SZENT ISTVÁN UNIVERSITY

Changes in the species composition of grasslands due to specific ecological and management factors

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1. Scientific background

Grasslands covering about 1 million hectares today are typical components of the Hungarian landscape providing basis for traditional animal husbandry, rural and farming lifestyle over the centuries. Traditional extensive grassland management lead to the development of several valuable grassland habitats where rare and protected plant and animal species can be found still today. This is verified by the fact that about every fourth protected plant species and every third endangered insect species have a close connection to grasslands in Hungary.

Unlike fields covered with arable crops, grasslands are special agroecosystems. They are plant associations formed by several species, and they can be regarded as complex communities of living creatures. As a result, grassland management cannot be compared to arable crop production since here a whole ecological system needs to be maintained by the farmer while performing useful production activities at the same time. Besides, the conservation of biodiversity is becoming an increasingly important issue. The natural grasslands of Hungary provide habitat for about 450-500 plant species from the 2400 known species of the Hungarian flora.

Unfortunately, our grasslands tend to be managed by less people and in a less professional way according to the current grassland management practices. The majority of our remained grasslands are unused fallow lands, which are unsuitable for intensive grassland management.

Since our European Union accession several programmes order the application of extensive and nature friendly grassland management methods for which subsidies or compensation can be claimed by the farmers. However, in many cases orders and restrictions which need to be observed by the farmers when joining the programme consider only the nature protection and habitat conservation functions of grassland management, and in fact they compensate for the loss of profit. In many special programmes all means of grassland management are prohibited or restricted, and maintenance is based only on mowing activities performed once or twice per year or grazing with a low number of animals. However, in the lack of real management grasslands are to be further degraded, since this way the process of succession (usually heading from grasslands towards forests in the Carpathian Basin) only can be delayed, but cannot be stopped. Since overseeding and weed control are prohibited in the above mentioned programmes grasslands become degraded, invasive and dangerous weeds appear, valuable grass species having a high forage value get rare, and finally these plant associations lose their stability which had been created by the former grassland management practices.

In my opinion, current nature conservation oriented grassland management practices should aim at following their original purpose that is grassland management, meaning to also perform a kind of extensive production – a so-called active nature conservation activity – beside the conservation and the protection of nature from the point of the vegetation, and to conserve the habitat of species-rich stands while keeping the dominance of grass species having a high forage value by using appropriate professional grassland management methods. Consequently, we should strive for maintaining the multifunctionality of grasslands.

2. Objectives

1) In my research I have been investigating the habitat related ecological impact tolerance of grassland forming species according to the annual changes recorded for 15 years by taking into account the specific ecological needs of the different species. The extensively managed grassland – which was planted in 1997 – consists of a randomly combined so-called “species-rich flowery grass mix”. My aim was to verify – through the assessment of the planting and ecesis related records of plant species with different ecological needs – that the ecological features of a specific habitat do affect the species composition.

2) The other objective of my research was the assessment of the changes in species composition generated by extensive grassland management practices in annually mowed planted and natural mesic grasslands located near Szeged in the Great Plain after the cessation of fertilization. In the case of the natural grassland the reintroduction speed and the resilience of the former grass forming species, while in the planted grasslands the speed of a similar process, namely transformation into natural grasslands, have been measured. I also searched for a method which could be used for the reliable measuring of the dynamics of resilience.

3) Connections between the various weather impacts experienced during the analysed time period and the vegetation dynamics related changes of species composition registered in the two grasslands have been also researched.

4) Impacts affecting the species composition of grasslands – especially the appearance of introducing (and not planted) species – have been analysed by modeling different grassland management practices in a Festuca species dominated extensively managed dry grassland. The research aimed at defining the different impacts of the applied grassland management methods on grassland forming species by keeping records of the changes in species composition and by revealing how the expected connection works.

5) Furthermore, based on the above mentioned data the research also aimed at the assessment of grasslands from nature conservation and forage production aspect in order to verify that these functions need to be dealt with together during nature conservation oriented extensive grassland management.

3. Material and method

3.1. Analysis of the species composition dynamics of the flowery grassland

Botanical Garden of the Szent István University – *Properties of the species-rich grassland planting experiment*

The species-rich flowery grassland planting experiment has been carried out in the Botanical Garden of the Szent István University in Gödöllő.

The aim of the experiment was the analysis of the plantability of the flowery grass mix. Based on the aggregated development data of the hand seeded plants and those covered with ground during planting consequences can be drawn about the applicability of the method for planting grasslands with a high diversity of species, and changes in the species composition – including the major milestones of the process – can be analysed beside keeping records of the number of species.

The experimental grassland has been planted by the leadership of the Department of Grassland Management of the Szent István University on 7th May 1998. The field had been fertilized by organic manure in the previous year during winter ploughing. Right before planting emerging weeds have been killed by rotary cultivation, and then the surface of the soil was closed by a roller. Afterwards, neither nutrient supply nor watering has been carried out in the field.

Before planting a soil sample had been collected. When it was analysed by a laboratory it turned out that the chemical reaction of the soil is acidic (ranging between pH 5-6), its humus content is low, and none of the layers contain calcium carbonate.

In the double factor experiment the seed mix consisting of 26 species has been planted in 3 different variations and in 3 repetitions. In the first seed mix the number of plants was 21.000 pieces/m^2, in the second one it amounted to 22.300 pieces/m^2, while in the third one it reached 22.900 pieces/m^2. These plant density values reach only 2/3 of the advised germ count, which is around 30.000-60.000 pieces/m^2. Besides, the germ count of grass species was 19.000 pieces/m^2 in the first seed mix, it reached 20.600 pieces/m^2 in the second one, while it amounted to 22.100 pieces/m^2 in the third one.

The parcels were 6×5 m large, and they were separated by 0.5 m wide tracks. Half of the parcels have been covered by organic seed mat made of waste cotton before planting, which was fixed with the help of a 15-20 mm thick layer of pit sand. The greatest advantage of this covering was the mitigation of the number of competitive weed species and the hindering of their emergence.

Methods for the assessment of the species-rich grassland planting experiment

Botanical survey

For the botanical survey of the grasslands coverage estimation has been performed by using 1×1 m quadrats according to the method of BALÁZS (1949).

During the estimation of the species composition of the stand first always the uncovered areas had been measured, and then the ratio of the grass species and the other species were determined for the definition of estimated coverage in the field experiment carried out in the botanical garden. Botanical surveys have been made each month after planting, while later they were conducted twice per year (in May and in October). I joined this experiment in 2005, and conducted my botanical surveys once per year (in June).

Ecological indicator values developed by Zólyomi, Simon and Borhidi

During the assessment of the data I applied relative ecological indicator values. I used the ecological indicator values developed by SIMON (1992) and also those developed by BORHIDI (1993) for summarizing the characteristics of the plants. From the system developed by Zólyomi I used T (thermal balance), W (water balance) and R (reaction of the soil) values, while from Borhidi's system the indicator numbers of relative thermal demand (TB), relative groundwater and ground humidity (WB), soil reaction (RB) and the relative nitrogen demand of the species (NB) have been applied beside Simon's naturalness value categories (NVC).

