Restoration potential of sand grasslands

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Native grasslands are destroyed at a high rate in Hungary (Biró et al. 2013)

- **Pannonic steppe and sandy grasslands** are threatened

Natural regeneration is hindered (Molnár et al. 2008):
- non-native tree plantation (I.)
- surplus nutrients in the soil (II., V.)
- presence of invasive species (III.)
- dispersal limitation of specialist species (IV., V.)
- soil seed bank: small role (I.)

- Secondary succession is slow
- We have to find the restoration methods required to facilitate and direct the natural succession of dry grasslands

**Introduction**

![Graph showing invaded area of different habitats and species](image)
Studies:
• areas: in Kiskunság
• 1990s: many agricultural fields were abandonment
• aims: restoration of sandy dry grasslands by several methods
• areas: in Kiskunság
• started in 1998
• single and combined treatments have been compared regarding soil variables and vegetation composition

Exp.1. non-native tree plantation (I.)
Exp.2. surplus nutrients in the soil (II., V.)
Exp.3. combined restoration methods (V.)
Exp.4. presence of invasive species (III.)
<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Area in Hungary</th>
<th>Characteristic species</th>
<th>Soil</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open sandy grasslands</td>
<td>11 000 ha</td>
<td><em>Festuca vaginata</em>, <em>Corynephorus canescens</em>, <em>Jasione montana</em>, <em>Hypochoeris radicata</em>, <em>Rumex acetosella</em></td>
<td>loose, low humus-content sandy soils at flat or dune areas</td>
<td>maximum cover of 75% cryptogams - drought resistant</td>
</tr>
</tbody>
</table>
Conservation problem 1. NON-NATIVE TREE PLANTATION

1. Spontaneous and induced successional trends following clear-cut of black locust forests (1995-2001)

**Problem: black locust (Robinia pseudoacacia L.)**
- World-wide one of the most commonly cultivated tree species > major component of plantation
- N-USA origin, invasive species
- Habitat transformer:
  N-enrichment of soil
d  lower species richness of undergrowth
  > major driver of biodiversity decrease

**Main aim: to restore open sand grassland in place of black locust plantations with the help of mowing**

(Botta-Dukát et al 2008)
Material and methods

Areas: Izsák, Fülöpháza, Bugac

1. Restoration interventions
   - Clear-cutting of *Robinia* plantation
   - Chemical treatment (Garlon) for seedling of *Robinia*
   - Mowing and removing of biomass
     - 10 m x 10 m mown/control quadrats/site

2. Monitoring
   - 2 m x 2 m permanent plots in restoration, control and reference sites
   - soil surveys (sum of nitrogen)
   - soil seed bank survey
Results and conclusion

Mowing:
- sum N content of soil was decreased
- species with higher nitrogen requirements were decreased
- more target sandy species (e.g. *Festuca vaginata*)

Without mowing:
- increasing abundance of species of closed grasslands and woody habitats
- increasing cover of shrub (*Crataegus monogyna*)

Soil seed bank: small role in regeneration

Conservation problem: I. NON-NATIVE TREE PLANTATION

**MEASURE: Clear-cutting + Mowing**

![Graph showing average cover of hawthorn (*Crataegus monogyna*) between 1995 and 2017.](image)

Average of target species cover between 1995 and 2017.
Conservation problem: I. NON-NATIVE TREE PLANTATION

MEASURE: Clear-cutting + Mowing

Results and conclusion

Restoration of secondary sandy grassland is an alternative possibility in place of extraction of *Robinia* forest

- treatment samples are closer to the reference than controls along the first axis
- formed secondary open grasslands with invasive and disturbance tolerant species

- Initial years: treatment trajectory was satisfactory
- Long-term monitoring (>20 years): the recovery process was too slow, and the system was not resistant to invasion.
- Mowing alone is insufficient to restore sandy grasslands after eliminating *Robinia*
  - further management is needed to enhance resistance to increasing invasion pressure


**Problem:** due to earlier agricultural activity, nutrients accumulated in the soil favouring the establishment of weedy species

Carbon addition influences the competitive relationships between the species through decreasing the available N content of the soil, thus accelerating the natural secondary succession and directs the vegetation development towards the target community.

