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Improving the quality of NATURA 2000 - meadows: the contribution of seed bank and hay transfer

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Abstract
In Central Europe a strong decline of poor, species-rich grassland takes place since 3-4 decades. However, long-term efforts on the (re-)establishment of species-rich meadows on former fields or intensively used grassland often fail or last more than 10-20 years, because of factors regarding content of soil nutrients, seed bank or dispersal. We present two case studies on meadow restoration studying the significance of seed bank and hay transfer for the improvement of SIC-habitats. We found that the seed bank of former fields is poor in individuals and numbers of grassland species, consisting mainly of weed and ruderal species. The seed bank of mountainous meadows is richer in grassland species, which, however, were found also in the present vegetation. Therefore, in concordance with similar studies, the seed bank hardly contributes to the (re-)establishment of species-rich meadows. In SW- and NW-Germany we studied hay transfer on 18 areas to create mesophilous meadows (Arrhenatheretum, Geranio-Trisetetum). In a pilot project 2004 we transferred species-rich hay from a donor meadow to three field areas at Tüllinger Berg. After 2-3 years many grassland species have colonized these areas while the number of weed and ruderal species has continously declined. As already shown for grassland of dry and wet habitats, hay transfer plays an important role also for the (re-)establishment of poor, mesophilous species-rich grassland.

Key words: hay transfer, meadows, re-establishment, restoration, seed bank, SIC habitats.

Riassunto
Migliorare la qualità delle praterie nei Siti Natura 2000: il contributo della banca semi e del trasferimento di fieno. Da 3-4 decenni in Europa centrale si assiste ad un forte declino delle praterie magre polifitiche. Malgrado ciò, i tentativi di ricostituire cenosi prative ricche di specie a partire da campi abbandonati o da prato-pascoli intensamente sfruttati spesso si rivelano fallimentari o necessitano di tempi molto lunghi (più di 10-20 anni) a causa di problematiche quali il contenuto di nutrienti nel suolo e la disponibilità di semi nella banca semi o tramite mancante disseminazione.
Vengono qui presentati due casi di studio relativi al ripristino delle praterie, che analizzano il ruolo della banca semi e del trasferimento di fieno nel miglioramento di habitat erbacei all'interno di Siti di Interesse Comunitario. Dagli studi condotti è emerso che la banca semi dei campi abbandonati è costituita prevalentemente da entità ruderali ed infestanti e risulta povera sia di individui che di specie tipiche delle praterie. La banca semi delle praterie montane appare più ricca di specie tipiche, che sono però presenti anche nella vegetazione attuale. In accordo con indagini analoghe, si deduce quindi che la banca semi può scarsamente contribuire al ripristino delle praterie ricche di specie.
Il presente studio riguarda il trasferimento di fieno in 18 aree della Germania S- e N-occidentale, finalizzato al ripristino di praterie mesofile (*Arrhenatheretum, Geranio-Trisetetum*). Nel 2004, nell'ambito di un progetto pilota, il fieno polispecifico sfalciato in una prateria 'donatrice' è stato trasferito in tre aree agricole a Tüllinger Berg. Dopo 2-3 anni, numerose specie tipiche di prateria hanno colonizzato le aree mentre il numero di entità infestanti e ruderali si è gradualmente ridotto. Analogamente a quanto già noto per habitat aridi ed umidi, è emerso che il trasferimento di fieno svolge un ruolo importante anche nel ripristino delle praterie magre mesofile ricche di specie.

Parole chiave: banca semi, Habitat, praterie, restauro ambientale, ripristino ambientale, SIC, trasferimento di fieno.

Introduction

In central Europe a strong quantitative and qualitative decline of species-rich meadows tooks place since 3-4 decades. This decline is caused by:
(1) the transition into fields by ploughing (cereals, maize, rape and others);
(2) intensification of grassland use: frequent cutting or intensive pasture management with high livestock density, combined with regular application of fertilizers;
(3) drainage of humid and wet meadows;
(4) fallowing;
(5) afforestation;
(6) destruction by building to establish industrial or residential areas.

