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Role of megaherbivores in restoration of species-rich grasslands on former arable land in floodplains

Bedeutung der Megaherbivoren-Beweidung für die Renaturierung artenreicher Feuchtgrünländer auf ehemaligen Ackerflächen

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Abstract

Species-rich wet grasslands in floodplains are on focus of European nature conservation policy. However, since the seventies of the last century large areas with grasslands in floodplains have been meliorated, ploughed and used for intensive cropping in Germany. Therefore, restoration strategies for large-scale conversion of former arable land into species-rich grasslands and integration into a long-term sustainable land use regime are needed. Dealing with large areas in restoration projects causes high costs which often exceed the possibilities of NGO's or other stakeholders. Aiming to develop and implement new cost-efficient strategies for restoration and long-term management of wetlands on former arable land local NGO's and the Anhalt University of Applied Sciences started a co-operation within a project in a heavily degraded floodplain in the Elbe river valley. Up to now, more than 40 ha former arable land was successively bought and immediately grazed by large herbivores (Heck-cattle and Przewalski-horses). The local farmers apply a year-round grazing regime without additional feeding and low stocking density. Scientific evaluation of the project progress and experiments with different re-vegetation variants (natural recovery, hay transfer, seeding of commercial seed mixture) revealed the following results: (1) on former arable land immediate grazing with large herbivores without additional feeding is possible and leads to a successive development of typical grassland communities with low nutrient status, (2) integration of old pastures into the grazing system enhances colonization of native grassland species alongside animal tracks, (3) seeding of a commercial seed mixture impedes the colonization of native grassland species, (4) transfer of species-rich hay accelerates the colonization rate of several grassland species, and (5) highest cover of target species was found on regularly wet sites. Therefore, we conclude that grazing with large herbivores proved to be successful in converting former arable land into species-rich grasslands. Nevertheless, rising of the groundwater table is most important for further development of species-rich wet grasslands in the Wulfener Bruch.

Keywords: *restoring former arable land, floodplains, species-rich grassland, megaherbivore grazing, natural recovery, animal tracks, hay transfer, seeding of commercial seed mixture*

Zusammenfassung

Artenreiche Feuchtgrünländer stehen stark im Fokus europäischer Naturschutzstrategien. Dennoch wurden auch in Deutschland, insbesondere in den 70er Jahren des vergangenen Jahrhunderts, viele dieser Feuchtgrünländer durch Meliorationsmaßnahmen, Umbruch oder intensivste Grünlandnutzung zerstört oder degradiert. Es werden jetzt dringend Renaturierungsstrategien benötigt, die eine großflächige Umwandlung und nachhaltige Landnutzung dieser ehemaligen Ackerflächen in artenreiche Grünlandbestände gewährleisten können. Diese großflächigen Renaturierungsvorhaben überschreiten jedoch häufig die finanziellen Möglichkeiten von Naturschutzorganisationen oder anderen Interessensgruppen, so dass Methoden entwickelt und getestet werden müssen, die effektiv und dennoch kosteneffizient sind. Zusammen mit dem vor Ort aktiven Naturschutzbund initiierte die Hochschule Anhalt (FH) ein Projekt, um solche ehemaligen Ackerflächen in den Auenbereichen der Elbe wieder in artenreiches Grünland umzuwandeln und langfristig zu sichern. Mittlerweile konnten über 40 ha ehemalige Ackerflächen erworben und unverzüglich in ein Beweidungssystem mit Heckrindern und Przewalski-Pferden integriert werden. Durch die Bewirtschafter wird eine extensive Ganzjahresbeweidung ohne Zufütterung umgesetzt. Auf Basis der wissenschaftlichen Begleitung dieses Beweidungsprojektes und der Durchführung von verschiedenen Versuchsvarianten zur erfolgreichen Begrünung der Flächen (Spontanentwicklung, Mahdgutübertrag, Ansaat einer kommerziellen Regelsaatgutmischung) können mittlerweile folgende Ergebnisse belegt werden: (1) durch die extensive Beweidung mit Megaherbivoren unter dem Verzicht auf eine Zufütterung können auf ehemaligen Ackerflächen erfolgreich standorttypische Grünlandgesellschaften mit einem vergleichsweise niedrigen Nährstoffstatus entwickelt werden, (2) die Integration bereits bestehender artenreicher Grünländer in das Beweidungssystem fördert die schnelle Etablierung von Zielarten, insbesondere entlang der Hauptweidepfade, (3) eine Ansaat von herkömmlichen Regelsaatgutmischungen behindert die Etablierung standorttypischer Grünlandarten, (4) durch Mahdgutüberträge wird die Etablierungsrate verschiedener Zielarten erhöht, (5) am erfolgreichsten ist die Etablierung der Zielarten auf den bereits ganzjährig nassen Standorten. Die extensive Ganzjahresbeweidung mit Megaherbivoren ist folglich eine geeignete Methode für die Renaturierung artenreicher Grünlandbestände auf ehemals intensiv ackerbaulich genutzten Flächen. Es wird jedoch auch deutlich, dass neben der Beweidung die Anhebung der Grundwasserstände enorm wichtig für die positive Entwicklung dieser Grünlandbestände im Wulfener Bruch ist.