3.2. Analysis of the impacts of extensification in planted and natural grasslands

Zsombó site of the Cereal Research Non-Profit Ltd. (Szeged) – *Properties of the experiment with no nutrient supply*

Botanical surveys have been conducted in grassland parcels at the Zsombó site of the Cereal Research Non-Profit Ltd. (Szeged) where heavy fertilization had been carried out in a fertilization experiment in the preceding 5 years (between 2001 and 2005), and where extensive production was started after the cessation of fertilization, sill aiming at first hay production. I could start my surveys in 2009, and they have been conducted for four years until 2013.

The active agent doses of fertilizers used in the original experiment were the following:

1. Untreated,
2. N100,
3. N150,
4. N100+50 (separately),
5. P40,
6. P80,
7. N100P40,
8. N100P80,
9. N150P40,
10. N150P80,
11. N100+50 (separately) P40,
12. N100+50 (separately) P80.

These fertilizer doses have been used both in the planted grassland (1) and in the natural one (2) located next to it during the 5 years of the experiment between 2001 and 2005. Since even the first botanical surveys could not show significant differences among the coverage data of parcels getting a higher nitrogen dose one or in two phases (being fertilized separately), later – in order to ease the handling of the huge amount of data and the elaboration of statistical assessments – not all the data of the original parcels have been assessed as they were irrelevant also from the point of my own research. Consequently, only the “major parcels” are referred among the results including: UN: untreated, 2: N100, 3: N150, 5: P40, 6: P80, 7: N100P40, 8: N100P80, 10: N150P80.

The seed mix of the grassland planted in 2001 (1) includes the following species:

Perennial ryegrass (*Lolium perenne* L.) - 6.2 kg/ha,
Red fescue (*Festuca rubra* L.) - 10.8 kg/ha,
Smooth brome (*Bromus inermis* Leyss.) - 11.2 kg/ha,
Crested wheatgrass (*Agropyron pectiniforme* Roem. and Schult.) - 13 kg/ha,
Reed canarygrass (*Phalaris arundinacea* (L.) Rauschert) - 4.4 kg/ha,
Kentucky bluegrass (*Poa pratensis* L.) - 8 kg/ha.

In this case my analyses focused on the assessment of the impacts of switching from intensive to extensive management methods in both planted and natural grasslands. In the case of planted grasslands (1) the *process of transformation into natural grasslands* can be measured after the cessation of intensive management practices, while in natural grasslands (2) the process of *resilience* can be researched.

Methods for the assessment of the extensification experiment

Botanical survey

For the botanical survey of the grasslands coverage estimation has been performed by using 1×1 m quadrats according to the method of BRAUN-BLANQUET (1951).

During the botanical surveys of the experiment at Zsombó my botanist colleagues also helped me. They made estimations about the relative coverage ratio of the different species during defining the species composition of the stand. Here it sometimes happened that there was no uncovered area at all, and that coverage values exceeded 100% since species overgrew each other in the stand before mowing.

Surveys have been conducted once per year before the harvest of the first hay.

The system of Simon's 'naturalness value categories' (NVC)

Species indicating natural conditions:

U: unique species: Relictum and very rare species being protected or highly protected. Apart from a few exceptions they can be found in less than 10 sites in Hungary.
KV: highly protected species

V: protected species
E: species forming associations: Natural species having a major role in the formation of natural plant associations.
K: accompanying species: Simple, natural species of the original flora. Several rare special species – most being protected – also belong to here.
TP: pioneer species: Group of species to first colonize an area.

<u>Species indicating degradation:</u>
TZ: disturbance tolerant species: These species can tolerate a low level of disturbance, and even spread well under such circumstances.
A: adventitious species: Artificially introduced alien species. One of their groups appears in natural, not degraded associations only rarely, but their other group is very dangerous since its species spread invasively by suppressing natural plant associations.
G: produced plants: Species produced from various purposes. Some of them grew wild, and became an aggressive weed species.
GY: weed species: They appear as a result of human activities in secondary, degraded habitats. Some of them are native species in Hungary, and spread from the natural vegetation, while others are adventitious, artificially introduced plant species of foreign origin.

The calculation of degradation

The level of degradation can be measured in plant associations by using the "*degradation degree*" (D_d) developed by Simon, which can be easily calculated by dividing the coverage ratio of species indicating degradation by the ratio of species indicating natural conditions. Consequently, the level of degradation can be calculated in a given site with the help of Simon's naturalness value categories (NVC) by using the following formula:

$$D_d = \frac{\Sigma TZ + \Sigma A + \Sigma G + \Sigma GY}{\Sigma U + \Sigma KV + \Sigma V + \Sigma E + \Sigma K + \Sigma TP}$$

Higher degradation degree values indicate a higher level of degradation in the plant stand.

The calculation of the agricultural value of grasslands

In order to quantify the economic value of grasslands more forage value calculating formulae have been developed.

In Hungary it was NAGY (2003) who developed a method for defining the agricultural value of grasslands according to which the agricultural value of the different species of the analysed grassland can be calculated as follows:

$$\mathbf{AV_{species} = 1/100 \times Coverage_{species} \times Productivity_{species} \times Forage\ quality_{species}}$$

The agricultural value of the grassland containing an optional number of species equals to the sum of the values calculated for the different species.

$$\mathbf{AV_{grassland} = 1/100 \times \sum_{i=1}^{n} CO_i \times PR_i \times FQ_i}$$

CO = coverage ratio of the species (%)

PR = productivity factor of the species

FQ = forage quality factor of the species

According to the author, productivity and forage quality factors are quantified by a scale ranging from 1 to 5 (see *Table 1*), where the most important grass and leguminous species are categorized.

Table 1: Productivity and forage quality categories according to NAGY (2003)

Productivity categories		**Forage quality categories**	
1	Poor, very low	**1**	Valueless, animals do not eat it (poisonous, prickly weeds)
2	Moderate, below average	**2**	Poor, animals eat it only in emergency
3	Medium, average	**3**	Medium, animals do not like it after a certain development phase
4	Good, above average	**4**	Good, animals like to eat it
5	Excellent, very productive	**5**	Excellent, most preferred by the animals

Differences among the agricultural values of various grasslands can be well detected and defined with the help of this method. Although agricultural value indicates a certain state it is not a static characteristic of the grassland since species composition always changes due to various factors. As a result, this method can be also used for recording the changes of agricultural value in the analysed grasslands.

Statistical assessment

Recorded data have been aggregated in Microsoft Excel tables, and average values have been calculated from the values of repetitions. For the statistical analyses I applied cluster analysis and linear discriminant analysis (LDA) (RIPLEY 1996, VENABLES and RIPLEY 2002) by using the R program package (R DEVELOPMENT CORE TEAM 2011). Regression (correlation) coefficient has been calculated with the help of Microsoft EXCEL.

3.3. Analysis of utilization models in grasslands planted by using multiple species

Szárítópuszta – ***Properties of the experiment on the analysis of utilization methods***

The experiment was started in the area of the Szárítópuszta Plant Production and Biomass Utilization Display Centre by the colleagues of the Department of Grassland Management of the Szent István University in 2008.