**Theoretical background**

- Carbon-rich organic matter addition to the soil
- Increase of soil microbial biomass and activity
- Inorganic N (NH$_4^+$, NO$_3^-$) immobilization, decrease of available N for plants
- Competitive advantage for late successional species over the fast-growing nitrophilous weeds

**Conservation problem:** II. NUTRIENT SURPLUS IN THE SOIL

Main aim: to restore open sand grassland on abandoned field with the help of carbon amendment
Material and methods

Areas: Fülöpháza; 3 sites/same farmland (Meadow, Hummock, Depression)

1. Restoration interventions
   - Carbon amendment
   - 8 times sucrose + 2 times sawdust
   - 6 C amended, 6 control

2. Monitoring
   - Vegetation: 2m x 2m permanent quadrats in restoration and reference sites
   - N content: available nitrogen (ammonium, nitrat) from soil samples and ion exchange resin bags
   - C content: microbial biomass
MEASURE: Carbon amendment

Results and conclusion

- Carbon amendments: increased significantly soil microbial biomass reduced soil nitrogen availability after 2 years
- Total vegetation cover was reduced by reducing soil nitrogen availability
- Total species richness was not impacted
- Cover of early-seral species decreased, and species richness and cover of late-seral species increased irrespective of nitrogen immobilization

- After 4–6 years reducing soil nitrogen availability hampered the spread of moss under vascular vegetation

Török et al. 2014

Conservation problem: II. NUTRIENT SURPLUS IN THE SOIL
Conservation problem: **II. NUTRIENT SURPLUS IN THE SOIL**

**MEASURE: Carbon amendment**

**Results and conclusion**

Reference grassland was clearly separated from old fields, and its trajectory demonstrated a relatively stable state during the 6 years.

This study supports the efficacy of carbon amendment as a tool to immobilize available soil nitrogen in the upper soil layers. The desired impact on vegetation was not fully achieved despite application over several years.

3. Control of Asclepias syriaca in the restoration of fallow land (2006-2010)

**Problem:** Common milkweed (*Asclepias syriaca*)
- invasive species, N American origin
- spontaneous spread, invading large areas of sandy grasslands, disturbed areas
- changes abiotic (light, nutrient) and biotic (competition, allelopathy) conditions of vegetation
  > inhibits natural regeneration

**Main aim:** to test the impact of herbicide treatment on target vegetation
Conservation problem: III. ALIEN PLANT INVASION

MEASURE: Herbicide application + seeding

Material and methods
Areas: Fülöpháza, 3 old-fields

1. Restoration interventions
- 3 type of patches: - Poa perennial
  - Cynodon perennial
  - Annual- mosses, annual grasses
- Treatments: herbicide (glyphosate, Medallon)
  seeding (monocots, mono-dicots, control)

2. Monitoring
1m x 1m coenological quadrats

Glyphosate application

- 15 June 2006
- 30 June 2006
Glyphosate had serious effects on the non-target vegetation.  
- Species number decreased by 25%, while total vegetation cover dropped an average of 50% in the following year.  
- The treatment homogenized the vegetation that reverted to an early successional stage dominated by annual species.

Results

Seeding were most successful in case of Poa and Cynodon patch types.  
Moss type impeded germination of the sown seeds.  
Forbs proved to be dispersal limited in this time scale despite the proximity of the propagule sources.
MEASURE: Herbicide application + seeding

Conclusion

• herbicide treatment:
  milkweed successfully killed in the short term
  had significant negative effect for the rest of the vegetation

• sowing: was successful (8-18 % cover) in 5 years
  did not help spontaneous re-establishment of the non-seeded native species

Glyphosate treatment proved to be a cost-effective way to control common milkweed in the short term. However, in the longer term milkweed recovered already
> further treatments are required

4. Use of the seed bank samples for reintroduction of species (2011-2016)

Main aim: to study the effect of collection year, sowing year, and seed bank storage for seedling of 10 species two years after sowing.

<table>
<thead>
<tr>
<th>Species name</th>
<th>Family</th>
<th>Nature conservation status</th>
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<tbody>
<tr>
<td>Festuca vaginata</td>
<td>Poaceae</td>
<td></td>
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<tr>
<td>Koeleria glauca</td>
<td>Poaceae</td>
<td></td>
</tr>
<tr>
<td>Centaurea arenaria</td>
<td>Asteraceae</td>
<td></td>
</tr>
<tr>
<td>Dianthus serotinus</td>
<td>Caryophyllaceae</td>
<td>Protected</td>
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<tr>
<td>Echinops ruthenicus</td>
<td>Asteraceae</td>
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</tr>
<tr>
<td>Euphorbia seguierana</td>
<td>Euphorbiaceae</td>
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<tr>
<td>Gypsophila fastigiata subsp. arenaria</td>
<td>Caryophyllaceae</td>
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<td>Onosma arenaria</td>
<td>Boraginaceae</td>
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<tr>
<td>Scabiosa ochroleuca</td>
<td>Dipsacaceae</td>
<td></td>
</tr>
<tr>
<td>Silene borysthenica</td>
<td>Caryophyllaceae</td>
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Conservation problem: IV. DISPERSAL LIMITATION