Schlüsselwörter: Renaturierung ehemaliger Ackerflächen, Flussauen, artenreiches Grünland, Megaherbivoren-Beweidung, spontane Besiedlungsprozesse, Tierpfade, Mahdgutübertrag, Ansaat herkömmlicher Regelsaatgutmischungen

1 Introduction

Species-rich wet grasslands in floodplains are on focus of European nature conservation policy (European Council 1992). However, since the seventies of the last century large grasslands areas in floodplains have been meliorated, ploughed and used for intensive cropping in Germany. Comparable trends have been observed in many other regions in Europe (Neuhauser 2001). In addition to the substantial loss of biodiversity, important ecosystem functions of wet grasslands such as water retention or carbon storage had been damaged and the intensive farming led to severe eutrophication of nearby ecosystems, especially of water courses. Therefore, restoration schemes for restoring species-rich grasslands on former arable land in floodplains are needed (Šeffer et al. 2008, Donath et al. 2003, Hölzel & Otte 2003, Vécrin et al. 2002).

In converting former arable land into species-rich grasslands active restoration measures such as topsoil removal and/or transfer of species-rich hay from donor populations in the surroundings had been successful (Hölzel & Otte 2003, Donath et al. 2003). Dealing with these methods on large areas in restoration projects causes high costs though which often exceed the possibilities of NGO's or other stakeholders. In addition, as for many other semi-natural grasslands of high nature conservation value, securing an adequate management regime is a major challenge. The restored floodplain grasslands are typically used for hay production. However, hay from species-rich grasslands of nature conservation value is often not suitable to be used in intensive cattle breeding. Furthermore, management of large-scale wetlands by mowing is often economically inefficient and long-term success depends largely on the availability of agri-environmental subsidies (Kaphengst et al. 2005). Besides these economical aspects large-scale meadows often lack structural diversity because of a uniform mowing regime (e. g. Kleijn et al. 2001). Therefore, cost-efficient restoration strategies for large-scale conversion of former arable land into species-rich grasslands and integration into a long-term sustainable land use regime are needed.

Aiming to develop and implement such a new strategy local NGO's (Nabu Köthen and Primigenius gGmbH) and the Anhalt University of Applied Sciences started a co-operation within a project in a heavily degraded floodplain in the Elbe river valley in 1999. Up to now, more than 40 ha former arable land was successively bought and immediately grazed by large herbivores (Heck-cattle and Przewalski-horses). Similar grazing project were successfully carried out in other floodplain areas in Europe (e. g. Bunzel-Drüke et al. 2008, Pykälä 2000, Oppermann & Luick 1999, Vulink & Van Eerden 1998).

Nevertheless, the immediate grazing of fallow arable land without seeding of grassland species was never tested before and provoked many critical questions in the first years of the project. Therefore, a systematic evaluation of the project progress was started in 2002 focusing on the following questions: (1) How long does it take to restore species-rich wet grasslands on former arable land using megaherbivore grazing with regard to plant species composition and soil parameters? (2) Is it necessary to accelerate vegetation development by transferring species and how does seeding of commercial seed mixtures effects the colonization of target species?, and (3) Is there any evidence that megaherbivore grazing supports the colonization of target species on the former arable land?

2 Methods

2.1 Study area

The Wulfener Bruch is situated near the town Köthen in Saxony-Anhalt. In former times it was periodically flooded by the river Elbe. Until the seventies of the last century the groundwater table was high even in spring and summer. That resulted in the formation of soil with high organic content (> 15 %). Since the seventies of the last century large areas of the grasslands in the Wulfener Bruch were meliorated and used for intensive cropping. The remaining grasslands were intensely used. As a result of these changes in land use the organic soil has been degraded and many of the formerly species-rich grasslands has been destroyed or lost their typical species assembly. Nevertheless, 972 ha within the Wulfener Bruch are actually designed as Natura 2000 site and Special Protected Area for birds. The Wulfener Bruch is also integrated into the Biosphere Reserve "Mittelelbe".

The actual hydrological conditions are characterized by strong groundwater table fluctuations. Especially in winter and spring the groundwater table is relatively high, but the summer is characterized by long dry periods. During the last years a slow rise of the groundwater table was achieved in some parts of the Wulfener Bruch by regulating the drainage channels. However, a further rise of the groundwater table is not possible because of still existing arable land.

2.2 Grazing Regime

Most of the bought fallow arable land was fenced together with old pastures or already developed grasslands and left for natural recovery. The local farmers (Primigenius gGmbH) apply a year-round grazing regime without additional feeding and a low stocking density with 3 up to 6 animals per 10 ha.

2.3 Soil analysis

To investigate the effects of megaherbivore grazing the following soil properties were measured in 2008: pH ($CaCl_2$), total nitrogen and organic carbon content (Leco-analyzer), and calcium-acetate-lactate (CAL) soluble phosphorus and potassium (AG Boden 1994).

Samples were taken randomly at 14 locations on megaherbivore pastures formerly used as arable land, at four locations on megaherbivore pastures established on formerly intensive grasslands, and at four locations used as dunging areas by the animals above average.