Before planting the area had been ploughed, and mature manure was mixed into the soil followed by rolling activities performed in more phases. On 28th October 2008 a species-rich grass mix including also dicotyledonous flowering plants has been spread by hand on the area, and the seeds have been shallowly mixed into the soil with the help of star hoes. The parcels were 3×3 m large, and were divided by 0.5 m wide tracks. In order to ease the visibility of the tracks a variety of *Festuca pseudovina* called Puszta has been planted on them since its steel grey shade is easy to differentiate from the fresh green colour of *Festuca rupicola* used in the experimental seed mix.

After the grassland has been fully developed mowing activities were performed with different frequencies based on four types of models in three repetitions between 2011 and 2013:

• P1: parcel mowed every second week (on a regular basis); (model of proportional sheep grazing with a fixed recovery period)

• P2: parcel mowed according to the growth pace of grass species – when the major stand forming grass species reaches the height of 10 cm the grassland is mowed back to the height of 8 cm; (model of sheep grazing with changing recovery periods depending on the growth pace of grass species)

• P3: parcel mowed every month (model of professional proportional cattle grazing with a fixed recovery period)

• P4: parcel mowed twice per year (conservation farming, nature conservation oriented mowing)

Botanical surveys have been conducted in the grassland parcels four times per year (in May, June, July and August) for three years (2011, 2012 and 2013).

Mowing activities were performed by using a rear drum driven AL-KO Premium 48 BWR automower.

Besides the 12 experimental parcels a same sized parcel being prepared the same way also remained during the start of the experiment. Since this parcel was not seeded or treated (mowed), and was only mowed for clearing off the shrubs at the end of each vegetation period it remained an area naturally turning into a grassland where the introduction of the different species could be researched. Later during the botanical surveys weed species being present in the area and in the seed pool of the soil but being unable to enter the grasslands could be witnessed in this parcel This was necessary because there were intensively managed arable land parcels around the grassland experiment where weeds are not visible, and cannot be surveyed due to the application of herbicides.

Apart from mowing no other activities – neither nutrient supply nor watering – have been performed in the experimental area.

Methods for the assessment of the experiment at Szárítópuszta

Botanical survey

Botanical surveys have been conducted in the experiment at Szárítópuszta during the summer vegetation period four times per year (in May, June, July and August) according to the method of BALÁZS (1949).

The calculation of agricultural value

Here also the method developed by Nagy has been used for the calculation of agricultural value. During this experiment it became unambiguous that the greatest advantage of this method is that it does not give a static characterisation of a given stand but can be modified by the impacts of weather, consequently it can be also used for defining current changes.

Statistical assessment

Recorded data have been aggregated in Microsoft Excel tables, and average values have been calculated from the values of repetitions. For the statistical analyses I applied linear discriminant analysis (LDA) (RIPLEY 1996, VENABLES and RIPLEY 2002) by using the R program package (R DEVELOPMENT CORE TEAM 2011) in this case as well. Within the process only the analysis of introducing species has been included in the statistical assessment since the major grassland forming species reached a constant coverage ratio during the experiment.

4. Results

4.1. Results of the species-rich grassland planting

The results of the experiment started in the Botanical Garden of the Szent István University in spring 1998 were first assessed in 2005, but the recording of botanical changes continued after this year as well. Primarily, the plantability results of the species-rich flowery grass mix including also dicotyledonous flowering plants have been assessed by recording the changes in species composition. I was looking for those species surviving in the analysed habitat in a relatively closed environment, since there were no other impacts coming from out of the grassland. I also wanted to know how the species composition of these grasslands will change, since they were different only due to the varied planting values. In addition, the initial weed infestation of the species-rich seed mixes could be also assessed in the case of spring planting, because these parcels could be compared to the covered control grassland.

The composition and ratio of grassland forming plant groups and species

After planting botanical surveys have been conducted each month starting from June. This way it could be recorded how the ratio of grassland forming species changed after emergence, and what the process of weed infestation was like.

The results of the first year revealed that there is a difference between the initial species composition of traditionally planted and covered parcels. Changes in coverage recorded in the case of the *covered parcels* clearly show one of the greatest advantages of covering, namely the suppression of competitive weed species and the hindering of their emergence. Although the process of emergence took more time in the covered area, no alien species appeared here in the first year. This was the result of the weed seed free sand layer and the covering organic seed mat which proved to be impermeable by the emerging weeds. On the other hand, weeds already appeared in the first month in the *uncovered areas*, and ragweed *(Ambrosia artemisiifolia)* reached the coverage ratio of 35% by the end of the vegetation period. In the case of traditional planting grass species, wild flowers and leguminous plants have a smaller coverage ratio compared to the covered area. However, the ratio of planted species did not affect the level of weed infestation, which was estimated to be 5% in each parcel (except for the coverage of ragweed which is not included in this value). Weed seeds are supposed to originate from the organic manure spread in autumn before the year of planting.

In the case of grasslands planted by applying covering initial differences among the seed mixes can be better recorded in the lack of competitive weed species, which would affect the development of the species of the grassland. It was found that the higher dicotyledonous species ratio of the seed mix leads to a lower ratio of uncovered areas. It can be explained by the fact that the development of grass species is poor in the case of spring planting, consequently the faster and stronger development of dicotyledonous species will define the ratio of the covered area.

Plant stand estimations have been performed twice per year (in June and in October) after the year of planting. The results of these estimations showed that planted species progressed towards the formation of a specific plant stand, where coverage ratios became stabilized in the 4^{th}-5^{th} years. As a result, the changes of coverage ratios experienced in the following years were caused by the various yearly weather conditions and not by the differences already existing during planting. The plant stand became stabilized quite fast in the case of all the three seed mixes. It can be explained by the fact that – due to the characteristics of the area – apart from the seed pool of the soil and the planted seed mix there were no other propagule sources in this field from where alien not planted species could arrive.

In the case of *traditionally planted areas* weed coverage continuously decreased, and in the 5^{th} year alien introduced species have been recorded in none of the areas except for that one planted with seed mix No. 1. In those areas seeded with this seed mix only ragweed is present after five years with a coverage ratio of 5%. This can be traced back to the fact that the lowest grass species coverage ratio has been recorded in these areas (it was 55% when the stand got stabilized), and probably ragweed could also germinate under such conditions. It was also observed that the ratio of grass species continuously increased. However, in the third year their ratio decreased in the case of all seed mixes by the botanical survey performed in autumn, which was caused by the dry yearly weather. It was the time when the more sensitive grassland forming species – such as *perennial ryegrass and Kentucky bluegrass* – also disappeared. In the fourth year the ratio of grass species slightly increased again, and *common bent (Agrostis capillaris) and Festuca species* started to spread. From this point the coverage ratio of grass species did not change in the grasslands, since in the lack of overseeding and treatments grass species requiring cultivation cannot survive in the area on the long run. The coverage ratio of wild flowers and leguminous plants did not change so extremely. In the first year they developed faster, consequently they had a higher coverage ratio than grass species. In the following years their coverage ratio became stabilized.

In the case of the *covered parcels* it can be stated that no weeds have been appeared in the experiment until now except for the parcel planted with seed mix No. 1 where the coverage ratio of ragweed reached 5% in the fourth and the fifth years. This can be also traced back to the drought experienced in the given years since the ratio of grass species in the seed mix already containing the lowest ratio of these species further decreased to the level of about 50%. As a result, ragweed had the possibility to germinate from the seed pool of the soil. In the case of the weed free covered parcels the coverage ratios of wild flowers and leguminous plants were found to be more varied than in the traditionally planted areas. After an initial high coverage ratio phase – reaching peak values in the second year – their coverage ratio decreased by 10% by the third year. This was caused by the fact that grass species reached their highest coverage ratio level this time.

According to the results of the first five years, it can be stated that seed mixes containing the lowest ratio of grass species (seed mix No. 1) were more susceptible to weather extremities, for example drought. This lead to extensive parching, decreasing coverage ratios and the strengthening of competitive weed species.

In the following years of the experiment differences among the seed mixes and the planting methods disappeared, and the various parcels of the grassland slowly "merged". Today differences among the different seed mixes are not visible at all. From statistical points of view significant differences disappeared among the seed mixes from the 10^{th} year (see *Table 2*).

From the 26 planted species and varieties today only 9 can be found in the grassland. The current species composition of the grassland is the following:

- Grassland species (from the planted 5 species and 7 varieties 2 different species remained):

Festuca ovina L., *Agrostis capillaris* L.

- Leguminous species: two leguminous species have been planted, namely *Lotus corniculatus* L. and *Trifolium dubium* Sibth. Today none of them have a significant coverage ratio, only *Lotus corniculatus* L. can be found in some places.
- From the 17 planted “wild flowers” only 6 can be found in the area today, namely:
    - *Achillea millefolium* L.
    - *Dianthus carthusianorum* L.
    - *Plantago lanceolata* L.
    - *Salvia pratensis* L.
    - *Sanguisorba minor* Scop.
    - *Thymus pulagioides* L.
- Other recorded species: (they have an extremely low coverage ratio, only 1-2 specimens of the introduced species survived in the grassland, which appear sometimes)
    - *Festuca arundinacea* Schreb.
    - *Ambrosia artemisiifolia* L.
    - *Erigeron annuus* L.
    - *Convulvulus arvensis* L.
    - *Asclepias syriaca* L.
    - *Vicia cracca* L.
    - *Centaurea jacea* L.
    - *Silene vulgaris* Moench.
    - *Medicago falcata* L.

It can be stated that the plant association of the area is dominated by two grass species and four dicotyledonous species, since higher coverage values (5-10-15%) can be found only in the case of *Achillea millefolium* L., *Dianthus carthusianorum* L., *Salvia pratensis* L. and *Thymus pulegioides* L. The other mentioned dicotyledonous species have only negligible coverage ratios. Compared to its originally planted coverage ratio *Achillea millefolium* L. occupies about a 10 times as large area today. Only a few specimens of *Lotus corniculatus* L. can be found in the area nowadays. According to the above mentioned, it can be stated that there is no connection between the coverage ratio and the number of species in my experiment.

Table 2: The coverage ratio of grass species and wild flowers (coverage ratio in %)

	1st year	2nd year	3rd year	5th year	10th year
Grass species					
K1	20	34	43	57	62
K2	30	50	53	64	63
K3	40	60	63	77	52
LSD 5%	2.00	11.61	8.78	6.63	16.31
	*	*	*	*	
Wild flowers					
K1	25	25	33	30	27
K2	20	20	23	20	28
K3	9	14	20	15	40
LSD 5%	5.96	11.02	7.45	2.00	13.13
	*		*	*	

*In case significant difference is P=0.05

It was found that in case of a lower number of wild flowers a higher coverage ratio can be also reached. Consequently, it is not necessary to decrease the ratio of grass species in the seed mix in order to increase that of the wild flowers.

All in all, it can be stated about the seed mixes that after such a long time (15 years) the ratio of the planted species is not important, since the ratio of grass species and wild flowers stabilized at the level of 50-40% irrespective of the original planting ratios.

Assessment of the species-rich grassland by using ecological indicator values

The TWR values of the planted species (according to SIMON 1992)

The most important question of the grassland planting experiment was which ecological needs do the surviving species have, since these factors determine the development of the given plant association.

The TWR values of the planted and the survived species are presented by *Table 3*. Based on relative thermal demand (T-value), the introduced species prefer the climate of deciduous forests except for one species. As for relative water demand (W-value) it can be stated that the water demand of the introduced species ranges from the moderately dry to the mesic level. By analysing the reaction of the soil (R-value), it was found that dicotyledonous species preferring neutral or slightly calcareous soils have been introduced in the area. According to my results, it was found that the introduced plant species had similar heat, water balance and soil demands. However, this result does not reflect the properties of the soil.

Table 3: The T, W and R values of the planted and the survived (highlighted in bold) grassland forming species (according to SIMON 1992)

Species name	Life form	T value	W value	R value
***Achillea millefolium* L.**	**H**	**5k**	**5**	**0**
Anthemis nobilis L.				
Bellis perennis L.	H	5a	6	0
***Dianthus carthusianorum* L.**	**H**	**5a**	**3**	**3**
Glechoma hederacea L.	H (Ch)	5	7	0
Hieracium pilosella L.	H	5a	1	3
Leontodon hispidus L.	H	5a	4	0
Leucanthemum vulgare agg.				
Pimpinella saxifraga L.	H	5a	3	3
***Plantago lanceolata* L.**	**H**	**5a**	**4**	**0**
Potentilla verna L.				
Prunella vulgaris L.	H	0	6	0
***Salvia pratensis* L.**	**H**	**6**	**3**	**0**
***Sanguisorba minor* Scop.**	**H**	**5k**	**3**	**4**
***Thymus pulegioides* L.**	**Ch**	**5a**	**4**	**3**
Veronica arvensis L.	Th			
Veronica chamaedrys L.	H- Ch	5a	4	4
***Lotus corniculatus* L.**	**H**	**5a**	**4**	**0**
Trifolium dubium Sibth.	Th- TH	5a	4	3
Lolium perenne L.	H	5a	5	0
Poa pratensis L.	H	5	6	0
Festuca rubra L.	H	5	5	0
***Festuca ovina* L.**	**H**	**5a**	**4**	**2**
***Agrostis capillaris* L.**	**H**	**5a**	**3**	**2**

In order to make the data more accurate the average coverage ratios of the species have been multiplied by the W and the R values (see *Table 4*). As a result, real ecological demand characterizing the habitat was found through weighting by the coverage ratios. From these results it turned out that the water demand of the vegetation is 4, meaning it is moderately mesic.

Table 4: W and R values weighted by the coverage ratio of the species

Species name	Coverage ratio %	W	Weighted W	R	Weighted R
Achillea millefolium L.	4	5	20	0	0
Dianthus carthusianorum L.	7	3	21	3	21
Plantago lanceolata L.	1	4	4	0	0
Salvia pratensis L.	5	3	15	0	0
Sanguisorba minor Scop.	1	3	3	4	4
Thymus pulegioides L.	9	4	36	3	27
Lotus corniculatus L.	1	4	4	0	0
Festuca ovina L.	40	4	160	2	80
Agrostis capillaris L.	22	3	66	2	44
Total/Average	**90**		**3.65 ~4**		**1.9~2**

Assessment of the results by using the ecological indicator values developed by Borhidi

The weighted ecological indicator values of BORHIDI (1993) also verified that a plant association typical of the given habitat has been developed in the area (see *Table 5*). According to these values, the habitat belongs to the zone of montane mesophilous deciduous forests. The soil is slightly acidic, and based on the nitrogen demand the plant association is moderately oligotrophic.

