Successfully Recovered Grassland: A Promising Example from Romanian Old-Fields

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Abstract

In this study, I analyzed the natural recovery of grasslands on abandoned agricultural fields in the Transylvanian Lowland (Câmpia Transilvaniei), Romania. I examined fields that were abandoned 1–40 years ago and considered how successful they have been in recovering spontaneously as compared to reference grassland, especially in relation to species composition and dominance structure. Diverse, nondegraded seminatural grasslands from the surroundings were chosen as targets for the recovery. Five such grasslands were analyzed in order to have multiple references that accounted for site heterogeneity and different land use history. This study found that the number of natural and seminatural habitat species increased, whereas the number of weeds and aliens decreased with age. Old-fields had become very similar in species composition and dominance structure to reference grasslands over a 14- to 20-year time interval, with the only failure being the unsuccessful or slow colonization of a few grassland species. Because spontaneous succession is efficient, human interventions are not needed to restore target communities on the old-fields. Propagule pressure expressed by the area of potential seed source in a 500-m-radius buffer was found to have a strong influence on recovery success of old-fields. The success of grassland species in colonizing postagricultural fields was not affected by their dispersal mode but by their frequency in the landscape, this being another evidence for the importance of propagule availability in the course of recovery. In order to maintain the potential for recovery of this landscape, we need to protect those close to natural habitats that contain a high amount of native flora.

Key words: Câmpia Transilvaniei, dispersal limitation, landscape, propagule availability, secondary succession, spontaneous regeneration.

Introduction

In highly degraded ecosystems (e.g., huge mining areas or urban and suburban sites), we cannot usually hope for the spontaneous recovery of transformed sites because highly modified soil and hydrological factors, landscape homogenization, missing natural propagule sources, and exotic invasions upset the expected recovery processes (Zedler & Callaway 1999; Wilkins et al. 2003). Smaller site-injuries in moderately influenced landscapes, however, may have the ability to recover naturally without human interventions (Prach et al. 2001*b*; Lee et al. 2002; Pensa et al. 2004). We must be able to decide whether to leave spontaneous processes to progress on their own or whether we need a more active form of reclamation using management techniques (Dobson et al. 1997). In some cases, spontaneous succession can be more efficient than human activities at restoring degraded sites to a more natural state (Prach & Pyšek 2001; Prach et al. 2001*a*; Pensa et al. 2004).

In Romania, rehabilitation programs designed by engineers, foresters, or researchers have often used exotics or other species inappropriate to regional habitats and flora (e.g., Maruşca & Dincă 2001). Selecting a proper goal for restoration and developing a reclamation program are current problems that require cautious scientific approach.

Habitat destruction and fragmentation are the main causes of modified landscape configuration, and this leads to altering the functioning of landscape scale processes (McIntyre & Hobbs 2000; Vellend 2003). Dispersal limitation was demonstrated to be the most important factor influencing the success of spontaneous succession and restoration programs in various grassland habitats in most of Europe and worldwide (Hutchings & Boots 1996*a*; Molnár & Botta-Dukát 1998; Poschlod et al. 1998; Stampfli & Zeiter 1999; Donath et al. 2003). Other studies support that the recruitment limitation is important in the recovery (Bartha et al. 2003), and these results most often originate from sites with harsh environmental conditions (Wood & del Moral 1987; Kirmer & Mahn 2001; Gretarsdottir et al. 2004).

In this study, the recovery success of abandoned fields is assessed. Species-rich, nondegraded seminatural grasslands from the surroundings, having similar habitat conditions with old-fields, were considered as targets for restoration. Five grasslands were analyzed in order to have multiple

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reference sites or "alternative steady states" (Aronson et al. 1995) that account for site heterogeneity and differences in land use history (Clewell & Rieger 1997; Palmer et al. 1997). I compared the compositional and structural characteristics of naturally recovering old-fields of different ages with reference grasslands. Different aged old-fields were studied in order to assess the interval needed for restoring sites without human interventions because no information is available on the potential for spontaneous processes on abandoned lands from the studied region.