In this paper we focus our attention on the (re-)establishment of former grassland areas that were managed as fields or intensively used meadows or pastures up to now or that have been abandoned. When intensively managed, species-poor meadows could be enriched in species by mobilisation of the seed bank as well as the promotion of natural and human dispersal vectors (e.g. wind, animals, flowing water; agricultural vehicles). Furthermore it is necessary to reduce the cutting frequency and the fertilisation as they might affect the impoverishment of soil conditions by decreasing the amount of available nutrients, and with this to achieve a more extensive agricultural land use.

However, long-term efforts on extensification and re-establishment of species-rich meadows often show only little or even no success, or the success of any conservation measures might appear only 10-20 years or more later. This fact may be caused by different factors:
(1) Various physical and chemical parameters have been irreveribly changed at the grassland site, e.g. wet sites by drainage (Rosenthal, 1992).

(2) Some nutrients, such as phosphate, nitrogen and/or potassium, show high soil concentrations (see Janssens *et al.*, 1998).
(3) The seed bank is poor in individuals and species (Donelan & Thompson, 1980; Pfadenhauer & Maas, 1987; Gugerli, 1993; Milberg, 1995; McDonald *et al.*, 1996; Bekker *et al.*, 1997, 1998; Thompson *et al.*, 1997; Edwards & Crawley, 1999; Schütz, 2000; Hölzel & Otte, 2001, 2004a; Touzard *et al.*, 2002; Jensen, 2004a,b).
(4) In some grassland species the germination rate in-situ and ex-situ is low (Budelski & Galatowitsch, 1999; Patzelt 1999; Hölzel & Otte, 2004a; Jensen, 2004a,b, and others).
(5) The seed bank can not be mobilised, mostly because of the lack of open soil sites (Bakker,1989; Kapfer, 1996; Kotorova & Leps, 1999).
(6) Additional species can not immigrate, as the donor populations are poor in individuals and/or situated too far from the recipient areas (Bakker, 1989; Tränkle & Poschlod, 1994, and others).
(7) Suitable dispersal vectors, such as grazing cattle or floodings or strong wind events or agricultural vehicles, are lacking (Bakker, 1989; Rosenthal, 1992; Bissels *et al.*, 2004; Vogt *et al.*, 2004).

Aiming at the restoration or new installation of species-rich meadows in two grassland projects (case studies 1 and 2), we concentrate our studies on the following open questions:
(1) Can we rely on a seed bank rich in viable diaspores of grassland species? Or is the seed bank rich in non-target species, mainly ruderals and/or nitrophytes and/or field weeds? Various studies on the seed bank of grassland communities have been carried out, but on some communities detailed studies are lacking (bog meadows) or rare (mountainous meadows).
(2) Is it possible to re-establish former or create new species-rich meadows by using specific methods, like seeding with commercially purchasable seeds, hay transfer, transfer of threshed mown grass or transfer of cut turfs (sods)? In our project "Re-establishment and creation of species-rich meadows – a contribution to nature conservation in intensively used landscapes", we only studied the hay transfer method.
(3) Which grassland habitat types of the Habitat Directive can be improved according to their ecological status and phytodiversity? With respect to their quality, the SIC-habitats are attributed to the quality classes A, B, and C, so that an ecological improvement from C to B and from B to A might be possible by appropriate methods such as hay transfer.

Species-rich meadows of the Habitat Directive in Germany

In our above named project predominantly the following four habitat types of regularly managed grassland ('Wirtschaftsgrünland') are represented:

6210 Mediterranean *Bromus* - *Festuca* - calcareous grassland (*Festuco* - *Brometea*), including 6212 *Mesobromion*, with *Carex caryophyllea, Polygala comosa, Orchis ustulata, Dianthus carthusianorum. Gentiana germanica* and others

6230 *Nardus* - grassland (*Violion caninae*, *Nardion strictae*), with *Thymus pulegioides, Arnica montana, Antennaria dioica, Genistella sagittalis, Leucorchis albida* and others

6510 Extensive, species-rich meadows of the lowlands (*Arrhenatherion*), with *Campanula patula, Pastinaca sativa, Crepis biennis, Geranium pratense, Knautia arvensis* and others

6520 Extensive, species-rich meadows of the mountainous regions (*Polygono* - *Trisetion*), with *Crepis mollis, Geranium silvaticum, Bistorta officinalis, Phyteuma nigrum, Carum carvi* and others