Table 5: Ecological indicator values and weighted average values calculated from them (according to BORHIDI 1993)

Species name	Coverage ratio %	TB	WB	RB	NB
Achillea millefolium L.	4	5 (20)	6 (24)	5 (20)	5 (20)
Dianthus carthusianorum L.	7	5 (35)	3 (21)	6 (42)	2 (14)
Plantago lanceolata L.	1	5 (5)	4 (4)	6 (6)	5 (5)
Salvia pratensis L.	5	6 (30)	3 (15)	8 (40)	4 (20)
Sanguisorba minor Scop.	1	6 (6)	3 (3)	8 (8)	2 (2)
Thymus pulegioides L.	9	5 (45)	4 (36)	6 (54)	1 (9)
Lotus corniculatus L.	1	5 (5)	4 (4)	7 (7)	2 (2)
Festuca ovina L.	40	4 (160)	4 (160)	3 (120)	5 (200)
Agrostis capillaris L.	22	5 (110)	8 (176)	4 (88)	2 (44)
Total/Average	**90**	**4.62~** 5	**4.92~** 5	**4.27~**4	**3.5~** 3

Both botanical methods show that these species of the planted seed mix were expected to become introduced in the area. It was verified that it is advised to compile the seed mix based on the properties of the soil, and to also take the ecological needs of the grassland forming species into account. However, analysing these factors only in the case of the different species is not enough, since by weighting with the coverage ratio much more accurate values can be found. This also proves the close interaction and connection among the different plant association forming species. In my opinion, if the weighted average better approximates the values of the soil analysis, the level and intensity of further possible changes will be lower, since in this case the group of species has already adapted to the environmental conditions.

4.2. Results of the extensification experiment

Botanical surveys have been conducted in grassland parcels at the Zsombó site of the Cereal Research Non-Profit Ltd. (Szeged) where heavy fertilization had been carried out in a former fertilization experiment, and where only mowing activities have been performed once per year after the cessation of fertilization aiming at first hay production. The most important questions of this analysis were how the vegetation of the area will turn into a semi-natural plant association, and whether the impacts of nutrient supply can be witnessed even after five years or not. In the case of the natural grassland resilience can be researched by measuring how fast and to what extent can the original natural grassland turn back into its initial state after the cessation of disturbance (meaning fertilization in this case).

Botanical changes in the grassland at Zsombó

During the botanical surveys it was found that the control natural grassland consists of 18-24 species on the average at the moment. Its dominant species are the following: *Poa angustifolia* (8-20%), *Festuca pratensis* (2-25%), *Arrhenatherum elatius* (2-15%), *Phragmites australis* (1-8%). It is visible that it is a natural grassland with a good composition of species.

On the other hand, the planted grasslands consisted of 16-23 species depending on the given parcel with the following dominant species: *Poa angustifolia* (10-25%), *Cirsium arvense* (8-20%), *Dactylis glomerata* (2-

10%), *Elymus repens* (2-10%). It can be observed that all the planted stand forming grass species (*Lolium perenne, Festuca rubra, Bromus inermis, Agropyron pectiniforme, Phalaris arundinacea* and *Poa pratensis*) have already disappeared in the lack of fertilization by now, but the valuable plant species of natural grasslands cannot reach a higher coverage ratio in the planted grasslands either without further treatments and grassland management methods. This situation is caused by first hay making, since in this case mowing is performed before the ripening of the seeds. *Poa angustifolia* became the most dominant species here as well, but in three of the parcels *Cirsium arvense* turned to be the major stand forming species, which is an aggressively spreading weed growing stolos and being harmful both in pastures and hayfields.

It is clearly visible that while more valuable grass species can be found among the major stand forming plants of the natural grasslands, in the parcels of the planted grasslands mostly tertiary grass species, pioneer species (*Elymus repens*) and other dicotyledonous weeds (*Cirsium arvense, Taraxacum officinale* or *Cichorium intybus*) became the most dominant. In addition, the presence of reed in both the natural and the planted grasslands is the result of the extremely wet year of 2010.

I can be regarded a major change that none of the planted grass species can be found in the area today due to the nitrogen demand of the used varieties (e.g. *Poa pratensis*). The conclusion was that improved grass species could not bear extensification. As a result of first hay oriented mowing these species could not regenerate themselves in the lack of seed ripening possibilities. Their places were taken over by more valuable grass species originating from natural grasslands – such as *Poa angustifolia* and *Dactylis glomerata* – whose propagule are spread by the wild animals or the wind.

The ecological indicator values and the degradation degree of the grassland at Zsombó

By comparing the naturalness value categories (NVC) developed by Simon it can be found that both weed species indicating degradation (GY) and disturbance tolerant species (TZ) had a fairly high coverage ratio in all the planted parcels compared to the control area. While the average coverage ratio of weed species was 10% in the untreated control parcel of the natural grassland in 2009, and reached 19% in 2012, this value exceeded even 30% in several parcels of the planted grassland.

The level of degradation in the plant stand can be quantified by degradation degree (D_d) developed by Simon, which can be easily calculated by dividing the coverage ratio of species indicating degradation (in this case species marked with TZ or GY) by the ratio of species indicating natural conditions (in this case species marked with E or K). Higher degradation degree values indicate a higher level of degradation in the plant stand. Differences between the NVC and degradation degree values of the natural grassland and the planted parcels are clearly visible in the diagrams. While the degradation degree of the natural grassland reached the value of 10 in none of the parcels, in the case of the planted grassland even extreme high values had been measured. However, it is a fact that the value of degradation degree fell below 5 in every planted grassland parcel by 2012. It was found that although the same fertilization experiment had been carried out in both the natural grassland and the planted one it took a shorter time for the vegetation of the natural grassland to become stabilized again. This can be explained by the higher ecological resilience of natural grasslands. Since they have a species pool typical of the area, they can turn back into their original state faster even in the case of serious disturbances (meaning heavy fertilization in this case). On the other hand, it is clearly visible that the originally planted species pool has disappeared from the parcels of the planted grassland, since the ecological conditions of the area did not fulfil the ecological needs of the planted species. However, the replacement and introduction of species is a slower process, this way it takes more time for the planted artificial grassland to turn into a natural one than the resilience of the original natural grassland.

As a result, the impacts of intensive management and heavy fertilization can be witnessed in the species composition of the grassland even after five years, but the differences among the various treatments cannot be clearly traced back to the various fertilizer doses. Mostly not the valuable grassland forming species but the alien and aggressively spreading weed species enter the planted parcels from the neighbouring natural grasslands.

According to my results, it can be stated that degradation degree developed by Simon can be well used for the measuring of resilience as well.