For each soil sample ten soil cores were taken in a depth of 0–10 cm using a 3 cm diameter corer, and subsequently pooled for analysis. The same method was applied at eight locations on remnants of species-rich old grasslands and at 8 locations on still existing arable land. The number of soil samples was adapted to the extension of the studied sites. For statistical analysis of data we applied a Kruskal-Wallis Test and a Post Hoc Test (Tamhane) using SPSS 16.0.

2.4 Experiments

On newly integrated fallow arable land experiments were implemented to test the effect of hay transfer from adjacent species-rich grasslands as well as sowing of commercial seed mixtures against the natural recovery of the grasslands. The two experiments were implemented in complete block design in 2002 and 2003 with three replicates for the three variants (= 3 blocks). The three variants (natural recovery – nat, hay transfer – hay, and seeding of commercial seed mixture – seeds) were randomly arranged within the three blocks. The size of one block is approximately 240 m x 100 m (three stripes for each of the variants; stripe size 80 m x 100 m).

For hay transfer, material was harvested on two of the species-rich wetland remnants of the Wulfener Bruch (Hirschteich and Strudellöcher) which are characterized by C n i d i o n -plant communities. They are approximately in 1,300 m respectively 900 m distance from the receptor sites. The hay-transfer ratio from donor to receptor sites was 2 : 1.

The commercial seed mixture consisted mainly of different *Festuca rubra*-varieties, as well as *Lolium perenne* and *Dactylis glomerata*.

Depending on the uneven ground profile the water conditions vary from dry to periodically wet. Experiment A is characterized by wet conditions in most parts whereas experiment B shows predominantly dry to periodically wet conditions. Complete species lists with frequency classes were compiled for the whole area of each replicate.

On each replicate of the variants relevés with percentage cover of each single species were performed on five permanent plots (size 25 m^2, altogether 15 permanent plots per variant). In addition the individuals of target species were counted on these permanent plots. Plant species (e. g. *Cnidium dubium*, *Serratula tinctoria*, *Allium angulosum*, *Galium boreale*, *Centaurea jacea*, *Leucanthemum vulgare* and *Sanguisorba officinalis*) were considered as target species if they occurred regularly in old species-rich grasslands of the Wulfener Bruch. Rare species were included if they are typical for species-rich floodplain grassland in general.

During the monitoring it became obvious that some parts of the megaherbivore pastures are benefiting more from the local rising of the groundwater table and vegetation develops differently from the dryer parts. Therefore, we established additional permanent plots on those sites in 2006. In order to compare the natural recovery within the experiments with vegetation development on regularly wet sites we randomly selected twelve 25 m^2-plots in nearby parts of the pastures representing such conditions and monitored them in the same way since 2006.

2.5 Floristic and animal track mappings

Since 2002 complete species lists of all vascular plants were compiled on the megaherbivore pastures. In 2005 and 2009 all locations of target species were mapped on former arable land which has been connected with already developed species-rich old grasslands by fencing these sites together. In addition we drew all visual recognizable animal tracks in another map. Finally these two maps were blended together.

3 Results

3.1 Soil Analysis

The soil analyses reveal the degradation of the former organic soil (Fig. 1). This is particularly true for the pastures on former arable land, but the carbon content is already slightly higher compared to still existing arable land in the surroundings. Megaherbivore pastures on former grassland sites have much higher carbon content. Remnants of species-rich wet grasslands (= target vegetation) can be found only in small depressions in the Wulfener Bruch. These grasslands show a carbon content of about 10 to 14 percent.

Potassium and phosphorous values reveal dislocation processes on the megaherbivore pastures. Dunging areas have much higher potassium and phosphorous values, but they occur only in small parts of the pasture. Large areas of the megaherbivore pastures have potassium and phosphorous values comparable to those of the target vegetation or show even lower values. Phosphorous values of the megaherbivore pastures are particularly low compared to the still existing arable land in the surroundings. PH-values range from 6.7 to 7.6 without notable differences between groups.

3.2 Experiments

Figure 2 shows the development of target species (dots) and ruderal species (rectangles). Ruderal species increased rapidly in the first two years in nearly all variants, but continuously decreased afterwards. Only on dry to periodically wet sites the commercial seed mixture impeded the development of ruderal species. However, the dense grass swards created by this seed mixture also impeded the colonization of target species, which was faster on all other sites. On periodically wet sites the commercial seed mixture did not work. Therefore, the development was similar to the control variants.

Transfer of species-rich hay from other wetlands accelerated the percentage coverage of target species. In the last year control variants achieved comparable cover of target species. The realized transfer rate on receptor site was 86 %, but the population density and coverage, especially of rare species, is still rather low and some rare species of the donor sites are still missing. However, all together 35 species, which were not able to colonize spontaneously, could be established by hay transfer until 2008, among them typical wetland species such as *Allium angulosum*, *Cirsium canum*, *Tetragonolobus maritimus*, *Galium boreale*, and *Sanguisorba officinalis*. High transfer rates and coverage on receptor sites were observed for more common species such as *Centaurea jacea*, *Leucanthemum vulgare*, and *Galium album*.

