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Ph.D. Thesis Abstract

# HERBIVORY AND FIRE AS KEY PROCESSES IN GRASSLAND DYNAMICS: FIELD STUDIES IN OPEN PERENNIAL SAND GRASSLANDS

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# I. Introduction and aims

I studied the effects of disturbance regimes on the composition and production of open sand grasslands in the forest-steppe vegetation of the Danube-Tisza Interfluve, in various temporal and spatial scales. Grazing and fire regimes are the most important large-scale disturbances in semiarid and arid grassland communities (van Langevelde et al. 2003; Ghermandi et al. 2004; Feldman & Lewis 2005); while in fine-scale it is the physical disturbances of the animals (Anderson 1983).

Grazing is one of the studied disturbance factors in my thesis. Herbivore density has gradually decreased in the Sand Ridge area of the Danube-Tisza Interfluve since the middle of the 19. century. One important cause for this was the decline in stock density of cattle and sheep. Additionally, the abundance of rabbit decreased dramatically in the 1990s in Hungary. Decreased herbivory drew the attention to the role of grazing intensity in vegetation processes. The other studied disturbance factor in my thesis is fire, which caused expanded damages in the Sand Ridge during the past decades. Extensive fires are expected to become more frequent due to climate change in Hungary, as has similarly occurred in the Mediterranean (Veblen et al. 2003).

In most cases, fire and herbivory are independently investigated, although more and more recent studies have examined these two disturbances together. However, there is few research on how these two agents influence the function of each other (Archibald et al. 2005). As fire and herbivory are two different agents of disturbance with distinct and interactive effects on the community, land use play an important role in the fire risk.

There were extensive wildfire events in the Kiskunság National Park (Hungary) in the area of the Sand Ridge in 1976, 1993, and 2000, which caused considerable damage to expansive areas of the national park. Open sand grassland patches play a substantial role in transmitting fire among the woody patches of the *Juniperus-Populus* community in the forest-steppe vegetation. After the fire event, fast regeneration processes start in the grasslands; the sprouts of *Populus* species appear in a few weeks. However, invasive species can play a role during post-fire succession, due to their high abundance in the surrounding landscapes, therefore fire endangers the semi-natural state of the forest-steppe mosaics in the Danube-Tisza Interfluve.

The aims of my studies were to investigate the validity of the compensatory growth and the intermediate disturbance hypothesis in grazed semi-arid grasslands, and to investigate the long-term effects of grazing and fire on vegetation dynamics, including conservation biological aspects. Therefore, my thesis consists of three field experiments, in which I studied step by step the effects of grazing on the production and composition of the sand grassland, and on the spread of fire, finally I studied the characteristics of post-fire secondary succession.

To meet these aims the following questions were addressed:

1. Can *Festuca vaginata* and *Stipa borysthenica* (matrix-species of open sand grasslands) compensate the effects of different grazing intensities, i.e. how strong grazing pressure is sustainable in open sand grasslands?
2. Which level of intensity of grazing induces compositional changes in sand grasslands, and how does vascular plant species richness and dominance order change during the process?
3. Which are the effects of changed litter amounts on primary productivity and species composition?
4. Is grazing an appropriate management tool to decrease fire spread in open sand grasslands? Can grazing be applied as a nature conservation management tool in the Sand Ridge?
5. Which are the short-term effects of fire on the species composition of open sand grasslands?
6. Which succession stages occur in burnt sand grasslands during the decades following fire events? Do burnt and unburnt grasslands differ in this point of view?
7. Which are the characteristic features of the course of succession and of the succession state-transformations dynamics in the burnt and unburnt sand grasslands?
8. Can rabbit grazing modify post-fire secondary succession processes?
9. How do expanded wildfire events alter vegetation patterns in the forest-steppe vegetation of the Sand Ridge Area? How long time do the regeneration of the vegetation take?

## II. Materials and methods

Field studies were conducted in perennial open sand grassland community (*Festucetum vaginatae*). Studies in the Kiskunság involved annual open sand grassland stands and closed perennial stands as well. The study area of simulated grazing is in the Kis-Tece Pasture Nature Preserve 30 km NE of Budapest, in the outskirts of Vácrátót village. Investigation of sheep and rabbit grazing on fire spread, and monitoring of post-fire succession processes were conducted in the area of the Kiskunság National Park, in the outskirts of Bugac, Bócsa and Orgovány. The field experiment of fire spread was performed at the edge of the National Park in Orgovány, while post-fire succession was monitored in core areas, in the juniper-poplar-grassland mosaics of Bugac, Bócsa and Orgovány.