4.3. Changes in the species composition of grasslands according to the simulated utilization methods

In the grassland experiment started in October 2008 at Szárítópuszta four types of utilization methods have been simulated in order to research the possible differences. The different utilization methods have been modeled by mowing and extensive maintenance without any nutrient supply or watering.

The assessment of botanical changes

During the botanical surveys I found that although furrowed fescue (*Festuca rupicola*) stayed the dominant species in the grassland according to the species ratio set in the seed mix during planting, it did not reach its originally planned coverage ratio (85%).

The state of the grassland can be regarded as satisfactory in all parcels, but in the lack of watering and proper nutrient supply the ratio of uncovered areas may reach even 10% sometimes, and these uncovered patches (usually being the remains of mole hills) enable the germination of weeds.

In the parching period uncovered patches become visible. As a result, the total coverage ratios of the P3 and P4 grassland parcels fall below 80% in July, and P1 and P2 parcels also exceed this value only slightly. A difference has been witnessed in the average coverage ratio of introduced species between the more frequently mowed parcels (P1 and P2) and the less often mowed ones (P3 and P4). In May the highest coverage ratio of introduced alien species has been registered in the case of P1 and P2 parcels, which can be traced back to the fact that here grass species cannot shadow the area so much due to the more frequent mowing activities than in the less often mowed parcels (which are still not mowed in May). As a result of the more regular and frequent mowing activities rubs become more visible, and species emerging from seeds may easily appear at these places.

In the case of the P3 parcels – being mowed every month – the coverage ratio of not planted species is relatively constant during the whole year. During the botanical survey performed in August 2011 it was experienced that also the development of such species slowed down in the parching period, while in P4 parcels they reached a higher coverage ratio in the lack of regular treatments. According to the botanical surveys of August 2012, it can be stated that the coverage ratio of the planted grassland forming species was 10% lower in the less often mowed parcels than in the case of the more frequently mowed ones in spite of the fact that during the surveys conducted in 2011 useful plants reached a higher coverage ratio in these two parcels by the end of August.

In 2012 the coverage ratio of introduced species has decreased compared to the previous year, and they had a lower ratio in all the parcels at the beginning of the year, except for P4 parcels where they could spread further due to the late mowing activities.

By the end of 2012 the impacts of the two extremely dry years following each other became clearly visible in the grassland experiment as well. In 2013 the coverage ratio of the planted grassland forming species was already even in all the parcels, reaching about 80%. Although the coverage ratios of introduced species were still higher in the P1 and P2 parcels at the beginning of the year, they decreased by the end. In the case of the P3 and P4 parcels an opposite trend could be observed since there the coverage ratios of introduced species were lower at the beginning of the year, and increased by the end.

On the whole, it can be stated that by comparing coverage ratios and precipitation data the trends of total plant coverage rather follow the changes of weather than the way of utilization. However, in the case of the introduced species differences have been recorded as a result of the various utilization methods.

During the three years of the experiment 16 species have been registered which originally had not been planted in the grassland, so they originate from the surrounding propagule sources (primarily from the seed pool of the soil). These species are the following:

Ambrosia artemisiifolia, *Artemisia vulgaris*, *Cichorium intybus*, *Cirsium arvense*, *Convolvulus arvensis*, *Crepis rhoeadifolia*, *Daucus carota*, *Elymus repens*, *Lolium perenne*, *Medicago lupulina*, *Medicago sativa*, *Plantago media*, *Sonchus oleraceus*, *Taraxacum officinale*, *Trifolium repens* and *Vicia villosa*.

Some of them appeared only in a few parcels with 1-2 specimens, they did not reach significant coverage ratio, and could not survive in the plant stand on the long run either. Such species included *Ambrosia artemisiifolia*, *Artemisia vulgaris, Daucus carota, Sonchus oleraceus* and *Vicia villosa*. These specimens probably entered the grassland through the newly opened patches of the grass layer, but they could not spread in the closed stand. Partially, this could be also caused by the extremely dry weather. This was the reason why weeds with a higher water demand – such as *Trifolium repens* and *Medicago lupulina* – also disappeared from the area. While these species had been found in all the parcels in 2011, they disappeared from the grasslands by 2012.

Although the specimens of *Convolvulus arvensis*, *Crepis rhoeadifolia*, *Elymus repens* and *Plantago media* became stabilized in the stand, their coverage ratios were different depending on the way of utilization. During the botanical surveys I found that annual weed species appearing in the area – e.g. *Ambrosia artemisiifolia* and *Crepis rhoeadifolia* – could not reach a significant coverage ratio due to the mowing activities.

Beside the above mentioned species the following plant species were also found in the control (C) parcel: *Dactylis glomerata, Erygeron canadensis, Festuca rubra, Plantago major, Stenactis annua* and *Tripleurospermum inodorum*. Although these species were constantly present in the unplanted control parcel and at the edge of the arable land surrounding the grassland, they could not be recorded in any of the parcels during the grassland experiment. Consequently, it can be stated that they either cannot bear regular mowing activities and disturbance, or they cannot get through the well closed grass layer.

It was observed in the case of species growing stolos (such as *Cirsium arvense, Convolvulus arvensis* and *Elymus repens*) that their coverage ratio could not exceed 1% in P1 parcels mowed every second week in the first year of the experiment, while – probably due to the drier yearly weather – they have reached higher coverage ratios in all parcels irrespectively of the frequency of mowing activities by 2012. However, through mowing activities performed only twice per year (such as in the case of P4 parcels) – which is usually ordered by nature conservation oriented and only maintenance based programmes – their spread could not be stopped. Although their coverage ratio fell back from 8% to 2% after the mowing activities performed at the beginning of July in the first year, in the lack of further mowing activities it reached 3.5% again during the survey conducted in August. The coverage ratio of these species also decreased after the first mowing in 2012, but introducing species growing stolos reached a coverage ratio exceeding 9% by the end of the year. The same trend could be observed in 2013 when species spreading with stolos have reached the coverage ratio of 9-10% by August in the less often mowed parcels. P4 parcels need to be highlighted with their special mowing pattern, where the coverage ratio of *Elymus repens* was 4-5% in 2013. On the other hand, annual plant species emerging from seeds – e.g. *Crepis rhoeadifolia* – could reach a higher coverage ratio in P1 and P2 parcels.

4.4. The agricultural value of the grassland at Zsombó

In order to quantify the degradation of grasslands not only from plant association aspects but also from the point of utilization and farming, agricultural values developed by NAGY (2003) have been also calculated in the case of the different grasslands. During defining the agricultural value of the different plant species aggressively spreading invasive weed species were given the value of 1, while herbs grazed by animals were given the value of 2 or 3 depending on different aspects.

It was found that the agricultural value of all grasslands included in the *planted grassland experiment at Zsombó* has decreased by 2012 compared to the 2009 values. In some parcels the level of decrease is negligible (e.g. in the control natural grassland or in the parcel being fertilized with 100 kg of N per hectare and 40 kg of P_2O_5 per hectare), while in others agricultural value decreased significantly and fast (e.g. in the treatment applying /N100P80/ or the one using /N150P80/). By analysing the changes it was found that in some parcels agricultural value temporarily increased during 2011 (e.g. in the case of the parcels affected by the following treatments: /N100/, /N150/, /N100P40/), which could be traced back to the impacts of the yearly weather.

