FINAL REPORT ON THE PROJECT 'EFFECTS OF EXTENSIVE GRAZING ON VEGETATION IN NON-CONVENTIONAL PASTURE-LANDS (MARSHES AND FORESTS)' (2016-2020+1year) (NKFI K 119478)

MAIN ORIGINAL OBJECTIVES OF THE PROJECT (ORIGINAL FROM THE APPLICATION)

Overall objectives of the research:

- detailed documentation of grazing practices of marshes and forests from the mid-18th century, with a particular focus on the effects on vegetation;
- documentation of recent grazing practices of marshes and forests, their effects on vegetation, comparison with the past practices and states, and with ungrazed control sites.

A general objective of the project is the combined use of three main data sources:

- analysis of written historical documents (ethnographic, local sources, forest management plans, etc.) for all types of marshes and forests in Central and Eastern Europe (part 1)
- oral historical interviewing of living memory of practices of the past 70 years in key types of marshes and forests of the Carpathian basin (part 2);
- survey of vegetation of presently grazed lowland marshes and alluvial forests of the Carpathian basin (part 3).

MAIN RESULTS OF THE PROJECT: KEY TOPICS AND THE 7 KEY D1 PUBLICATIONS (+ 3 MANUSCR. IN PREP.) AND DEVIATIONS FROM THE ORIGINAL PLANS

We covered all planned topics in the planned depth, and surveyed five sites in three countries. Originally seven papers were planned. We published seven D1 papers, two local papers, while three Q1/D1 papers are under preparation close to submission (analyses finished).

Historical documents

We reviewed the historical information on marsh and forest grazing available in Hungary and the neighbouring countries, as planned. The results on marsh grazing based on 412 historical records (1720-1970) is published (Biró et al. 2019), the review on forest grazing based on 860 (16th-20th century) historical records is under preparation, close to submission (Öllerer et al., in prep.).

Oral history

We studied herders' and other livestock keepers' living memories and traditional knowledge on forest grazing (Varga et al. 2020). We also prepared 31 interviews on marsh grazing but the data were not enough for a high-ranked publication. We studied the traditional ecological knowledge of pig keepers on the impact and practices of marsh and forest grazing in the Bosut forest in a more detailed way as planned earlier (two publications), as we realized the rapid erosion and the European significance of this knowledge. Results on ethnobotanical knowledge are already published (Molnár et al. 2021), knowledge on pig foraging is close to submission (Molnár et al., in prep.). Traditional knowledge on cattle grazing and the behaviour of traditionally grazed cattle in a grassland-marshland mosaic was studied at the Kunpeszér site (Hungary) (Molnár et al. 2020).

Recent botanical surveys

We studied grazed marshes along grazing intensity gradients in the Hortobágy (Hungary), along the Teuz river (Romania) and in the Bosut Forest (Serbia). Results were published in Biró et al. (2020). Impact of forest grazing by cattle was studied in poplar plantations along the Tamis river (Serbia) (Demeter, Molnár et al. 2021) and impacts of foraging pigs on the herb and shrub layer of hardwood floodplain forest stands in the Bosut Forest (Demeter et al. in prep.). We prepared a global review of the international scientific literature which was originally not part of our plans, as we realized how little we know about the impacts of livestock grazing on forest vegetation in the temperate zone (Öllerer, Varga et al. 2019).

DETAILED INTRODUCTION OF KEY PUBLICATIONS AND MANUSCRIPTS

Historical information on marsh grazing (Biró et al. 2019)

We studied the Pannonian biogeographic region and its neighborhood in Central Europe and searched ethnographic, local historical, early botanical, and agrarian literature for historical traditional knowledge in online databases and printed sources. The findings were analyzed and interpreted by scientist, nature conservationist and traditional knowledge holder (herder) co-authors alike. Among the historical sources reviewed, we found 420 records on traditional wetland grazing, mainly from the period 1720–1970. Data showed that wetlands in the region served as basic grazing areas, particularly for cattle and pigs. We found more than 500 mentions of habitat categories and 383

mentions of plants consumed by livestock.

The most important reasons for keeping livestock on wetlands were grazing, stock wintering, and surviving forage gap periods in early spring or mid-late summer. Besides grazing, other commonly mentioned effects on vegetation were trampling and uprooting. The important outcomes were vegetation becoming patchy and remaining low in height, tall-growing dominant species being suppressed, litter being removed, and microhabitats being created, such as open surfaces of mud and water.