The percent of canopy cover of plant species in the sampling quadrates was recorded by visual estimation in each study. I also estimated the above ground biomass using non-destructive field spectroscopy techniques. During the simulated grazing study, I dried and weighed the above-ground biomass removed by clipping treatments for each quadrate. In the case of the burning study, I measured the maximum height of vegetation and recorded the time-span between the start and the end of the burning in each quadrate.

Effects of simulated grazing on open perennial sand grassland

The experiment was carried out in a patch of the Kis-Tece Pasture (N 47˚ 42,05’, E 19˚ 13,59’) dominated by *Festuca vaginata*. I started the experiment in November 2000 and ended in November 2003. A two-way factorial experiment was performed. Factors were the removal of the leaves of matrix species *Festuca vaginata* and *Stipa borysthenica* by clipping and changing the amount of the litter. The clipping treatment had three levels: control, moderate clipping, and heavy clipping. The litter treatment had four levels: control, litter replacement, litter removal, litter addition. The experiment was fully factorial in randomized block design, i.e. in each block we had 12 quadrates according to the 3 clipping by 4 litter treatment levels. The size of quadrates was 80 cm × 80 cm. We designed eight repeats, thus we had 96 quadrates altogether. We arranged the quadrates in a grid with 12 columns and 8 rows.

The samples were taken in March, May, and November from November 2000 to November 2003. We analyzed the data of each sampling date separately. Effects of the treatments in consideration of the canopy cover, the number of species per quadrate, the NDVI and the harvested biomass data were tested by three-way analysis of variance with two fixed (i.e., clipping and litter treatments) and one random factor (i.e., block) and interaction of fixed factors (treatments). If the effect of a treatment proved to be significant ($p < 5\%$), its levels were compared by Tukey’s HSD test.

Effects of sheep and rabbit grazing on vegetation composition and the spread of fire

We conducted the experiment in 2003. The size of the study site (N 46˚ 47,37’, E 19˚ 26,83’) was one hectare. Within the study site, we marked 10 blocks of the open sand grassland among the woody patches. Each block consisted of four differently treated grassland patches, namely, an ungrazed control plot, an early sheep grazed (middle of April), a late sheep grazed (end of May), and a rabbit grazed (end of May) plot. Each patch consisted of 1 m x 1 m quadrates. The patches were fenced during the grazing period which lasted until the sheep or rabbit (one animal per patch) reduced the original vegetation cover to 50% (estimated visually) through plant removal and trampling. We performed the burning treatment in July for all blocks on the same day. We burned half of each patch, including two of the four quadrates. There remained two unburned quadrates in each patch to examine regeneration following the grazing treatments.

I took samples three times in 2003. Sampling periods were before the grazing treatments in April, before the burning treatment in July, and after the burning treatment in September. I estimated the effects of treatments and sampling date on the species number, on the canopy cover of the vascular plants, and on the litter, using a three-way repeated measure ANOVA. Treatments (grazing, burning) were fixed factors, while the third factor (the block) was random. I analyzed the effects of grazing on plant height, burnt area, and speed of fire-spread by two-way ANOVA with one fixed factor (grazing) and one random factor (block). After both ANOVA analyses, pairwise comparisons by Tukey's HSD tests were carried out. I calculated Spearman's rank correlations between measured variables to show their relationships.

Secondary succession in open sand grasslands after fire events in the Kiskunság

We have conducted long-term monitoring studies in three burnt area of the Kiskunság National Park since 1997. We combine permanent quadrates method and the concept of space-for-time substitution. The Bugac site was burnt in 1976, the Bócsa site in 1993, and the Orgovány site in 2000. In Orgovány, the study was started in 2002. I processed the data for the period from 1997 until 2008. In each site, there were two fenced area marked on the burnt and two on the unburnt part of the grassland. The pairs of fenced areas were set for studying the effects of rabbit grazing on the succession process. The rabbit grazing treatment failed because of the extinction of the rabbits during the nineties, however, we saved the original experimental design. The size of the fenced area was one hectare. We sampled five one by one meters quadrates, which are arranged in grassland patches depending on the shape of the patch. Each fenced area contained ten patches. We sample the quadrates twice a year, in May (before the starting of the drought) and in October (at the peak of the summer annual aspect).

I chose the grassland patches, which were represented by five sampling quadrates, for the spatial unit of the study on the secondary succession processes. I used coenological states (coenostates) (Juhász-Nagy 1986) describing the composition of the grassland patches in each year. For coenostate identification I analyzed interspecific association relationships using the COCKTAIL method (Bruelheide 2000). I compared the theoretical (independent coenostates) and the empirical coenostate-transformation matrices with khi-square test using Freeman-Tukey deviates. Coenological stability of the grassland patches were tested by two factor u-test. The effect of precipitation on the state-transformations of burnt and unburnt areas was tested using linear regression analysis.

## III. Results

In the order of the addressed questions:

1.

a. I found that in semiarid open grassland community moderate clipping (50% removal of aboveground living biomass, twice a year) is compensated by the growth of the matrix species. In some cases moderate grazing pressure were resulted in overcompensation.

b. However, heavy grazing pressure (90% removal of aboveground living biomass, twice a year) leads to serious degradation of the dominant species in open sand grasslands.

2.

a. My results show that moderate grazing pressure has favourable effect on the open perennial sand grassland community in terms of species richness while it does not cause degradation of the matrix species.

b. Heavy clipping did not increase species richness, compared to moderate clipping, and destroyed the gap structure of the community.

c. Even moderate grazing pressure causes changes in species composition in the calcareous open perennial sand grassland community, but the development of compositional changes takes several years.

d. Moderate grazing of sheep and rabbit caused simple structural changes in a one-year experiment, for example sheep grazing decreased the height of the vegetation. However, the effect of grazing on vegetation structure depended upon the timing of the grazing treatments and the species identity of the grazer.

3.

a. Litter treatment hardly effected the vegetation composition at the beginning of the experiment, and it had minor effects later. Litter addition delayed the intensive growing of the gap species during the first spring. However, as the weather became warmer during the spring, gap species made up for their growing delay. So the added grass litter layer did not suppress the seedlings mechanically.

b. Litter treatment had no effect on the aboveground primary production of the grassland.

4.

a. Moderate grazing causes decreased fire-spread on open sand grasslands in the *Juniperus-Populus* forest-steppe. Timing of grazing treatments and species identity proved to be important factors.

5.

a. Fire had strong immediate effect on aboveground plant organs, the surface was covered by burnt biomass. Fire decreased species number in the short term, although this is attributed to the disappearance of some small forbs during the fire event.
b. Perennial grasses and forbs regenerate after a fire event, because their belowground organs can survive the fire spreading on the open sand grassland and they can resprout after the fire event.

6.

a. I found 9 coenostates during my 12 years long field studies in Bugac, Bócsa, and Orgovány in calcareous sand grasslands. These coenostates are: the „Bare sand” and the „Black spot” states, and the „Annual”, the „Festuca”, the „Stipa”, the „Carex”, the „Poa bulbosa”, the „Calamagrostis” and the „Poa angustifolia” dominated grasslands.
b. 8 of the 9 coenostates occurred on unburnt areas during the time span of the 12 years of the monitoring. I have not found „Annual” coenostate on the unburnt patches surrounded by juniper-poplar mosaics since the beginning of the study.
c. 7 of the 9 coenostates occurred on burnt areas. However, there were two missing coenostates, the „Bare sand” and the „Black spot”, thus patches were dominated by vascular plant species. The „Annual” coenostate appeared in the years after drought events.
d. *Juniperus communis* occupied no grassland patches during the study, and I found very few seedlings of it in the grassland. Sprouts of *Populus* species occurred in many patches; however, its sprouts remained mainly short shrubs. I found no strong interspecific association among the poplar and the grass or forbs species.

7.

a. Fire decreased the stability of open sand grassland and increased its drought sensitivity, even on the Bugac site, which was burnt more than 30 years ago. I conclude that drought has a freezing effect on coenostate-transformations, while there are more state transformations in humid years during the post-fire succession in burnt sand grasslands.
b. All of the eight observed coenostates vary very little on unburnt areas covered by dense juniper-poplar and open sand grassland mosaics. Linear regression shows no connection

between the two variables (i.e. precipitation and state transformation frequency) on unburnt grasslands.

c. Coenostate transformations showed mainly multidirectional and reversible changes both in the burnt and in the unburnt areas. Thus, post-fire succession processes are not in agreement with the clementsian succession concept, which assumes directional changes during succession.

8.

a. I found no modifying effect of rabbit grazing on post-fire succession, most probably because of the irregular and mild treatment.

9.

a. Fire has strong effects on the habitat structure of the juniper-poplar forest-steppe vegetation. Grassland patches regenerated in a year and expanded into formerly woody patches, while poplar sprouts appeared in several weeks in the grassland patches after fires. Post-fire succession starts from perennial states. *Calamagrostis epigeios* is one of the well spreading clonal grass species, which can expand its area during the years after fire. However, I found its self-thinning in Bócsa where patches belonging to „Calamagrostis” coenostate were replaced by „Festuca” coenostate. Cryptogam layer remained very sparse during the first decade after fire.

b. The regeneration of woody vegetation covers more than three decades. The fast re-sprouting of poplar species was followed by a self-thinning process. The regeneration of bird spread *Juniperus communis* might start under the woody vegetation.

## IV. Conclusions

I consider moderate grazing pressure favourable for survival of the subordinate species in open sand grasslands while it does not cause degradation of the matrix species. These results and the finding that compensation growth (McNaughton 1983) can occur in the case of moderate grazing pressure are in accordance to the intermediate disturbance hypothesis (Connell 1978). Both the biomass of the matrix species and the total above-ground green biomass showed compensation after moderate clipping. In case of heavy clipping, matrix species did not compensate the treatment. Compensation occurred in case of the total biomass due to the increased abundance of the gap species. Heavy clipping resulted in degradation of the matrix species and in increased abundance of the gap species after three years period of the treatment.

My results show that both the amount of combustible biomass (i.e. canopy cover of vascular plant and litter) and the structure of the vegetation (i.e. height) play a role in the spread of fire (i.e. speed of fire spread and burnt area). The amount of dry biomass could increase significantly from April to July only with the lack of grazing in the control patches, because grazing treatments removed approximately 50% of the green vegetation, resulting in less litter on the grazed patches during the early summer. Considering fire risk aspects of herbivory, moderate grazing of rabbit and moderate sheep grazing in late spring are beneficial in forest-steppe vegetation, because their effect might increase the extension of unburnt patches after a wildfire event.

Heavy grazing decreases the role of fire and leads to increased woody vegetation on savannas (van Langevelde et al. 2003). However, in fire-controlled habitats, decreased herbivory may lead to the dominance of grassland vegetation because fire mainly damages woody vegetation and is enhanced due to the increased biomass of the grassland (Belsky, 1992). In the case of the fragmented vegetation of the Sand Ridge in the Kiskunság, wildfire events caused extension of grasslands, because *Juniperus communis* can not regenerate after fire, while the recovery of woody vegetation takes decades.

Fire increased state-transformation dynamics during the first, second, and third decades of regeneration process as well, thus fire might have an indirect positive long-lasting effect on grassland patch dynamics. The most characteristic effect of fire is the extinction of junipers and decreasing the number of shaded microhabitats. The result that fire increased the precipitation-dependency of the semiarid sand grassland dynamics supports the concept, that the woody vegetation has a stabilising effect on the grassland dynamics due to shading.

Harmful effects of fire, in nature conservation sense, appear on the formerly *Juniperus communis* dominated mosaics, however white poplar and the grassland part of the forest-steppe vegetation regenerate fast and become more dynamic after fire. Woody patches increase habitat diversity by producing shaded and more humus-rich habitat patches, which results in the remarkable species richness characteristic of the Sand Ridge vegetation. Fire damages this pattern of the vegetation. Therefore, nature conservation strategy should involve instructions for decreasing fire risk in this area. I consider controlled grazing treatments as a management tool to decrease fire risk and maintain the integrity of the semi-arid forest-steppe habitats, especially in case of increasing temperature and drought frequency due to climate change. Fire may become the most important disturbance factor in Sand Ridge area if grazing intensity cannot be increased in the future.

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