However, it is worth studying the initial state and comparing the agricultural value of the parcels treated in different ways. In 2009 parcel No. 8 – being fertilized with 100 kg of N per hectare and 80 kg of P_2O_5 per hectare per year during the 5 years long experiment of the Cereal Research Non-Profit Ltd. (Szeged) – had the second highest agricultural value (AV=9.99) after the control natural grassland (AV=10.54). The planted and untreated area of parcel No. 1 ranked third with an agricultural value of 9.65. The lowest agricultural value (AV=6.12) was recorded in parcel No. 6 being fertilized with 80 kg of P_2O_5 per hectare per year.

By 2012 the control natural grassland became the first with its agricultural value reaching 9.52, however there also had been some fluctuations in this value in the previous years (it decreased in 2010 and 2011, while it increased in the next year). It is important to emphasize that in the case of the control parcel changes were not significant, and the agricultural value of the grassland can be regarded as stable. On the other hand, the agricultural value of all the other parcels fell below the value of 7 by 2012, and parcel No. 6 had the lowest value scoring only 4.04, which indicates a fairly poor grassland.

Regarding the *natural grassland* parcels of the experiment at Zsombó it can be stated that their agricultural values are basically higher than that of belonging to the planted grasslands. The lowest agricultural value was 4.8, while the highest one reached 13 in the natural grasslands, while in the case of the planted grasslands these values were 4.28 and 9.99 respectively. It was found that in natural grasslands the changes of agricultural value rather followed the impacts of the yearly weather than the impacts of the different treatments.

Table 6: Connection among the number of species, agricultural values (AV) and degradation degree (D_d) in the parcels of the experiment

	1				**2**				**3**				**5**			
	2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**
species number (natural grassland)	16	26	23	24	19	27	14	20	13	18	19	18	18	23	19	20
AV (natural grassland)	10.54	9.09	8.9	9.52	10.03	9.97	7.32	9.59	8.15	7.81	7.84	9.69	7.78	4.8	7.96	7.58
Dd (natural grassland)	0.82	1.15	3.26	1.26	1.50	1.32	2.50	1.00	2.11	0.83	6.33	1.30	1.38	1.52	5.31	1.68
species number (planted grassland)	18	29	20	17	16	29	18	19	17	25	19	20	15	25	16	22
AV (planted grassland)	9.65	8.63	8.62	6.75	9.27	6.24	6.93	6.46	7.61	6.94	8	4.28	9.58	6.9	5.13	6.6
Dd (planted grassland)	6.00	2.11	4.56	2.38	3.85	1.76	3.60	2.65	31.33	4.06	14.67	4.00	5.55	1.42	6.75	1.52
	6				**7**				**8**				**10**			
	2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**
species number (natural grassland)	19	21	21	21	16	20	24	20	18	20	18	20	15	17	14	22
AV (natural grassland)	9.2	6.6	7.69	7.49	10.69	8.53	8.8	10.25	9.07	6.36	11.27	8.87	6.59	6.92	7.35	13
Dd (natural grassland)	1.34	1.52	6.67	0.92	4.00	0.95	4.21	0.90	4.50	0.78	5.86	1.45	2.10	1.70	7.33	1.86
species number (planted grassland)	14	24	19	22	16	30	20	20	15	29	19	20	11	26	19	17
AV (planted grassland)	6.12	5.65	5.18	4.04	7.87	7.49	9.08	7.09	9.99	8.17	7.69	6.37	7.15	6.93	5.54	5.06
Dd (planted grassland)	42.00	4.47	12.00	3.31	3.67	1.54	3.20	1.68	5.13	1.30	6.82	1.96	5.33	2.82	7.00	2.55

It is interesting that the changes of agricultural value do not correlate with the changes experienced in the number of species (see *Table 6*). It can be observed in many cases that a more significant increase in the number of species leads to the decrease of agricultural value, meaning that probably weed species became more dominant in the plant stand. The same correlation was found between degradation degree and agricultural value. It could be expected that decreasing degradation degree leads to an increased agricultural value, but it was not verified during the experiment at Zsombó. This assumption has been proven statistically as well. According to the agricultural values of the grassland at Zsombó, it can be stated that the agricultural value of untreated grasslands mowed only once per year decreases. The level of decrease is significant in the formerly planted and fertilized grasslands compared to the control natural ones. Differences among the various treatments also can be detected by analysing the agricultural values.

Agricultural values developed by NAGY (2003) can be well utilized during the assessment of grasslands, and they can be used for the tracking of changes as well.

5. New scientific results

1. In the case of species-rich grassland planting no significant differences can be detected in the species composition of the plant stand after 5 years which could be traced back to the various ratios of the used monocotyledonous and dicotyledonous seeds. During the long-term (15 years long) experiment it has been verified that those plant species survived in the planted grasslands whose ecological needs were similar to the ecological features of the given habitat.

2. The impacts of the 5 years long heavy fertilization (applying 150 kg N per hectare) could be detected in the species composition of the plant stand even seven years after the cessation of nutrient supply. Especially the impacts of nitrogen fertilization are indicated by the introduced and the survived plants. Regarding the species composition of the grasslands, parcels getting a higher and a lower dose of fertilizer and those fertilized only with phosphorous for four years can be significantly differentiated based on the after effects of fertilization.

3. Since natural grasslands have a greater resilience the species composition of the plant stand turns back into its original state faster after extensification than in the case of planted grasslands. The whole process is much slower in the case of planted grasslands due to the replacement of species.

4. The climatic impacts of the subsequent years are more visible in the case of planted grasslands than in natural ones. Well stabilized extensive natural grasslands are less susceptible to climatic changes and extremities than the planted and extensively managed ones.

5. In differently utilized Festuca species dominated grasslands significant differences have been found regarding the introducing (not planted) species. Changes in the species composition of the grasslands are not only induced by the presence of propagule sources and weather impacts but also by the way of utilization. Weed species growing stolos can spread faster in rarely mowed grasslands, where mowing activities are carried out only twice per year.

6. The low number of mowing activities (meaning one or two late mowing activities) is insufficient for maintaining the proper state of grasslands, consequently their agricultural value decreases.

6.1. I verified that agricultural value decreases to a higher extent after the cessation of nutrient supply in the case of planted grasslands than in not planted (natural) grasslands.

7. I found that there is no connection between decreasing degradation degree and the increase of agricultural value. In the case of extensively managed grasslands no correlation has been found between the two values.

8. In the case of the researched grasslands degradation degree developed by Simon could be well used for measuring the advancement of resilience. Lower degradation degree values indicated that the plant stand started to turn back to its original species composition, and this case the process of resilience was in a more advanced phase.