Case study 1: Present vegetation and seed bank in bog meadows

In N-Germany huge areas of natural bogs have been subjected to strong drainage and melioration in the last 200 years. Naturally being very poor in nutrients, the thick peat layers rapidly mineralise after drying up and release big amounts of nutrients. The soils, however, impoverish in their contents of K and/or P after few years, if not fertilised. Bog grassland is often species-poor, the floristic composition being mainly dominated by nitrophytes (if fertilised by liquid manure) or by indicators of poor nutrient conditions and low pH values (if not fertilised). In any case typical species of the orders Molinietalia and Arrhenatheretalia and the class Molinio-Arrhenatheretea are often lacking, while single plant species like *Juncus effusus* (Fig.1), *Holcus lanatus*, *Rumex acetosa* or *R. obtusifolius* may form dense and extended populations. In the project "Re-establisment of species-rich bog meadows by sustainable land use, with particular view on the Soft Rush problems" we study over 5 years a total of 35 ha, divided into 7 management variants each consisting of 5 ha, which are situated at Vrees and Papenburg (NW-

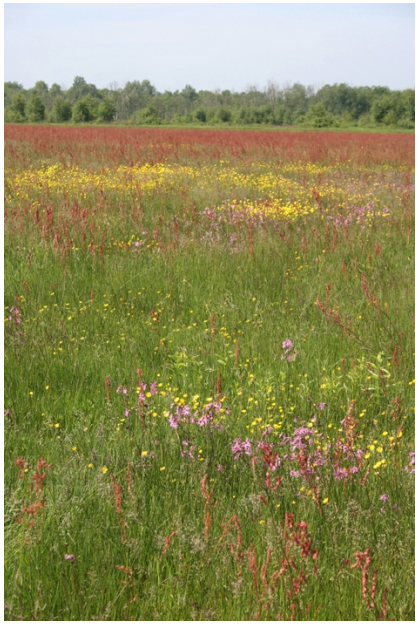

Fig.1 - The Soft Rush (*Juncus effusus*) forms dense tussocks with strong generative and vegetative dispersal; an adult individual is able to produce thousands or tens of thousands of seeds (left)! In some study areas grow species-rich bog-meadows with big populations of *Silene flos-cuculi, Rumex acetosa, Ranunculus repens* as well as various sweet grasses (Poaceae; right)

Germany, Landkreis Emsland). These variants are caracterized by a combination of the following factors: cut or pastured, with or without mulching in winter, fertilisation with PK or liquid manure.
We established 140 large permanent plots of 30 m^2 and 350 small permanent plots of 1 m^2 and studied the general development of flora and vegetation as well as the cover (in %) of the Soft Rush from 2006 to 2010. Furthermore, in spring and autumn 2006 we took 35 soil samples each, to estimate the possible regeneration of species-rich bog grassland with the help of the seed bank.

In the permanent plots we found as most frequent species (frequencies of large/small plots, in %) *Juncus effusus* (98/85), *Holcus lanatus* (72/62), *Poa trivialis* (66/53), *Rumex acetosa* (63/47), *Holcus mollis* (49/40), *Ranunculus repens* (46/43), and *Anthoxanthum odoratum* (43/24). In the seven variants the total number of species extends from 51 to 60, with an average of 56 (Tab.1). Most species (29-36 per variant) occur only in

Tab. 1 - Minimum, maximum and medium numbers of species in the seven variants of the studied bog meadows (Lkr.Emsland); soil samples taken in spring 2006, present vegetation studied in may /june 2006

Number of species per variant:	minimum - maximum (range)	mean
in seed bank	18 - 28	25
only in seed bank	4 - 7	6
in present vegetation and in seed bank	11 - 21	17
only in present vegetation	29 - 36	32
all species (in seed bank and/or present vegetation)	51 - 60	56

the present vegetation, while only few species were found exclusively in the seed bank. The total number of these exclusive seed bank species is 21; from these 8 are ruderals or field weeds or similar, 8 wetland species (e.g. *Juncus bulbosus*, *J. bufonius*, *Ranunculus flammula)*, 4 are species frequent in grassland (e.g. *Taraxacum officinale*, *Carex leporina*) and only 1 is a typical grassland species (*Trifolium pratense*). These results clearly show that the seed bank can hardly contribute to the enrichment of bog meadows with typical grassland species. The species-richest areas are assigned to the habitat type 6510 or to nationally protected meadow types of the alliance Calthion. The majority, however, is species-poor and should be enriched with typical grassland species by suitable restoration methods.