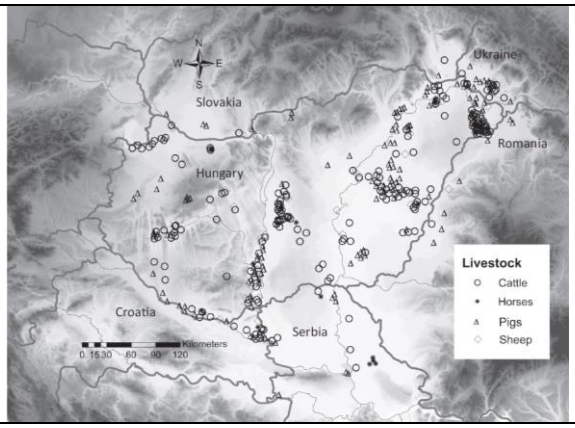

Fig. 1. Map of the study area in the Carpathian Basin, Central Europe. Symbols indicate localities of historical mentions of wetland grazing by domestic livestock. Country borders: thick grey lines, main rivers: thin grey lines (source: Natural Earth). Source of base map: ASTER-DEM, USGS, 2009.

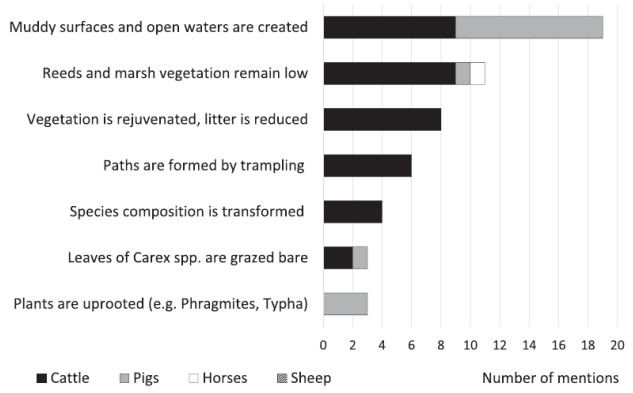

Fig. 6. Effect of domestic livestock on wetland vegetation, as mentioned in the historical sources.

Historical information on forest grazing (Öllerer et al. in prep.)

We studied the Pannonian biogeographic region and its surroundings in Central and Eastern Europe and searched early forestry, ethnographic, local historical and botanical literature for historical traditional knowledge in online databases and printed sources. We found 723 records mentioning effects of grazing by livestock in forests, and 137 further mentions of livestock presence, without explicit mention of forest elements consumed or impacted, mainly from the 17th–early 20th c. (1503–1984). These sources showed that forests represented a basic grazing area for livestock especially in the summer, when the pastures dried out, while only a few sources mention forest grazing being not more than occasional. Besides grazing and browsing, livestock impacted the forests also by breaking and rubbing against shrubs and young trees, by harming the roots and soil with their hooves and by trampling. The reviewed historical sources mention the use of timed cattle and sheep grazing in tree plantations and clear-cuts. Livestock grazing was used to control pioneer vegetation (ex. *Rubus*, *Epilobium angustifolium*) and other weeds, to aid the regeneration of target tree species by trampling the seeds into the soil and selective removal of competitive species, but also for fire prevention, removing the dry vegetation. Pig grazing was used to foster acorn germination, promoting oak regeneration.

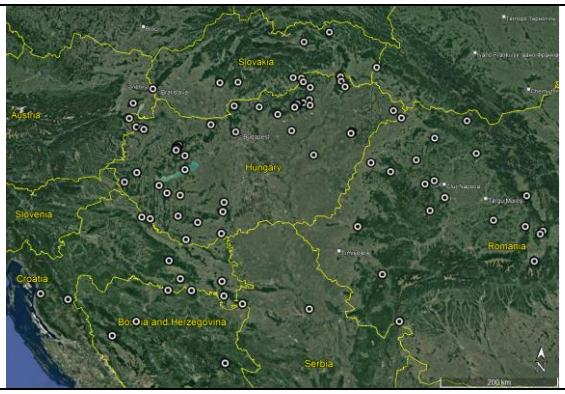

Fig. 1. Map of the study area in Central and Eastern Europe. Symbols indicate localities of historical mentions of forest grazing by domestic livestock. Country borders: yellow lines. Source base map: Google Earth (Landsat/Copernicus)

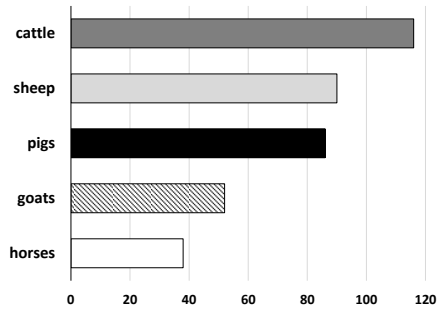

Fig. 2. The number of mentions of forest grazing by individual livestock species in the historical sources.

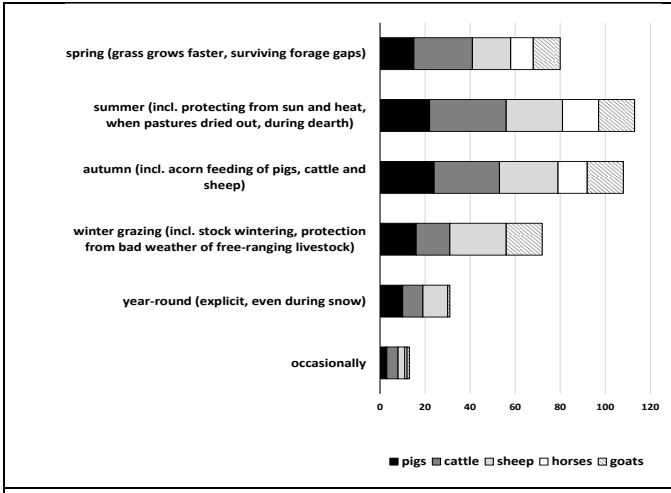

Fig. 3. The timing and reasons for domestic livestock grazing in forests, as mentioned in the historical sources.

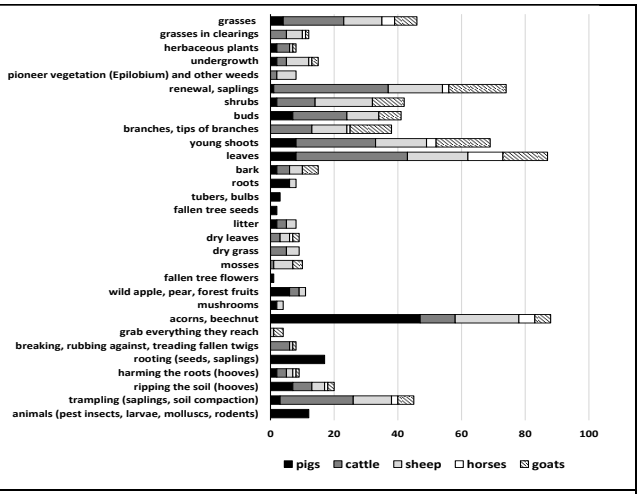

Fig. 4. Forest elements consumed by domestic livestock and impacts on forest, as mentioned in the historical sources.

Oral history information on the practices and impacts of forest grazing (Varga et al. 2020)

We interviewed 58 knowledgeable herders and participated in forest grazing activities in 43 study locations across Hungary. The results were analysed qualitatively.

We revealed a living ecological knowledge tradition and practice of forest grazing in native and non-native forest stands, despite the legal prohibition of this activity between 1961 and 2017. The impact of livestock grazing on native and non-native forests is not considerably different, in the view of the herders. For both forest types, the greatest impact of grazing was the suppression of the shrub layer, while grazing also increased the dominance and palatability ("tameness") of the grasses. Livestock could cause significant damage to seedlings during forest grazing, but if done with care, grazing could also be an integral part of forestry management.

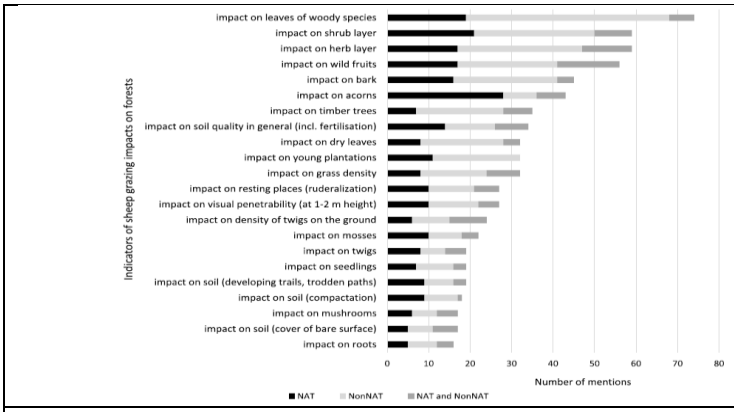

Fig. 2 Frequency of reported indicators of forest grazing impacts according to sheep, by forest type (NAT—native, NonNAT—non-native, NAT and NonNAT—not specified)

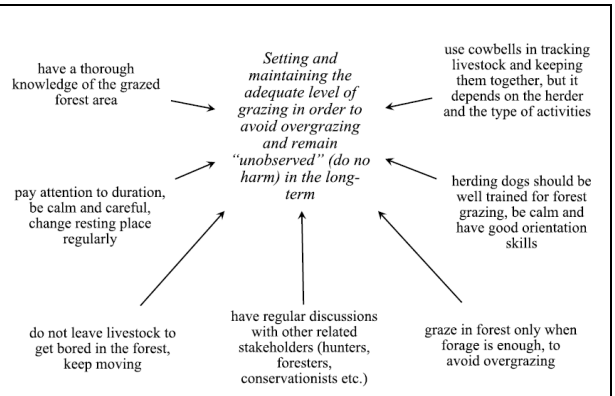

Fig. 4 Local and traditional knowledge-based rules for careful and sustainable forest grazing practice, as mentioned by the herders

Traditional ecological knowledge of pig keepers related to pig grazing in forests and marshes (Molnár et al. 2021)

We studied the knowledge of traditional pig keepers (*svinjar*s) on wild plants and pig foraging on the Sava-Bosut forest-marsh complex in Serbia. We conducted picture-based interviews about 234 locally common and/or salient plant species, and participatory fieldwork (11 days) and visual observation (21 days) on pig foraging.

181 wild plant species were known by *svinjar*s and 106 taxa were consumed by pigs. *Svinjar*s knew well and could name most regularly foraged species. 98 species were reported by *svinjar*s as foraged and 56 as not eaten. 28 species were observed by the authors as eaten regularly, while 21 were nibbled and 17 avoided. Contradictory information on foraging was rare both among *svinjar*s (8 species) and between *svinjar*s and researchers (7 species); several of these species were rare. Leaves of 92, fruits or seeds of 21 and 'roots' of 20 species were reported or observed as eaten, usually with high seasonality. *Svinjar*s were overall observant, but knew little about some less salient species (e.g. *Veronica*, *Circaea*). The most common forages (reported and/or observed) were fruits (*Quercus*, fleshy fruits), grasses (*Agrostis*, *Glyceria*), herbs (*Ranunculus ficaria*, *Circaea*), nutritious 'roots' (*Carex* spp., *Iris*), young shrub leaves (*Crataegus*, *Carpinus*) and 'tame' plants growing in the sun (*Persicaria dubia*, *Erigeron annuus*). Traditional, now extinct pig breeds were reported as less selective and more 'knowledgeable' about plants, as they received less additional

fodder. *Svinjar*s learnt their knowledge since childhood, from community members, but long-term personal observations and everyday encounters with pigs were also important sources of knowledge.

Categories of knowledge depth	Number of plant taxa (from the analysed 192)		
	Trees and shrubs	Grasses, sedges and rushes	Others (herbs etc.)
Well known	28	12	62
Moderately known	3	3	21
Little known	6	5	41
Not known	0	1	10
Total	37	21	134
Pig foraging behaviour	***Svinjars'* knowledge**	**Authors' observations**	**Overlaps**
Regularly eaten, loved	61	28	21
Nibbled, rarely eaten	37	21	10
Not eaten	56	17	8
No knowledge by *svinjars* / No observation by the authors	38	126	10
Total	192	192	49

Table 1 Overview of the number of plant taxa: *svinjars*' plant knowledge and authors' observations, species that were known by *svinjar*s as eaten or avoided by pigs and/or observed as eaten or avoided by pigs

Latin name, (local frequency), depth of local knowledge, folk names, (depth of knowledge regionally—Carpathian Basin)	Pigs eat/don't eat (*svinjars'* reports)	Pigs eat/don't eat (authors' observations)	Other uses and salient features (e.g. impact on pigs) reported by *svinjars*
Trees			
Acer campestre L. (3), well known, *klen* (well known)	Leaves are eaten eagerly in spring, liked more than *Carpinus* leaves, eaten less in summer but longer than other tree leaves, also fallen leaves in autumn, fruits are eaten in need	Leaves were eaten, also fallen leaves	Leaves have a sweet taste
Acer tataricum L. (2), well known, *žesta* (fierce, spicy) (moderately known)	Neither leaves nor fruits are eaten	(It was nibbled)	Common in forest and marsh edges, short-lived, resprouts and can have several trunks, has a different fruit than *Acer campestre*

Table 2 *Svinjar*s' knowledge of wild plant species and visual observations by the authors of pig foraging of the studied plant species in the Sava-Bosut floodplain, Serbia

Knowledge co-production with traditional herders on grazing in grassland-marshland mosaics (Molnár et al. 2020)

We studied the grazing behaviour (plant selection and avoidance) of beef cattle (c. 33,000 bites) on species-rich lowland pastures in Central Europe and traditional herding practices. We also did >450 outdoor interviews with traditional herders about livestock behaviour, herders' decisions to modify grazing behaviour and effects of modified grazing on pasture vegetation.

We found that cattle grazing on species-rich pastures displayed at least 10 different behavioural elements as they encountered 117 forage species from highly desired to rejected. The small discrimination error suggests that cattle recognize all listed plants by 'species'. We also found that herders had broad knowledge of grazing desire and they consciously aimed to modify desire by slowing, stopping or redirecting the herd. Modifications were aimed at increasing grazing intensity in less-desired patches and decreasing grazing selectivity in heterogenous swards.

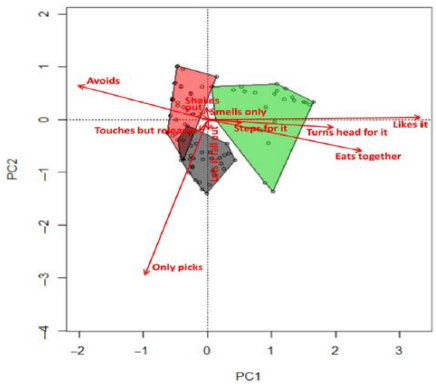

Figure 3 Principal component analysis (PCA) of the 117 plant species based on the 10 behavioural elements. Eigenvalues for first and second axis: 10.37 and 3.81, respectively; explained variance: 52.95% and 19.47% respectively. Green: desired species, grey: eaten together with others and picked, red: avoided but sometimes picked

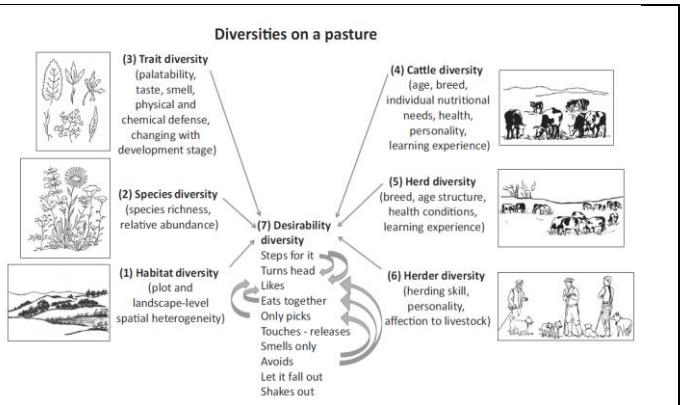

Figure 4 Conceptual framework of 'diversities' related to plant–livestock interactions on species-rich pastures grazed by herded livestock. Straight arrows indicate factors affecting livestock desire. Curved arrows indicate the directions in which herders modify behaviour of the livestock (mostly increase desire and intake, or motivate calm grazing by slowing herd movement).

Recent impacts of cattle and pig grazing on marsh vegetation (Biró et al. 2020)

We conducted free listing interviews with 15 conservationists and 15 herders to identify the key indicators of well managed, extensively grazed wetland habitats. To check the practical ecological relevance of these indicators, vegetation surveys were performed along a gradient from ungrazed to heavily grazed stands (45 sites) in three countries: Hungary, Romania and Serbia.

Positive trends for herders included increases in useful forage grasses and decreases in tall-growing marsh species; for conservationists, increases in wetland birds, protected and threatened plant species, habitat heterogeneity, and patches of open vegetation were all positive. Grazed marshes had lower vegetation cover and height, less litter cover and fewer shrubs. The proportion of open surfaces and the frequency of rare mud species and protected species increased along the grazing intensity gradient. As grazing intensified, 73% of the 15 vegetation attributes assigned to the indicators changed in a 'positive' direction, half of them significantly, showing the benefits of extensive but patchy heavy grazing. Despite differences in perceived benefits, there were no opposing preferred trends for any of the studied indicators, so patchy, occasionally and locally intense or heavy wetland grazing by livestock in these landscapes was considered as beneficial for herding and conservation alike. In the situation of mosaic-like, carefully herded extensive grazing, there was no trade-off between conservation management and utilisation.

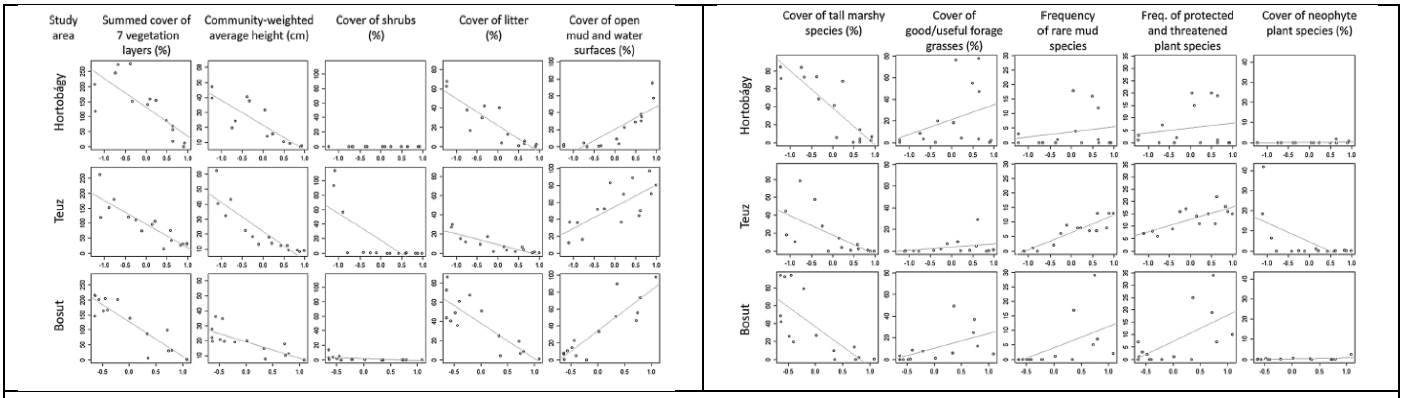

Fig. 1. Change of vegetation attributes along grazing intensity as quantified by the PC1 variable in the Hortobagy, Teuz and Bosut areas. Trend lines were fitted by a general linear model in all cases. For graphs with grey lines, the relationship was tested by Kendall tau rank correlation. For those with black lines, the test statistic was the slope of the linear model.

Recent impacts of cattle grazing on floodplain poplar plantations (Demeter, Molnár et al., 2021)

We studied cattle grazing impacts on the cover, composition and diversity of the herb and shrub layers in floodplain poplar plantations along the Tamis river, Serbia. Non-grazed, moderately grazed, intensively grazed and resting place stands were sampled in five locations in three sampling points.

Non-grazed stands had substantially higher cover of invasive alien shrub species (on average 65%) than moderately and intensively grazed stands, and resting places (5.17, 0.02 and 0.00%, respectively), but without considerable differences between the grazing intensity categories. The number of invasive alien species in the shrub layer decreased considerably from non-grazed to intensively grazed stands. Species composition in the herb layer changed from non-grazed to intensively grazed stands, while resting places differed substantially from the other categories. Total species richness, richness of native generalist herbaceous grassland species, and the cover of palatable grasses were the highest in moderately and intensively grazed stands. Our results suggest that cattle grazing in floodplains is effective at controlling invasive alien shrub species. Furthermore, continuous moderate or intensive grazing would contribute to multifunctional management of invaded floodplains by enhancing local biodiversity, reducing flood risk, and providing additional grazing areas for the local community.

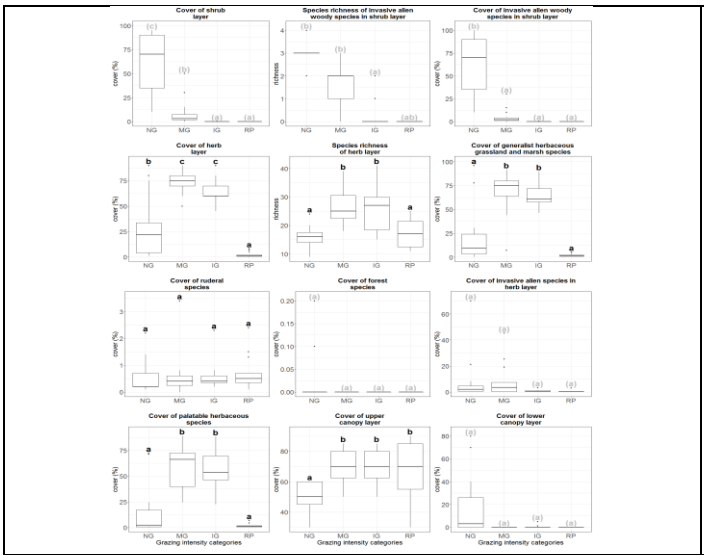

Fig. 3. Boxplots represent vegetation variables subdivided by

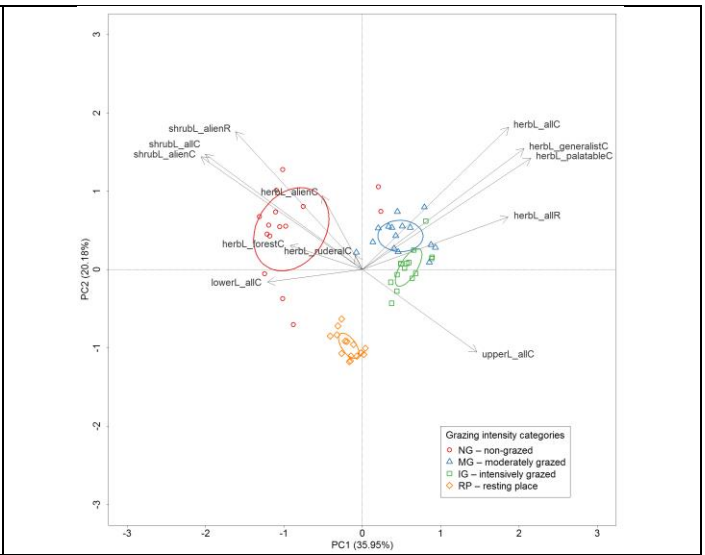

Fig. 5. PCA ordination of sampling points and vegetation

grazing intensity categories. Groups with identical letters are not significantly different from each other ($p < 0.05$). If any of the model assumptions of the underlying GLMM was violated, letters are displayed in grey in brackets and the significant differences between groups should be interpreted with caution. Grazing intensity categories: NG – non-grazed, MG – moderately grazed, IG – intensively grazed, RP – resting place.	variables. Grazing intensity categories: NG – non-grazed, MG – moderately grazed, IG – intensively grazed, RP – resting place.

Recent impacts of pig grazing on forest vegetation (Demeter et al., in prep.)

We studied the impact of pig grazing on the herb and shrub layer of a hardwood floodplain forest in Serbia. Vegetation surveys were conducted in 56 sampling points and 7 grazing intensity categories. Cover of each plant species was visually estimated per sampling point (0,25 ha) and the growing forms and damages caused by pigs to shrub specimens were measured along a 28 m long transect. Altogether 1680 subsamples, 30 at each sampling point (1m^2) were applied to collect species data from the herb layer.