6. Conclusions and recommendations

Species-rich grassland planting

By analysing different seed mix ratios it was found that seed mixes containing the lowest ratio of grass species (seed mix No. 1) were more susceptible to weather extremities, for example drought. During the experiment differences among the seed mixes and the planting methods disappeared, and the different parcels of the grassland slowly “merged”. From statistical points of view, significant differences among the different seed mixes disappeared after ten years. All in all, it can be stated about the seed mixes that after such a long time the ratio of the planted species is not important, since the ratio of grass species and wild flowers stabilized at the level of 50-40% irrespective of the original planting ratios. *Consequently, it is not necessary to decrease the ratio of grass species in the seed mix in order to increase that of the wild flowers.*

According to my results, I found that the introduced plant species had similar heat, water balance and soil demands. By weighting the ecological indicator values developed by Zólyomi and Borhidi with the coverage ratios I found that the soil properties of the area and the habitat requirements of the plant stand are the same. *Consequently, analysing ecological needs only in the case of the different species is not enough, since by weighting with the coverage ratio much more accurate values can be found.* This also proves the close interaction and connection among the different plant association forming species. In my opinion, if the weighted average better approximates the values of the soil analysis, the level and intensity of further possible changes will be lower.

The long-term effects of fertilization on the species composition of the grassland

After the cessation of long-term fertilization and intensive management planted grassland forming species disappear from the area quite soon. Their places were taken over by more valuable grass species originating from natural grasslands – such as *Poa angustifolia* and *Dactylis glomerata* –, but they cannot become dominant in the grasslands mowed once per year.

By comparing the naturalness value categories (NVC) developed by Simon it was found that both weed species indicating degradation (GY) and disturbance tolerant species (TZ) had a fairly high coverage ratio in all the planted parcels compared to the control area. This difference can be also expressed through the different degradation degree levels, since degradation degree reached higher values in all parcels of the planted grassland compared to the natural one. The plant stand of the natural grassland became stabilized faster after the cessation of fertilization than the vegetation of the planted grassland. As a result, natural grasslands have a greater ecological resilience. Since they have a species pool typical of the area, they can turn back into their initial state faster even in the case of serious disturbances (meaning heavy fertilization in this case). On the other hand, it is clearly visible that the originally planted species pool has disappeared from the parcels of the planted grassland, so the ecological conditions of the area did not fulfil the ecological needs of the planted species. However, the replacement and introduction of species is a slower process, this way it takes more time for the planted artificial grassland to get stabilized due to its poorer resilience. After the cessation of fertilization changes happen quite fast in the plant stand of planted grasslands, but the impacts of fertilization still can be detected through the species composition even years later. It is visible that in the lack of grassland management the process of turning into natural grasslands goes the wrong way. Consequently, total abandonment is not a good option for the development and the formation of semi-natural habitats. *According to my results, I would suggest to authorize the overseeding of the original plant stand of natural grasslands with proper dominant species even in the nature conservation oriented special grassland management programmes applying strict restrictions, because without this measure grasslands are to become further degraded.*

The impact of utilization methods on species composition

- P1: parcel mowed every second week (on a regular basis); (*model of proportional sheep grazing with a fixed recovery period*)
- P2: parcel mowed according to the growth pace of grass species – when the major stand forming grass species reaches the height of 10 cm the grassland is mowed back to the height of 8 cm; (*model of sheep grazing with changing recovery periods depending on the growth pace of grass species*)
- P3: parcel mowed every month; (*model of professional proportional cattle grazing with a fixed recovery period*)
- P4: parcel mowed twice per year. (*conservation farming, nature conservation oriented mowing*)

According to my botanical surveys, I found that there is a difference among the species composition of the plant stands depending on the way of utilization. I paid special attention to the analysis of the coverage ratio of not planted (introduced) species. By highlighting weed coverage data it can be observed that the weed cover of the parcels mowed every second week and those mowed according to the growth pace of grass species was more even, while the weed coverage ratio of the monthly mowed parcels and those mowed only twice per year fluctuated during the different years. On the whole, it can be stated that by comparing coverage ratios and precipitation data the trends of total coverage rather follow the changes of weather than the way of utilization. However, in the case of the introduced species differences have been recorded as a result of the various utilization methods.

During my botanical surveys it was observed that the coverage ratio of species growing stolos (such as *Cirsium arvense*, *Convolvulus arvensis* and *Elymus repens*) could not exceed 1% in P1 parcels mowed every second week – modeling proportional sheep grazing – in the first year of the experiment, while – probably due to the drier yearly weather – they have reached higher coverage ratios in all parcels irrespectively of the frequency of mowing by 2012. However, through mowing activities performed only twice per year (such as in the case of P4 parcels) – which is usually ordered by nature conservation oriented and only maintenance based programmes – their spread could not be stopped. By taking into account the species composition of the area the different mowing methods could be well differentiated, and the difference was significant.

Consequently, it was stated that changes in the species composition of the grasslands are not only induced by the presence of propagule sources and weather impacts but also by the way of utilization. It is of high importance that weed species growing stolos spread faster in the less often mowed grasslands (which are mowed only twice per year). On the other hand, it is also important to understand that some of the not planted species may have a high forage value (e.g. *Medicago sativa*).

The agricultural assessment of the grasslands

Based on the agricultural values of the grasslands I found that the agricultural value of grasslands maintained only by one or two mowing activities per year continuously decreased, while in the case of utilization methods modeling professional grazing activities the agricultural value increased. Consequently, two mowing activities per year are insufficient for the proper utilization of grasslands – especially if the first one is performed later during the year –, and they lead to the decreased quality of grasslands. In the case of professional grassland management activities the agricultural value of the grassland increases, and changes positively.

According to my results and conclusions, it is not advised to maintain natural or planted grasslands only by two mowing activities per year on the long run, because this leads to their degradation and the decreasing of their agricultural value. In the case of planted grasslands the authorization of overseeding would be important before starting nature conservation oriented treatments.

7. Publications of the author in the topic of the thesis

Articles in scientific journals:
In English:

M. Harcsa, L. Szemán (2012): Analysis of species-rich flowery grassland associations according to their ecological needs. *Acta Agronomica Hungarica*, 60(4), pp. 407–416 DOI: 10.1556/AAgr.60.2012.4.11

M. Harcsa, M. Zalai, A. Sallai, L. Szemán (2013): A study of a weed infestation of species-rich grasslands, mowed at different time intervals. Magyar Gyomkutatás és Technológia 2013/1

In Hungarian:

Harcsa M., Szemán L. (2008): Gyepalkotó növényfajok társítás-elemzése az ökológiai igények alapján. *Tájökológiai Lapok* 6 (3): 395-404.

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Harcsa M., Kulin B. Gy., Sallai A., Penksza K., Szemán L. (2011): Intenzív gyepek gyomosodási viszonyai a tápanyag utánpótlás megszüntetése után. *Növényvédelem* 47 (7) 321-326.

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In Hungarian:

Harcsa M., Szemán L. (2009): Fajgazdag díszgyepek gyomszabályozási lehetőségei. Budapest, 2009. február 23-24. *55. Növényvédelmi Tudományos Napok*, p. 56.

Harcsa M., Kulin B. Gy., Sallai A., Penksza K., Szemán L. (2011): Intenzív gyepek gyomosodási viszonyai a tápanyag utánpótlás megszüntetése után. Budapest, 2011. február 21-22. *57. Növényvédelmi Tudományos Napok*, p. 62.

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