Best results regarding target species were achieved on natural recovered permanently wet sites which were monitored since 2006.

The percentage cover of *Cirsium arvense* was extremely high in the first two or three years in all variants, except for the dry variant with commercial seed mixture. However, the percentage cover decreased rapidly in the next years (Fig. 3).

3.3 Floristic and animal track mappings

Floristic mappings revealed that more than 280 species spontaneously colonized the former arable land since 2002. Among them are rare or red list species such as *Carex vulpina*, *Centaurium pulchellum*, *Cnidum dubium*, *Inula britannica*, *Pulicaria dysenterica*, *Samolus valerandi*, *Scutellaria hastifolia*, *Senecio aquaticus*, *Teucrium scordium*, *Thalictrum flavum*, and *Viola stagnina*.

The mappings of the selected target species locations show a predominantly linear pattern. By blending the results together with the mappings of the animal tracks almost all species were found alongside these animal tracks (Fig. 4). For all target species we located donor populations in the old species-rich grassland which is connected by a passage with the former arable land. That refers to dispersal by fur, dung and adhesion on hooves whereas wind dispersal should not be excluded since the old grassland is situated in the main wind direction (west of the pasture on former arable land). At the same time the animals created through their hooves prints small disturbances in which the target species could establish. In autumn 2008, we even could find many seedlings from *Cnidium dubium* on open sites in hooves prints of the animals. Nevertheless, target species density was higher on wet sites close to the ditch “Landgraben” or in wet small depressions within the pasture. In 2009 population sizes of most target species increased considerably.

4 Discussion

4.1 Grazing with megaherbivores as a tool for developing wetlands after abandonment of arable land?

Our results are in line with many studies which show the benefits of grazing with large browsing animals in wetland restoration (McCoy & Rodriguez 1994, Redecker et al. 2000, Vulik 2001, Reeves & Champion 2004, Bunzel-Drüke et la. 2008). Even in our special case of developing wetlands after abandonment of arable land grazing with megaherbirvores proved to be most successful in converting the initial ruderal plant communities to species-rich grasslands. For reducing rude-