Total cover of shrub and herb layer decreased along the grazing intensity gradient, while the species number of both layers showed no significant differences between the grazing intensity categories (Fig. 1.). Species composition of the shrub layer did not differ between the studied grazing intensity categories, while the herb layer showed differences. Sampling points located in abandoned sites were well-separated from actively grazed sampling points, while the resting places had completely different species composition based on the DCA of herb layer (Fig. 3.). The number of forest generalist and specialist species decreased along the grazing intensity gradient. However, only resting places showed higher number and abundance of non-forest ruderal species (Fig. 2.). The shrub layer structure of abandoned and actively grazed sampling points differed from each other. Actively grazed sampling points were dominated by demorf and sprout origin specimens, often with high cover of moss species at the base of the specimens (Fig. 4.).

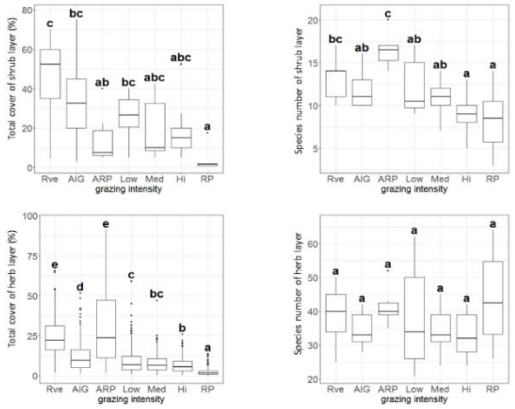

Fig. 1. Total cover and species number in the herb and shrub layers. Legend: Rve – forest reserves, AIG – abandoned intensively grazed stands; ARP – abandoned resting places; Low – stands with low intensity of grazing; Med – stands with medium intensity of grazing; High – stands with high intensity of grazing; RP – active resting places. Groups that share no common letter differ significantly (α =0.05) from each other according to the studied variables based on Tukey's HSD

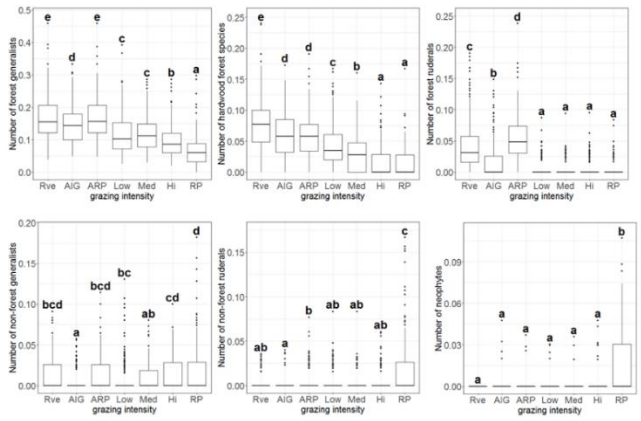

Fig. 2. Species number per different groups of species in the herb layer.

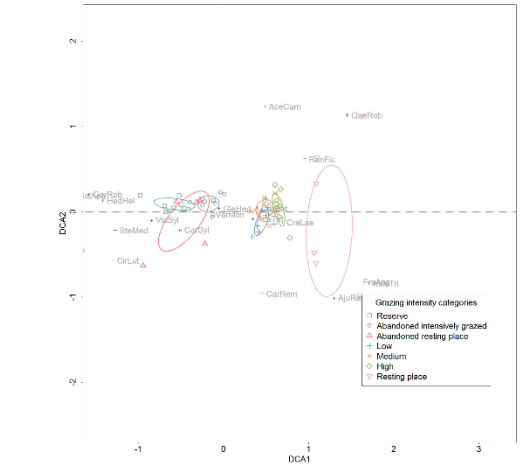

Fig. 3. Detrended correspondence analysis (DCA) of frequency data of species in the herb layer. Species frequencies were counted from 30 subsamples per sample site.

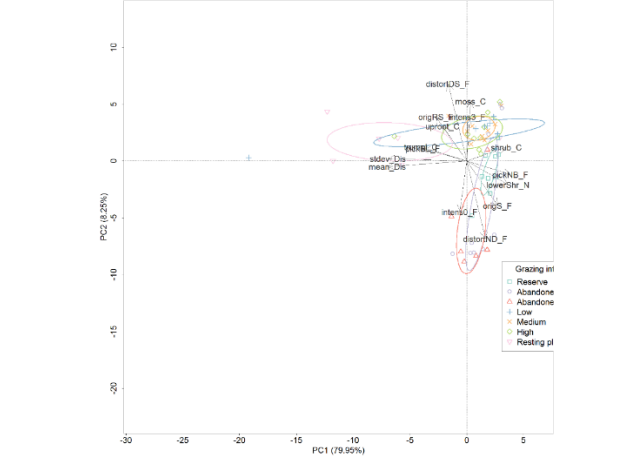

Fig. 4. Principal component analysis (PCA) of shrub layer variables.