Case study 2: Seed bank of former fields and species-poor meadows and hay transfer from donor to recipient areas

The project "Re-establishment and creation of species-rich meadows by hay transfer – a contribution to nature conservation in intensively used landscapes" aims at the ecological improvement and species enrichment of species-poor meadows and at the creation of new meadows from former fields or fallow areas. This might be facilitated by introducing typical grassland species with hay transfer from a donor meadow to a recipient area. The general objective is to promote the connectivity of species-rich meadows in intensively managed landscapes, that is to reduce the negative aspects of fragmentation and isolation in various grassland types. As a specific aim, the meadow types listed in annex 1 of the Habitat Directive (see above) should be improved with respect to their ecological situation and their floristic composition, and the respective areas should be enlarged so that the present plant populations might stabilize and populations of additional species might settle. With the hay transfer method freshly cut grass is transported from a species-rich donor area to a species-poor recipient area, which is subject to the same ecological conditions, so that as many as possible plant populations which grow in the donor meadow can be tranferred (Fig.2). Together with the cut grass lichens, mosses, fungi are also transferred, as well as animals (eggs, larvae, pupae, and small adults).

Until September 2007 hay transfer was carried out at 8 sites in NW-Germany (Stadt Oldenburg; Landkreise Oldenburg, Wesermarsch, Vechta) and 10 sites in SW-Germany (Stadt Weil/Rhein; Landkreise Lörrach, Breisgau-Hochschwarzwald). Intensively studied are the hay transfer to 4 sites in SW-Germany, two to former fields (Mattfeld, Zienken) and the other ones to former mesotrophic (Gisiboden) or eutrophic (Belchen) grassland. Before the hay transfer the present vegetation consisted to 75-90% (meadows) and 35-65% (fields) of grassland species (Tab.2). The seed bank samples

Fig. 2 - Study area "Mattfeld"(1); donor meadow (2); mowing (3); transport (4); unloading (5); distribution (6) of the cut grass

Tab . 2 - Number of species in the present vegetation and the seed bank of four recipient areas in SW-Germany

study area	former utilization	total no. of species in present vegetation (before hay transfer): total / grassland (%)	total no. of species in seed bank: total / grassland (%)	no. of species in seed bank, but not in present vegetation: total / grassland (%)
Mattfeld	field	38 / 14 (37)	18 / 8 (44)	8 / 3 (38)
Zienken	fallow field	26 / 16 (62)	14 / 6 (43)	8 / 2 (25)
Belchen	fertilized meadow (Polygono-Trisetion)	27 / 24 (89)	14 / 11 (79)	7 / 4 (57)
Gisiboden	mesotrophic grass-land (Nardion / Polygono-Trisetion)	36 / 28 (78)	12 / 9 (75)	4 / 2 (50)

were taken in september 2006. The seed bank is rather species-poor and shows a medium (fields) resp. high (meadows) percentage of grassland species (Neugart, 2007). However, only few species occur exclusively in the seed bank but not in the present vegetation. 25-60% of them are classified as typical grassland species. Like in the bog meadows, the seed bank of the recipient areas with mineral soils is poor and consists to a considerable part of non-grassland species.

As a pilot scheme we have carried out a hay transfer in 2004 to 3 former fields at the Tüllinger Berg (Landkreis Lörrach, SW-Germany), using a species-rich area with *Arrhenatheretum salvietosum* as donor meadow very nearby (Buchwald *et al*., 2006a). Many species from the donor area got established in all the 3 recipient areas, as *Arrhenatherum elatius, Festuca pratensis* et *F. rubra* agg., *Onobrychis viciifolia, Rhinanthus alectorolophus, Vicia angustifolia* and others. Few species were successfully transferred to two (e.g. *Crepis biennis, Holcus lanatus, Trifolium repens)* or one *(Bromus erectus, Lolium perenne, Ranunculus acris* and others) former fields, while some species could not establish themselves in the recipient areas at all (e.g. *Lathyrus pratensis, Prunella vulgaris, Trisetum flavescens, Lotus corniculatus*).