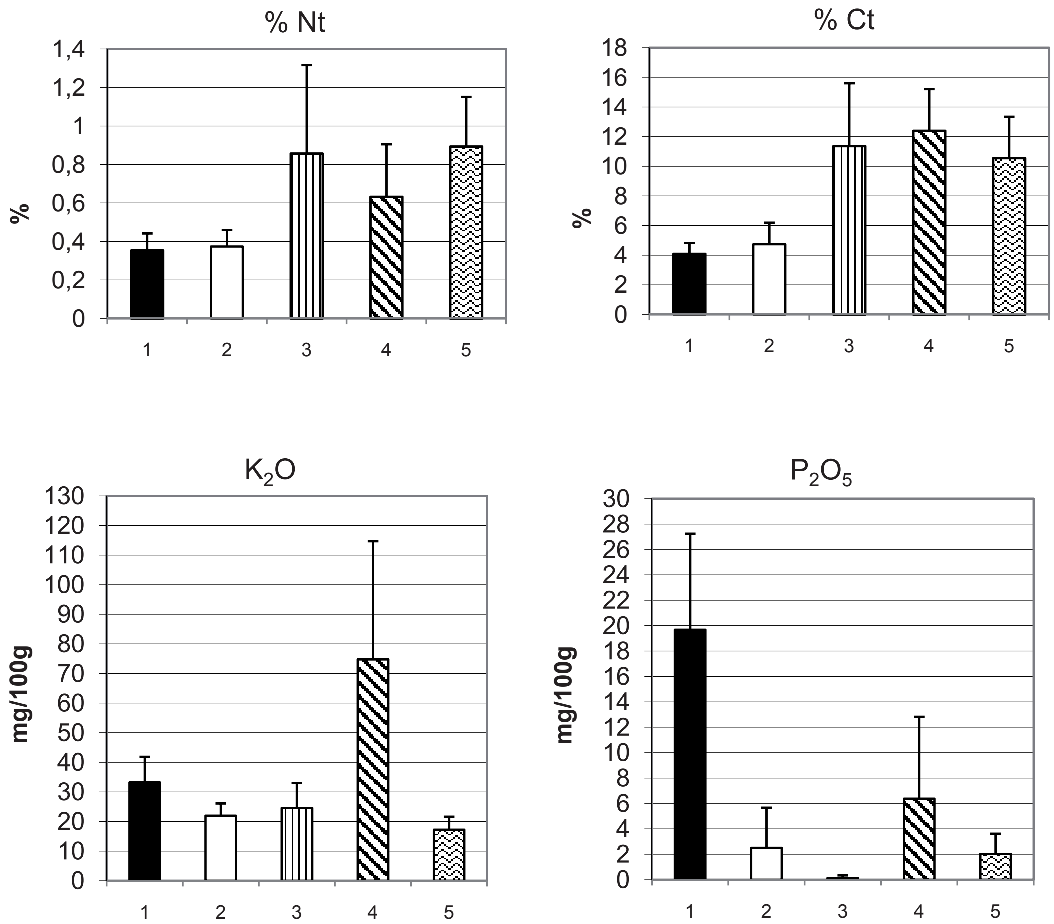

Fig. 1: Results of the soil analysis in 2008; 1 – arable land (n = 8), 2 – megaherbivore pasture on former arable land (n = 14), 3 – megaherbivore pasture on former intensively used meadow (n = 4), 4 – dunging areas on megaherbivore pasture (n = 4), 5 – target vegetation (n = 8); Kruskal-Wallis Test: significant differences between groups ($p < 0.05$); Post Hoc Test (Tamhane): differences are significant for % Nt 1–5 (0.006) and 2–5 (0.009), % Ct 1–5 (0.004) and 2–5 (0.006), K_20 1–5 (0.013), P_2O_5 1–2 (0.004), 1–3 (0.002), and 1–5 (0.004).

Abb. 1: *Ergebnisse der Bodenanalysen im Jahr 2008; 1 – Ackerflächen (n = 8), 2 – Extensivweide mit Megaherbivoren auf ehemaligem Ackerland (n = 14), 3 – Extensivweide mit Megaherbivoren auf ehemaligem Intensivgrünland (n = 4), 4 – Kotplätze/ Lagerflächen auf Extensivweide mit Megaherbivoren (n = 4), 5 – Zielvegetation (n = 8); Kruskal-Wallis Test: signifikante Unterschiede zwischen den Gruppen (p < 0.05); Post Hoc Test (Tamhane): Differenzen signifikant für % Nt 1–5 (0.006) und 2–5 (0.009), % Ct 1–5 (0.004) und 2–5 (0.006),* K_20 *1–5 (0.013),* P_2O_5 *1–2 (0.004), 1–3 (0.002) und 1–5 (0.004).*

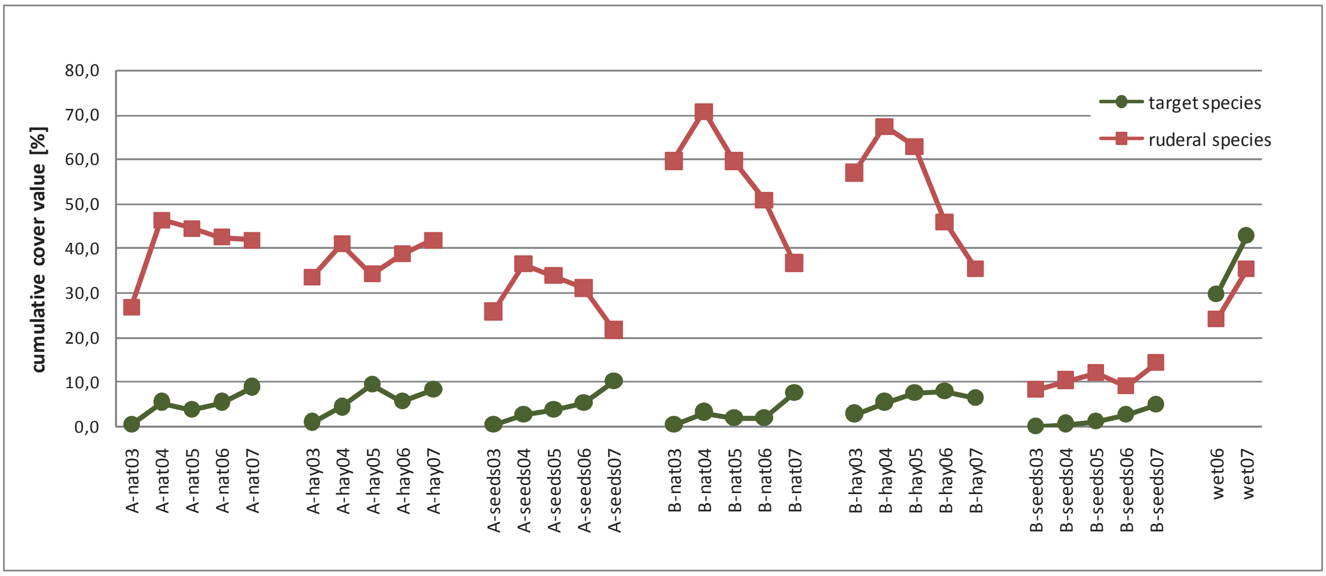

Fig. 2: Mean cumulative coverage of target species (dots) and ruderal species (rectangles); A – wet to periodically fresh conditions, B – dry to periodically wet conditions; variants: natural recovery – nat (n = 15), hay transfer – hay (n = 15), seeding of commercial seed mixture – seeds (n = 15); wet – plots with natural recovery on permanent wet sites (n = 12).

Abb. 2: *Durchschnittliche Deckungsgradsummen der Zielarten (Kreise) und Ruderalarten (Vierecke); A – feucht bis periodisch frisch, B – trocken bis periodisch frisch; Varianten: Spontanbesiedlung – nat (n = 15), Mahdgutübertrag – hay (n = 15), Ansaat mit Regelsaatgutmischung – seeds (n = 15); wet – Flächen mit Spontanbesiedlung und kontinuierlich guter Wasserversorgung (n = 12).*

ral species such as *Cirsium arvense* winter and early spring grazing was most important. Gerken et al. (2008) observed the same reduction of *C. arvense* on former arable land after grazing with cattle and horses. Only in these seasons ruderal species were consumed in large quantities. Five years after abandonment of intensive farming species composition is actually dominated by typical grassland species. Many target species have been established either by spontaneous colonization or after introduction by hay transfer and several Red list species could be determined. Even *Cnidium dubium* which is one of the typical species of alluvial grasslands and successful germination is considered a rather rare event (e. g. Kotorová & Lepš 1999) established successfully. On the other hand, the cover value of target species is relatively low except for the permanent plots characterized by permanent wet conditions. That refers to the importance to improve water conditions in the Wulfener Bruch in the future.

Large areas of the megaherbivore pastures have potassium and phosphorous values which are already favourable for restoration of species-rich floodplain grasslands. This is particularly important for phosphorous since floodplain restoration is only successful if plant available phosphorous is limited (Hölzel & Otte 2003). In contrast, after more than three decades of intensive cropping and melioration the carbon content of our studied former arable sites is still low. In addition to the unsuitable water regime in most parts of the

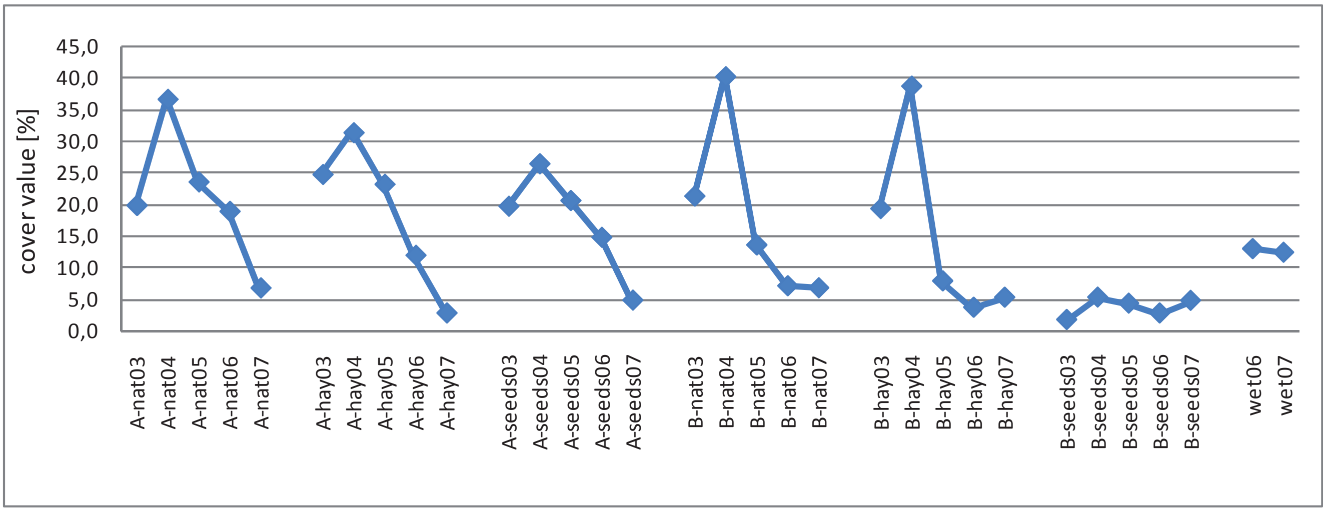

Fig. 3: Mean cover value of Cirsium arvense; A – wet to periodically fresh conditions, B – dry to periodically wet conditions; variants: natural recovery – nat (n = 15), hay transfer – hay (n = 15), seeding of commercial seed mixture – seeds (n = 15); wet – plots with natural recovery on permanent wet sites (n = 12).

Abb. 3: *Durchschnittliche Deckungsgrade von Cirsium arvense; A – feucht bis periodisch frisch, B – trocken bis periodisch frisch; Varianten: Spontanbesiedlung – nat (n = 15), Mahdgutübertrag – hay (n = 15), Ansaat mit Regelsaatgutmischung – seeds (n = 15); wet – Flächen mit Spontanbesiedlung und kontinuierlich guter Wasserversorgung (n = 12).*

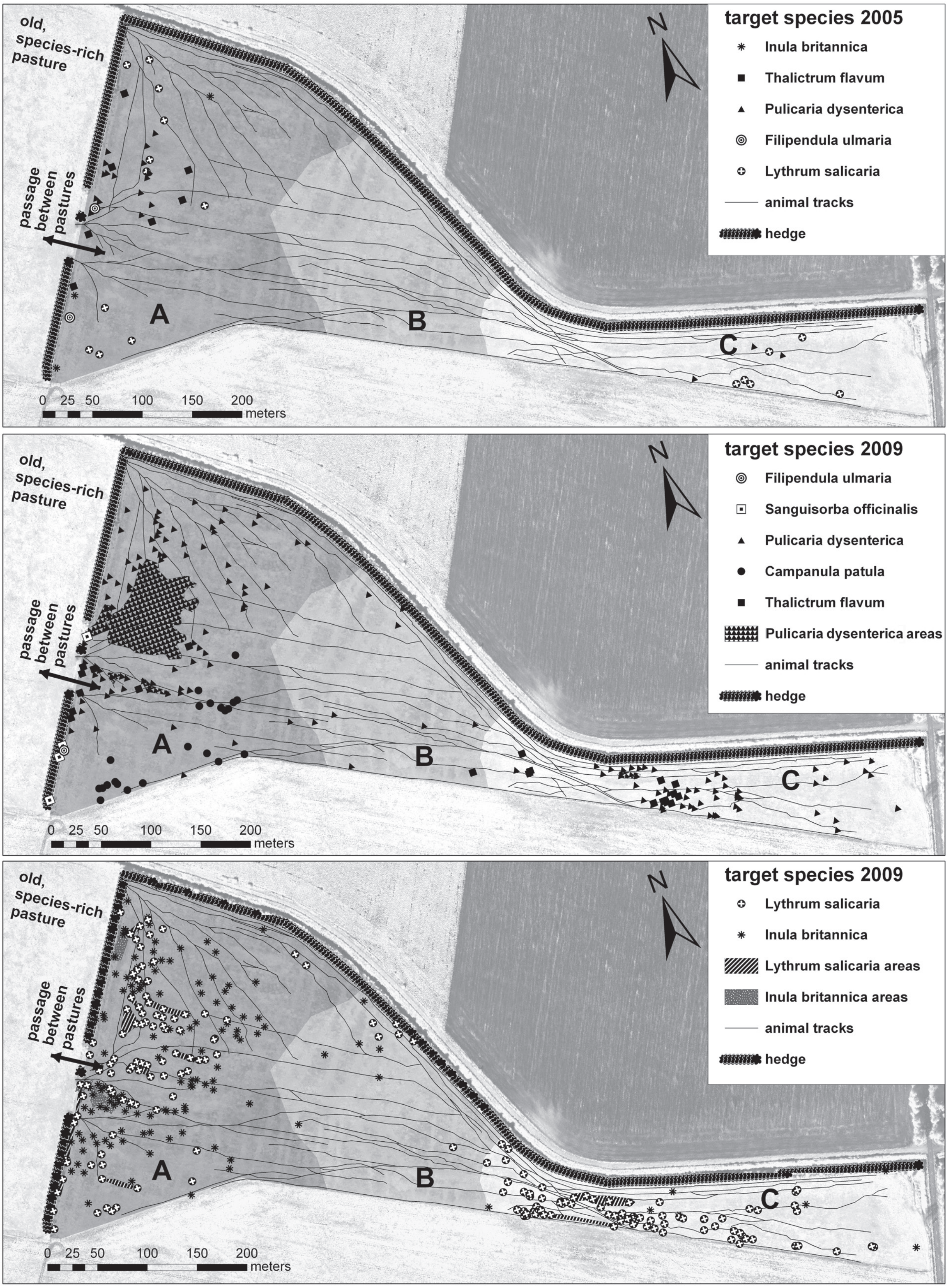

Fig. 4: Colonization of selected target species alongside animal tracks on pastures established on former arable (until 2001) land between 2005 and 2009. On the western edge the new pasture is connected with old species-rich grassland (see arrow). (A & C – wet to periodically fresh conditions, B – dry to periodically wet conditions; data source background map: aerophoto from area inventory 2005. Ministry for Agriculture and Enviroment Saxony-Anhalt)

Abb. 4: *Etablierung ausgewählter Zielarten entlang von Tierpfaden bis zum Jahr 2005 und 2009 auf einer Beweidungsfläche, die bis zum Jahr 2001 ackerbaulich genutzt und seit 2002 beweidet wird. Westlich der Hecke ist die Fläche mit einer artenreichen Grünlandfläche verbunden (siehe Pfeil). (A & C – feucht bis periodisch frisch, B – trocken bis periodisch frisch bis feucht; Datengrundlage Hintergrundbild: Aufnahme aus der Geländeinventur 2005 Ministerium für Landwirtschaft und Umwelt Sachsen-Anhalt)*

Wulfener Bruch that seems to be another reason for the relatively low cover value of target species up to now. Therefore, we conclude that high nature conservation value farmland on former arable land obviously needs time for development even under target-orientated management.

In context of landscape development our Megaherbivore project creates a multifunctional landscape (see also Schley & Leytem 2004). Besides the improvement of biodiversity and structural diversity the extensive grazing regime supports carbon fixation and soil formation. Furthermore a sustainable and high quality meat production had been established at former intensively used farmland. And last but not least, our megaherbivore project achieves best regional acceptance because there is always an opportunity to watch the impressive Heck-cattle and wild horses on the pastures.

4.2 Is it necessary to accelerate vegetation development by transferring species and which effect causes seeding of commercial seed mixtures?

Many studies showed that without species introduction colonization of target species on former arable land proved to be less successful (e. g. Bakker & Berendse 1999, Verhagen et al. 2001, Donath et al. 2007). Hay transfer is obviously the most applied method for transferring species in restoration projects and leads to high transfer rates and the development of plant communities rich in target species (Kirmer & Tischew 2006). In our studies, hay transfer accelerated the development of target species in general. 35 species, which were not able to colonize spontaneously, among them many target species which did not have donor populations in the nearby surroundings, were transferred to the study site. Nevertheless, in the fifth year spontaneously developed sites reached a similar target species-cover.