Global review of the impacts of forest grazing on vegetation (Öllerer, Varga et al. 2019)

We analysed 71 publications discussing the impact of livestock grazing on vegetation in forests. Grazing reduces vegetation biomass, but less obvious effects relevant to conservation include increased habitat diversity and increased regeneration of selected canopy tree species. Moreover, detailed guidance on how grazing should be carried out for conservation purposes is limited because the results are strongly context dependent. The direction and amplitude of effects can be influenced not only by forest type and stocking levels, but by foraging preferences of livestock, availability of alternative forage, grazing season and herder activity. We stress the need for well-planned real-world experiments and observations, and for more quantitative studies to foster evidence-based conservation management. Grazing differences between wild ungulates and livestock should be better studied, because the effects are often overlapping. We suggest widening the temporal and spatial scales of case studies.

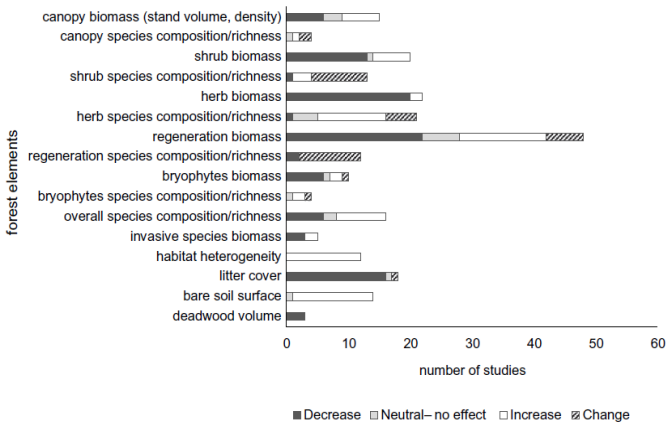

Fig. 5. Impacts of grazing by domestic livestock on forest elements.

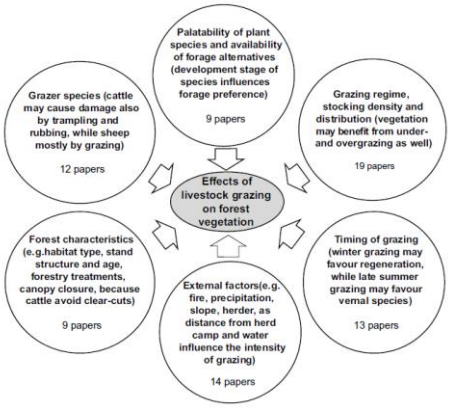

Fig. 6. The main biotic and abiotic factors that influence the effects of forest grazing by domestic livestock (with number of references stressing out each factor), based on the reviewed literature (see Table S2 for a complete list of references).

CONCLUSIONS

Historical sources lay firm foundations for developing innovative nature conservation management methods both in marshes and in forests. Traditional herders still holding wetland and forest management knowledge could contribute to this process when done in a participatory way, fostering knowledge co-production. We stress the need to create space and openness for interdisciplinary and participatory research and conservation approaches, initiating knowledge co-production on the benefits and dis-benefits of grazing in non-grassland habitats (non-conventional grazing lands), and in order to gain a better understanding of the effects of livestock grazing on vegetation. We proved that the historical and recent traditional herd management practices may have significant conservation and potential economic benefits.

Papers prepared from the project (core publications only)

Biró, M., Molnár, Zs., Babai, D., Dénes, A., Fehér, A., Barta, S., Sáfián, L., Szabados, K., Kis, A., Demeter, L., Öllerer, K. (2019): Reviewing historical traditional knowledge for innovative conservation management: a re-evaluation of marshland grazing, *Science of the Total Environment* 666, 1114-1125. **D1, IF: 6,55**

Biró, M., Molnár, Zs., Babai, D., Dénes, A., Fehér, A., Barta, S., Sáfián, L., Szabados, K., Kiš, A., Demeter, L., Öllerer, K. (2019): Történeti adatok pannon vizes élőhelyek legeltetéséről az elmúlt évszázadokból – szemelvénygyűjtemény, In: Tóth, A., Tóth, Cs. (Eds.) A Hortobágyi Természetvédelmi Kutatótábor 45 éve. Alföldkutatásért Alapítvány, Kisújszállás, pp. 143–165.

Biró, M., Molnár, Zs., Öllerer, K., Lengyel, A., Ulicsni, V., Szabados, K., Kiš, A., Perić, R., Demeter, L., Babai, D. (2020): Conservation and herding co-benefit from traditional extensive wetland grazing, *Agriculture, Ecosystems and Environment* 300: 106983. **D1, IF: 4,24**

Demeter, L., Kiš, A., Bede-Fazekas, Á., Öllerer, K., Szabados, K., Biró, M., Molnár, Zs. (2022): Recent impacts of pig grazing on forest vegetation. (in prep.)

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