Problem:
- Seed mixtures specific for open sand grassland are not available on the market.
- Seed bank has a big role in conservation of biodiversity and in habitat restoration with the long-term seed preservation of the wild vascular flora.
- First two years are the most important for seedling in habitat restoration.
- Germination and survive of sowing species influence the success of restoration.
Material and methods

Areas: Fülöpháza, 5 sites

1. Restoration interventions
   - 2 grasses and 8 perennial forbs
   - seeds: orthodox, collected in the vicinity of the reintroduction area
   - stored in the Pannon Seed Bank
   - pretreatment: to spot-spray milkweed, herbicide (Medallon)
   - treatment: ploughing and sowing in lines
   - different variables: year of sowing
   - year of seed collection
   - storage in seed bank

2. Monitoring
   - seedlings were counted in 0,5 m² units along two seeding lines per plot

Conservation problem: IV. DISPERSAL LIMITATION

<table>
<thead>
<tr>
<th>Year of collection</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tr>
<td>2011</td>
<td>x</td>
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<td>2012</td>
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<td>2013</td>
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<td>x</td>
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Survival rate:
- in first year (after sowing): *Dianthus serotinus* and *Festuca vaginata* had the highest survival rate
- the other species were more successful in second year

Collection year: 2011 was the most unsuccessful with fresh seeds without storage because of the dry weather of following year.

Long of storage: was not significantly effected

The sowing year: 2013 was the most successful, our target species germinated with high rate because of the high precipitation of following year.
Conclusion

- reintroduction experiment was successful by introducing the target species to the abandoned fields
- sowing year and the weather of following year (after sowing) have important role in restoration success

Restoration success was not influenced by storage of seed bank
> role of biodiversity conservation of seed bank has been strengthened

Conservation problem: V. DISPERSAL LIMITATION + NUTRIENT SURPLUS IN THE SOIL

5. Restoring fallow lands by combined restoration methods (2002-2008)

Main aim: to restore open sand grassland on 3 different abandoned field with the help of combined treatments

Areas: Fülöpháza, 3 different type of old-fields: fresh, 3 and 12 years old

1. Restoration interventions
   - Pretreatment: ploughing
   - Treatments: sowing (S) 5 species of sandy grassland, mowing (M)
                 C amendment (C) 45g sucrose/m2
                 + control (CO)

2. Monitoring
   - Vegetation: 1 m x 1 m coenological quadrats in restoration and reference sites
   - Soil samples: ion ex-change resin bags
Seeding: the most important treatment increasing species richness, vascular cover and enhancing target species composition.

Mowing: secondary role, acting primarily in interaction with the other treatments.

Carbon amendment: significantly reduced soil mineral nitrogen, but played a subordinate role in determining vegetation composition.

Significant interactions:
- Mowing and seeding
- Seeding and carbon-amendment

> determining primarily the structural characteristics of the vegetation in terms of vascular cover, moss cover, litter and bare ground

Halassy et al. 2016
Conservation problem: **V. DISPERSAL LIMITATION + NUTRIENT SURPLUS IN THE SOIL**

**MEASURE:** Species introduction by sowing, mowing and carbon amendment

Seeding plays a key role in determining the outcome of restoration measures followed by mowing, while the carbon amendment proved to have a weak effect.


Species composition changed primarily with time for seeded plots along the first axis, whereas non-seeded plots remained more or less unchanged.
Application of mowing/carbon amendment
- resulted in rapid changes in soil characteristics
- slower changes in cover of sandy specialist target species - propagule limitation

➢ Further treatments are needed to increase biodiversity

Sowing and combination of restoration methods
- seed bank storage: good basis for habitat restoration
- sowing plays a key role in determining the outcome of sandy grassland restoration
- interaction of combined methods should be taken into count in restoration decisions
- further treatments are necessary to prevent the recovery of alien plant in the longer term

Results so far demonstrate the complexity of regeneration constraints and the challenges of applying general methods in dry grassland restoration. Adaptive approach and combined methods are required to be able to cope with variations in local conditions and problems.
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<th>Participants:</th>
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<td>Török K.,</td>
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Thank you for your attention!
References:


