZIE, Gödöllő, 153-159.

Mancilla-Leytón, J. M.-Pino Mejías, R.-Martín Vicente, A. (2012): Do goats preserve the forest? Evaluating the effects of grazing goats on combustible Mediterranean scrub. Applied Vegetation Science 16: 63-73. https://doi.org/10.1111/j.1654-109x.2012.01214.x

Pignatti, S. (2005): Valori di bioindicazione delle piante vascolari della flora d'Italia. – Braun-Blanquetia 39: 1-97.

Póti, P.-Pajor, F.-Láczó, E. (2007): Sustainable grazing in small ruminants. Cereal Research Communications, 35: 945-948. https://doi.org/10.1556/crc.35.2007.2.195

Ramirez, R. G. (1999): Feed resources and feeding techniques of small ruminants under extensive management conditions. Small Rumin. Res. 34: 215-230. https://doi.org/10.1016/S0921-4488(99)00075-9

Rosa García, R.-Celaya, R.-García, U.-Osoro, K. (2012): Goat grazing, its interactions with other herbivores and biodiversity conservation issues. Small Rumin. Res. 107: 49-64. https://doi.org/10.1016/j.smallrumres.2012.03.021

Saitou, N.-Nei, M. (1987): The neighbor-joining method: a new method for reconstructing phylogenetic trees. Molecular Biology and Evolution 4: 406-425. https://doi.org/10.1093/oxfordjournals.molbev.a040454

Simon T. (2000): A magyar edényes flóra határozója. Tankönyvkiadó, Budapest

Stilling, F.-Póti, P.-Pajor, F.-Hajnáczki, S. (2022): Botanical investigation of goats pastures on natural and replanted grasslands. Gyepgazdálkodási Közlemények 22(1): 47-50.

Szentes, Sz.-Sutyinszki, Zs.-Szabó, G.-Zimmermann, Z.-Házi, J.-Wichmann, B.-Hufnágel, L.-Penksza, K.-Bartha, S. (2012): Grazed Pannonian grassland beta-diversity changes due to C4 yellow bluestem. Central European Journal of Biology. 7(6): 1055-1065.

Tasi J. (2011): Gyepgazdálkodás. Szent István Egyetem, Gödöllő

Tasi, J. (2007): Diverse impacts of nature conservation grassland management. Cereal Research Communications 35: 1205-1209.

Yayota, M.-Doi, K. (2020): Goat Grazing for Restoring, Managing, and Conserving "Satoyama", a Unique Socio-Ecological Production Landscape. Front. Sustain. Food Syst. 4: 541721. https://doi.org/10.3389/fsufs.2020.541721