The aim of this study was to assess the natural recovery potential of old-fields in the Transylvanian Lowland and to determine if active interventions are needed in order for abandoned lands to achieve a more natural state that resembles target grasslands. The main questions were the following: whether the number and abundance of natural and seminatural habitat species are increasing on old-fields over time, thus fields becoming more similar to grasslands and whether the number and abundance of weeds and exotic species are decreasing with the age of abandoned lands. This study also addresses questions about factors affecting the recovery process in this agricultural landscape.

Methods

Site Description

The study area is located in the central part of the Transylvanian Lowland (Câmpia Transilvaniei) in Romania, near the village Suatu (lat 46°46′N, long 23°58′E, 328–485 m a.s.l.). The climate is temperate continental, with the maximum precipitation occurring in summer (June, July, August); average yearly precipitation is around 550–600 mm, and the mean annual temperature is about 8.5°C. The soil types are chernozemic brown forest soils on clay, marl, and sandstone substrate. The natural vegetation is forest steppe/forest. The extensive deforestation of this region took place more than 1,000 years ago in order to obtain pastures. At present, small remnants of oak (*Quercus robur–Q. petraea*) and oak–Hornbeam (*Quercus petraea–Carpinus betulus*) woods can be found on the tops of the hills or on northern facing slopes. Following deforestation, mesoxeric grasslands dominated by Fescue (*Festuca rupicola*), Feather-grass (*Stipa tirsa*), Upright brome (*Bromus erectus*), and Tor-grass (*Brachypodium pinnatum*) were formed, taking the place of former woodlands. Species composition of these grasslands was developed over a several hundred-year or thousand-year time scale under various forms of land use (grazing and mowing). Because these grasslands are of secondary origin but have a natural-like character that supports the native flora, the term seminatural is often used for them. These seminatural grassland remnants are species rich, well conserved, and maintained by human management. The ancient grasslands are Feather-grass steppes dominated by *S. pulcherrima* or *S. lessingiana,* situated on very steep slopes of southern orientation and highly eroded marly soils, on marginal environmental conditions for agriculture. The slope degree, exposure, and past and present land use are the most important factors affecting the appearance of these grassland types (Bujorean 1931; Csűrös-Káptalan 1964). Due to agricultural land use, nowadays the amount of grassland habitat in the Transylvanian Lowland is relatively low, occupying only 7.5% of the landscape in the studied area (Fig. 1). Species rich, nondegraded steppe and mesoxeric grassland remnants represent important target vegetation types for nature conservation and goals for restoring abandoned lands (Szabó & Ruprecht 2001).

Data Collection

In the 2000–2004 period, I examined 40 old-fields abandoned 1–40 years ago. Eight of these old-fields were reexamined 2 or 3 years after the first investigation, so I had a total of 48 cases in the analysis. Area of each old-field was calculated, exposure was measured, and slope degree was visually estimated. Most fields are quite small, the average area being 1.7 ha. The habitat type (soil type, exposure, slope degree) of these old-fields was nearly similar: chernozemic brown forest soil on clay substrate, northern facing slopes of 0–20° or southern facing slopes of 0–5°, and mesoxeric moisture condition. The date of abandonment and last crop was determined by asking landowners. The last crop was most often a leguminous, Red clover (*Trifolium pratense*) and Alfalfa (*Medicago sativa*), used for hay. In other cases it was maize, sunflower, or grain (wheat, barley, oats). These fields are not completely abandoned because they are still used as pastures in spring and autumn for sheep, or as hayfields, mowed once a year in July. The habitat conditions of the five reference mesoxeric grassland are similar to that of the old-fields. The size of these grassland remnants was between 1 and 40 ha. For testing the dispersal limitation hypothesis, I surveyed the potential propagule sources from the landscape, thus five dry grasslands (steppes) and a dry secondary grassland (30-year-old abandoned vineyard) were also investigated. The dominant species and abundance order of these steppes are different from the mesoxeric grassland types; however, they have a lot of species common. Thus, they were considered to be propagule sources for the studied old-fields but to a lesser degree. All the studied fields and grasslands were situated approximately within a 3.54 × 3.27–km area (Fig. 1).

Percent cover of vascular plant species was visually estimated within 4 × 4–m plots arranged in a stratified random design. Four plots were examined per field or grassland stand.

Data Analysis

1. In order to have an accurate insight into compositional changes during the course of succession, species were classified according to Sanda et al. (1983): (1) species of natural and seminatural habitats; (2) species common to natural, seminatural, and weed communities; and (3)

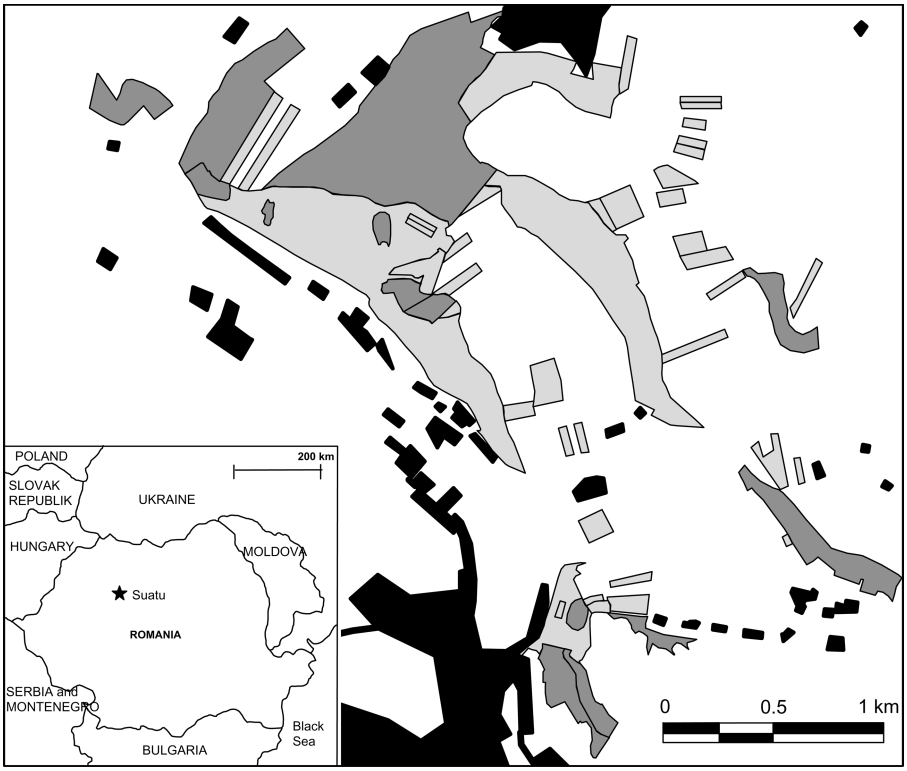

Figure 1. Map of the study area in the surroundings of the village Suatu, Transylvanian Lowland, Romania. Old-fields are appearing in light gray, source grasslands in dark gray, and settlements in black.

species of weed communities. The relative number of species (species number × 100/total species number) belonging to each one of these three groups was calculated for each old-field and seminatural grassland.

2. To follow the quantity of alien species over time, the relative cover and number of aliens were calculated for each old-field and seminatural grassland. Archaeophytes (introduced before the discovery of America, approximately 1500 AD) and neophytes (introduced after that date) were considered separately (Terpó et al. 1999; Pyšek et al. 2002; Balogh et al. 2004).
3. Pair-wise similarity, using the species abundance values, between different aged old-fields and target grasslands was calculated using the complement to Bray-Curtis index (1 − Bray-Curtis index). Similarity indexes were calculated between each old-field and each seminatural grassland (five grasslands). In the case of each old-field, the five similarity values of the old-field to the grasslands were averaged. To have a reference for calculated measures, similarity of each grassland to the others was calculated, then the four values were averaged. Similarity in species composition was calculated in the same way using the complement to Sørensen index of dissimilarity. The relationship between field age and the two similarity measures was tested by Spearman rank correlation.

For delineating vegetation changes on old-fields through time, space-for-time substitution method was used. By this method, a considerable amount of extensive data about landscape scale successional processes was possible to obtain. Using permanent plots as considered to be the most precise method in successional studies (Bakker et al. 1996) would not be appropriate to answer the questions of this study because data obtained by such intensive observations would represent only a limited portion of the landscape, thus it cannot serve for revealing landscape scale relationships.

4. A generalized linear model (GLZ) was performed to assess the effect of age, field area, habitat condition, and dispersal limitation on the success of recovery, where the success of recovery was measured by the number of grassland species from a field. The effect of management type was not possible to test because it was not independent from the age of the fields. Habitat properties were characterized by slope degree and exposure, and dispersal limitation by the amount of propagule sources. I measured the relative area of propagule sources within a 500-m radius around each field by digitizing and analyzing maps in ArcView 3.3 because it contains information not only about the distance of seed sources but also about the amount (area) of potential sources. In studies about dispersal limitation and isolation effects, 100-, 500-, and 1,000-m-radius

buffers were used (Grashof-Bokdam 1997; Butaye et al. 2002; Jacquemyn et al. 2003). The 500-m-radius buffer seems to be adequate in the present case. Grasslands and older fields were considered to be potential propagule sources for the recovering fields. Mesoxeric grasslands were considered to be perfect propagule sources for the old-fields included in this study because they have very similar habitat properties and the species composition of the fields became more and more similar to these grasslands. Older fields (abandoned 30–40 years ago) were also considered as propagule sources for the younger fields (abandoned 1–6 years ago), respectively, fields abandoned 40 years ago for the middle-aged fields (abandoned 10–14 years ago), because the quantity of grassland species they contained was similar to the quantity in mesoxeric grasslands. Dry grasslands (steppes) and dry secondary grasslands with different habitat condition had only half the amount of grassland species compared to mesoxeric grasslands, thus they were considered to be propagule sources for the recovering fields in half part. When calculating the total area of propagule source around an old-field, the area of mesoxeric grasslands and secondary mesoxeric grasslands (older fields) was multiplied by 1 and the area of dry grasslands and dry secondary grasslands by 0.5. The relative area of propagule sources from a buffer zone was used in the analyses, which was the total area of propagule sources in the respective buffer zone/area of the buffer zone.

5. I wanted to test which is the factor determining the colonization success of the grassland species on old-fields. The year of colonization (age of the youngest field in which a species was found) was considered the colonization success: the sooner a species appears on a field after abandonment, the more successful it is in colonization. Between factors supposed to affect the colonization ability, the abundance and frequency (in how many of the 10 grassland stands is a species present) of the species in the source mesoxeric and dry grasslands and dispersal mode were tested. Because the abundance and the frequency of a species in the source grasslands correlated (Spearman rank correlation; rs $= 0.88$, $t = 20.96$, $n = 129$, $p < 0.0001$), I finally used only the frequency in the analyses. Three frequency groups were created: 1 (frequency values between 0 and 2), 2 (frequency values between 3 and 5), and 3 (frequency values between 6 and 10), and the colonization success was compared between these three frequency groups. The distribution of frequency values in the three groups is unequal, the third frequency group containing more frequency values, attributable to the fact that there were much fewer species having frequency values above 6 than below. Dispersal mode was used based on the Biological parameters of population management in plants (BIOPOP) database (Poschlod et al. 2003) accessible within Flora-web Internet portal (www.floraweb.de) and in the case of species not found in this database, the work of Csontos et al. (2002) was used. Only those species (129 of 140) were included in the analyses of which dispersal mode could be found in the mentioned databases. The relationship between the colonization success and the four most frequent dispersal mode (dispersal by wind, birds and mammals, ants, and self-dispersal) was calculated one by one (Nomenclature: Flora Europaea [http://rbg-web2.rbge.org.uk/FE/fe.html]).

Results

Species of the Natural and Seminatural Habitats

When species were classified based on their naturalness in three groups species of natural and seminatural habitats, species of weed communities, and species appearing in both, it was found that the number of natural habitat species was increasing rapidly through succession. Fields abandoned 20 years ago had just as many natural habitat species and just as few weeds as target grasslands (Fig. 2).

Alien Species

The relative cover and number of alien species were decreasing sharply in the first 6 years of succession and then remaining at very low values in the later stages. Older fields contained very few exotics (Fig. 3). Archaeophytes—the common weeds of arable lands that are of alien origin naturalized in our country—were the most abundant aliens on recovering fields. Occurrence of neophytes, with some invasive species or potential invaders among them, was quite insignificant in the early stages of recovery (Fig. 3).

Similarity of Recovering Old-Fields to Reference Grassland

Abundance order of old-fields to reference grassland as measured by the Bray-Curtis index was rising significantly

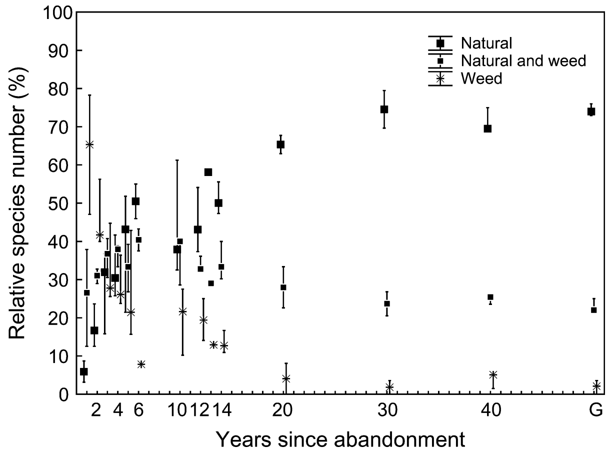

Figure 2. Change in the number of species of different habitats (species of natural and seminatural habitats; species common to natural, seminatural, and weed communities; species of weed communities) during spontaneous recovery on old-fields in the Transylvanian Lowland, Romania. Values are medians and quartiles. G, target grasslands.

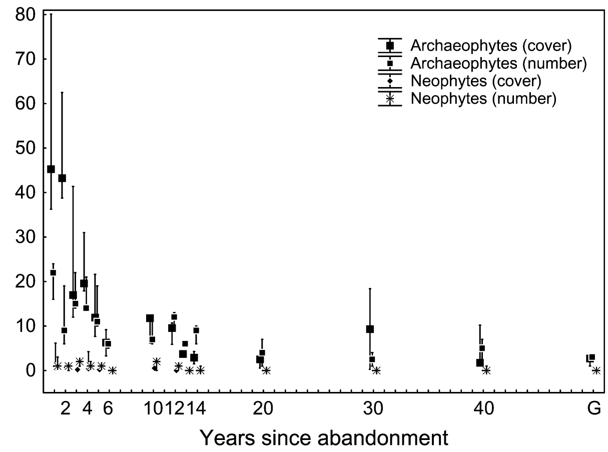

Figure 3. Change in the number and relative proportion of alien species (archaeophytes and neophytes) during spontaneous recovery on old-fields in the Transylvanian Lowland, Romania. Values are medians and quartiles. G, target grasslands.

(Fig. 4) over time, dominance relations between component species from the old-fields approached the dominance structure found in natural grasslands after 12–14 years. Species composition of the old-fields was becoming more and more similar to that of the target communities (Fig. 4).

Factors Affecting the Recovery Success of the Old-Fields

The logarithm of age and relative area of propagule sources around the recovering fields was a significant predictor of grassland species richness on old-fields (Table 1). Other factors such as the logarithm of field area and habitat properties characterized by exposure and slope degree had no effect on the recovery success (Table 1).

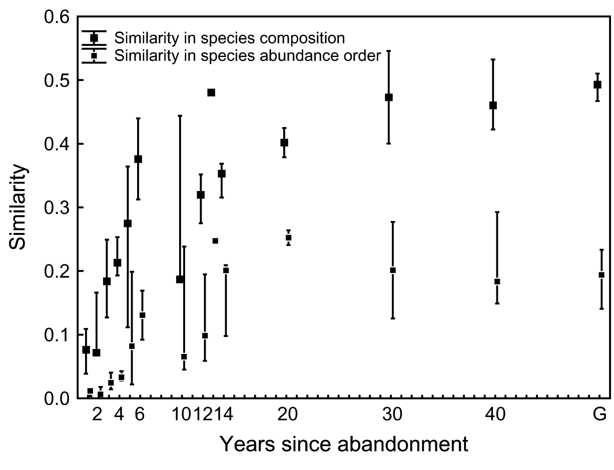

Figure 4. Similarity in species composition and species abundance order of recovering old-fields to target grasslands in the Transylvanian Lowland, Romania. Spearman rank correlation between complement values to Sorensen index and age, $rs = 0.85$, $t = 10.79$, $n = 48$, $p < 0.0001$, and between complement values to Bray-Curtis index and age, $rs = 0.84$, $t = 10.67$, $n = 48$, $p < 0.0001$. Values are medians and quartiles. G, target grasslands, where each grassland had a value (the average of its similarity to the other grasslands), and the median and quartiles of these five values is represented in the figure.