Considering the floristic composition of the recipient areas, we take Tüllinger Berg 2 as one single example. The hay transfer was carried out in july 2004. During the first 3 years (2004-2006) we found a total of 38 plant species before and/or after the transfer. They are divided in three types of origin:

- 12 species had already been found in the former fields: 3 grassland species (*Brachypodium pinnatum, Trifolium pratense, Veronica chamaedrys*), and 9 ruderals/weeds (*Cirsium arvense, Chenopodium album, Elymus repens*, and others)
- 4 species settled spontaneously, that is from seed bank and/or by dispersal: *Amaranthus retroflexus, Daucus carota, Glechoma hederacea, Convolvulus sepium* (all ruderals / weeds)
- 22 species were very probably introduced by hay transfer: all grassland species (e.g. *Sanguisorba minor, Knautia arvensis, Salvia pratensis, Trifolium pratense, Tragopogon pratensis*)

How can we value the measures of hay transfer carried out up to now? We classified the plant species regarding to their value for the species-rich meadow, which we hope to develop with the help of the transferred diaspores: rare grassland species (important target species), frequent grassland species (target species), rare companion species, frequent companion species, and unwelcome ruderals/nitrophytes/weeds (all: non-target species). As an example, we present the numbers of species in the 5 classes named above in the recipient area Austen (NW-Germany, Landkreis Oldenburg). The hay transfer from a species-rich Calthion meadow to the species-poor wet meadow (composed mainly of frequent wetland species and ruderals) was done in july 2006, and the flora was studied in June and September/ October 2006 (Franke, 2006; Buchwald *et al*., 2006b). Before the hay transfer, the majority of the present species was classified as 'target species' (Tab. 3). After 2-3 months we found 3 species probably transferred, all target species as well. However, 20 species settled spontaneously from the seed bank and/or by seed dispersal, from which 2/3 are classified as problematic ruderal or weed species. These results show that 2 to 3 months after the transfer measure 45% of the present flora (n = 44 species) consists of frequent grassland

Tab. 3 - Percentage of five species groups in the study area "Austen"(NW-Germany):probably introduced by hay transfer, or spontaneously from seed bank or by seed dispersal, or not established after 2-3 months

Type of plant species	no. rare grassland species (+++) **= target species!!**	no. frequent grassland species (++) **= target species!**	no. rare companion species (+)	no. frequent companion species (0)	no. ruderals, nitrophytes, field weeds (-)
Percentage of species:					
♦ present before hay transfer (n = 21)	0	71	0	5	24
♦ probably transferred species (n = 3)	0	100	0	0	0
♦ from seed bank and/or **dispersal** (n = 20)	0	10	0	25	65
♦ total (n = 44)	0	45	0	14	40
♦ not established in the recipient area (n = 23)	13	39	17	30	0

species and 40% of ruderals/weeds. Additional 23 species have not been found at Austen in the first year, maybe as they were not transferred or as they did not germinate up to now; future studies will show how many and which of them will be established in the next years.

Conclusions

1. As we showed for bog meadows and mountaineous grassland, the SEED BANK DOES NOT OR HARDLY CONTRIBUTE to the species enrichment of species-poor meadows and to the creation of new species-rich meadows, because of a long-year intensive management as a meadow or field or of long-year lying fallow. A considerable part of the grassland species exhibits a seed bank that is poor in individuals and/or temporary (= short lived).

2. In intensively used landscapes with small and widely isolated habitats effective dispersal vectors are often lacking so that the CONNECTIVITY OF SEMI-NATURAL HABITATS like species-rich meadows must be promoted by specific programs.

3. HAY TRANSFER IS A USEFUL METHOD to improve the quality of protected habitat types (annex 1 of the Habitat Directive), mostly more effective and less expensive than other methods (transfer of threshed grass, application of bought seeds, transfer of sods). Until now we were successful at re-establishing or newly creating species-rich meadows, predominantly of the alliances *Arrhenatherion* (habitat type 6510) and *Mesobromion* (habitat type 6212); however, we hope to be successful also with the habitat types 6520 (*Polygono-Trisetion*) and 6230 (*Nardion, Violion caninae*) as well as *Molinietalia* meadows.

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