In contrast to the above mentioned studies our sites were a) connected with sites were many target species have donor populations and b) instead of mowing the sites were managed by grazing. Both circumstances obviously supported the natural recovery of species-rich grasslands. Therefore, in similar situations hay transfer should be applied on selected (rather small) sites to add species which do not have nearby donor populations and subsequently colonization of the whole site can be expected afterwards. That procedure also reduces the relatively high cost for species introduction dealing with large areas (Neuhauser 2001).

In addition special preparation of sites where seed-rich hay is to be applied is recommended to enhance establishment of target species. In our study hay transfer was performed when vegetation cover was already more or less closed with ruderal species and some grasses. That high competitive situation caused high seedling mortality of the target species. Therefore, we recommend for hay transfer experiments to create at least small stripes of bare soil by ploughing or harrowing (see also Donath et al. 2007).

Sowing of commercial seed mixtures led to dense vegetation cover, mainly dominated by the sown species and delayed the colonization of target species. These findings are in line with a study by Vécrin et al. (2002) where ruderal and annual species had decreased three years after restoration, but target species were still poorly represented in the sown grasslands. Commercial seed mixtures are often used because they are cheap and they suppress the development of ruderal species on fallow arable land. However, in addition to the above mentioned negative effects related to delayed colonization of target species there is a risk for bastardization with native flora since non-native species or genotypes are introduced by these seed mixtures (McKay et al. 2005). By using native grass ecotypes in restoration projects of floodplain meadows along the northern Upper Rhine simultaneous sowing of grasses did not hamper seedling recruitment from seed-rich hay in most cases, and thus seems to be a feasible measure to accelerate the integration of newly created floodplain meadows into farming systems (Donath et al. 2006).

4.3 Is there any evidence that megaherbivore grazing supports the colonization of target species into the former arable land?

Seed dispersal via ingestion, defecation or adhesion in combination with the creation of small-scale disturbances caused by hooves prints is assumed to support the colonization of target species in restoration projects (Wessels et al. 2008, Mitlacher et al. 2002, Couvreur et al. 2004). Sheep disperse high amount of seeds in their fleece (Fischer et al. 1996), but cattle and horses disperse orders of magnitude more seeds via dung than via their fur (Couvreur et al. 2004). Mouissie et al. (2005) found that cattle disperse approximately 2.6 Million seeds per animal per year per dung. Seed density in horse dung ranges from 280 to 525 seedlings per litre (Cosyns & Hoffmann 2005). On the other hand, current studies demonstrated that measured germination from dung under glasshouse conditions often over-estimates likely rates of establishment in the fields (Pakeman & Small 2009). Moreover, other studies highlight the potential threat of invasive plant spread, for example weed and grass input into Scottish heather moorland by cattle dung (Welch 1985). Schwabe & Kratochwil (2004) and Süss et al. (2004) emphasize that seed input from non-target communities into target communities caused by migratory grazing negatively affected biodiversity for inland sand ecosystems. Mouissie et al. (2005) showed that in grazing systems with high and low productive parts mainly seeds of common species were dispersed from high productive parts to low productive parts and not in reverse. The authors of that study recommend integrated grazing with only target plant communities and not with plant communities on fertile soils rich in non-target ruderal species as performed in our study. In contrast to these studies we could not find negative effects on species assembly caused by seed input from ruderal species of the newly abandoned fields into the nearby old species-rich pastures although certainly many seeds of ruderal species were consumed by the animals and consequently dispersed by dung. Surprisingly, in reverse many target species from the old species-rich pastures colonized the former arable land. The distribution pattern of target species is strongly connected to animal track pattern. This can be explained by three processes. First of all the old pastures have significantly less nutrient content and therefore ruderal species are less competitive (site-condition filter). Secondly, the year-round grazing by Heck-cattle and wild horses obviously suppressed the establishment of ruderal species on the old pastures. The continuous decrease of ruderal species even on the former arable land supports that explanation. And thirdly, the animals create niches for establishment by producing small-scale disturbances which are obviously particularly needed by the less-competitive target species. Altogether the connection of old species-rich pastures with the newly abandoned arable land proved to be very successful regarding the dispersal and establishment of target species. Gerken et al. (2008) also observed that target species like *Isolepis setacea*, *Peplis portula* and several species of mosses and lichens followed the animal tracks.

4.4. Implications for practice

Our studies show that on former arable land immediate grazing with large herbivores is possible and leads to a successive development of species-rich grassland communities with low nutrient status. The integration of old pastures into the grazing system considerably enhances colonization of native grassland species, especially alongside animal tracks. Seeding of a commercial seed mixture is not only needless, but above all impedes the establishment of native grassland species. The transfer of species-rich hay accelerates the colonization rate of several grassland species, which were not able to colonize the former arable land spontaneously. Nevertheless, rising of the groundwater table is most important for the development of species-rich floodplain grasslands since highest cover values of target species were found on regularly wet sites.

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