Colonization of Grassland Species

Frequency in the surrounding landscape had a significant effect on the colonization success of grassland species, and species present in more than two grasslands from the surroundings colonized successfully the abandoned fields (Fig. 5). A difference in colonization success between species incapable of self-dispersal and self-dispersed species was found, with significantly lower colonization success in the case of self-dispersed species (Mann Whitney U test; $Z_{[103,26]} = 2.15$, $p = 0.03$), but self-dispersal was found not to be independent from the frequency in the landscape (Chi-square test, $p < 0.05$). So self-dispersed species are unsuccessful in colonization not because their seeds are self-dispersed but because they are less frequent in the landscape.

Discussion

Studied old-fields were proven to have high potential for natural recovery. The increased importance of natural and seminatural habitat species in the species composition of old-fields with time suggests that recovery occurred and secondary vegetation on abandoned fields has gained a natural-like character in 20 years. Another joyful aspect is that fields abandoned 5–14 years ago contain a low number of weeds, and 20-year old-fields have become almost completely free of weeds. Dominance structure and species composition were becoming similar to the reference grasslands in 14 years. Because fields abandoned 14–20 years ago contain a large amount of the natural flora, among grasslands they also deserve the attention of nature conservation efforts. Compared to other studies on spontaneous recovery (e.g., Hutchings & Boots 1996*a*; Molnár

Table 1. Generalized linear model (GLZ) of factors affecting the recovery of the old-fields in the Transylvanian Lowland, Romania. Log transformation was applied to field age, field area, and size of propagule source to linearize relationships with grassland species number. Exposure was introduced in the analyses as a categorical variable with two categories: southern orientation (slopes of southwestern, southern, southeastern, and western exposure) and northern orientation (slopes of eastern, northeastern, northern, and northwestern exposure).

	Estimation	*p*
Log age old-field	0.55	<0.0001
Log area old-field	0	n.s.
Habitat properties: exposure	0.07	n.s.
Habitat properties: slope degree	0.01	n.s.
Habitat properties combined: exposure and slope degree	−0.01	n.s.
Log relative area of propagule source	0.07	<0.05

n.s., not significant.

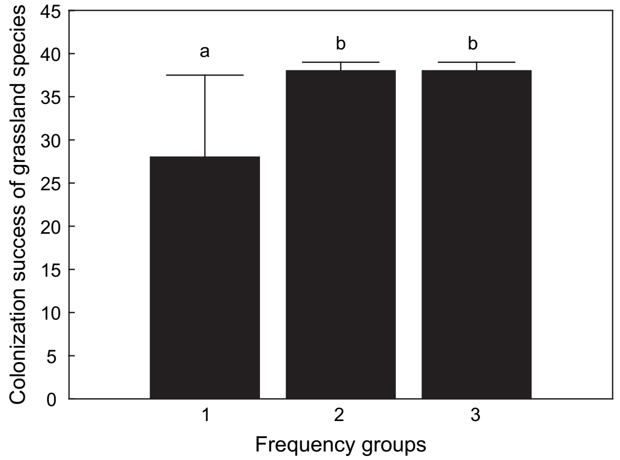

Figure 5. Relationship between colonization success of grassland species and their frequency in the landscape in the Transylvanian Lowland, Romania (Kruskal–Wallis test; $\chi^2_{[2,129]} = 19.96$, $p < 0.0001$). Values are medians and quartiles. Species with higher frequency values (b) were more successful in colonization than species with low frequency values (a) (Dunn post hoc test; $p < 0.01$ [between frequency groups 1 and 2] and $p < 0.001$ [between frequency groups 1 and 3]), and there was no significant difference between frequency groups 2 and 3, both noted as b in the figure.

& Botta-Dukát 1998), it is obvious that spontaneous succession lead to very good results and there is no need for human intervention in this case. Successfully recovering systems such as this one can serve as good examples for designating the goals of restoration plans and spontaneous succession because it can expose key features of the points of reference restoration ecologists can choose (Prach & Pyšek 2001; Prach et al. 2001*a*).

Recently, more attention has been given to the role of alien species in succession (Davis et al. 2001; Meiners et al. 2001) and the temporal distribution of aliens in old-field succession (Meiners et al. 2002). Disturbed, fragmented, and nutrient-rich vegetation types, such as the young successional ecosystems, especially those having a slow recovery rate, are the most susceptible to invasion by alien species that can alter dynamic processes (Rejmánek 1989; Richardson et al. 2000; Rejmánek et al. 2005). It is very promising that the amount of alien species is decreasing through succession, and neophytes or invasive species are in very low abundance on recovering fields. The fact that native species replace aliens is another piece of evidence of the successful recovery. Here, restoration efforts to eradicate alien species are not necessary at the present time. Applying space-for-time substitution for analyzing the role of alien species in the recovery can cause some mistakes. We can suppose that in the past, the quantity of these species was lower and less species were present in the surrounding landscape than today. They may be less present and in low abundance in the fields abandoned 10–40 years ago. That should make us cautious in interpreting such results.

Time expressed as age of the recovering fields was an important predictor of grassland species richness in old-fields, as expected, but propagule availability was also affecting the recovery success. In general, the colonization of grassland species on old-fields was successful, only 9 of 140 species have not been able to colonize within 40 years. Among these species, there are locally and also regionally rare species (e.g., *Scorzonera hispanica*, *Cirsium pannonicum*) that can be why their appearance on old-fields had low likelihood. Propagule limitation was found to be the cause of some grassland species colonizing relatively early and establishing successfully on old-fields, whereas others not. If a species is present in more than two grassland stands from the landscape, its colonization on abandoned fields will be highly probable. It is generally accepted that diaspore number declines with increasing distance from the diaspore source (Bullock et al. 2002), thus in landscapes altered by human activity, where seminatural habitat remnants are sparse, propagule limitation occurs (Jacquemyn et al. 2003; Vellend 2003). Studies reporting about unsuccessful spontaneous successional processes specify as the major cause the propagule limitation (Hutchings & Boots 1996*a*; Molnár & Botta-Dukát 1998; Poschlod et al. 1998; Stampfli & Zeiter 1999; Donath et al. 2003). Thus many restoration efforts are directed toward seeding to treat dispersal limitation (Sluis 2002; Klips 2004; Lawson et al. 2004).

No effect of field size on grassland species richness was found, probably due to the small range of variation in field area. Site conditions (e.g., moisture condition) can influence the speed of successional processes (Prach et al. 1993; Martínez-Ruiz et al. 2001), but in this study, slope degree and orientation did not affect the success of recovery. Management techniques are reported to influence positively the establishment of natural habitat species on former arable lands (Hutchings & Booth 1996*b*; Rebele & Lehmann 2002; Lawson et al. 2004). In this study, the effect of management on the colonization success of grassland species could not been analyzed because the young fields were preferentially mowed and the middle-aged and older fields were preferentially grazed, which would cause an artifact in the results. Therefore, further study focusing more carefully on which type of management stimulates the appearance of grassland species on old-fields is necessary.

Dispersal mode was found not to influence the colonization success of grassland species on old-fields probably because the majority of these grassland species (90.7%) have high-distance dispersal capacity with alternative dispersal mode (dispersal by wind, animals, and man).

This study provides evidence, both from the recovery success and from the colonizing grassland species point of view, for a strong influence of landscape context on the recovery of grassland communities on postagricultural sites.

Implications for Practice

Several unsuccessful restoration attempts (Allison 2002; Sluis 2002; Donath et al. 2003) call the attention to the difficulty of recreating grassland communities because these are complex, vulnerable systems. This study demonstrated that spontaneous succession can be a good tool for restoring grassland habitat. Recovering fields have become enriched in grassland species relatively fast because in the surrounding areas, there were several natural seed sources. It is obvious that spontaneous processes lead to very good results, and there is no need for human intervention in this case.

In the future, the recovery of postagricultural fields will likely depend on the extent to which seminatural habitats and species-rich secondary grasslands are conserved. Management efforts should be directed in a way to conserve the existing grassland remnants and also preserve landscape scale processes in order to maintain the potential for recovery of the disturbed and transformed sites.

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