Seeds from semi-natural grassland as a source of biodiversity improvement

Krautzer, B.[1], Kirmer, A.[2], Haslgrübler, P.[1], Graiss, W.[1]

[1)]AREC Raumberg-Gumpenstein
[2)]Hochschule Anhalt

Summary
The conservation and maintenance of bio-diversity on agriculturally used areas has become a special concern of agrarian- and environmental policy. Therefore, restoration projects with the objective of creating semi-natural grassland, have obtained increased importance throughout Europe in recent years. Procedures that are as close to nature as possible have gained special significance. Species-rich semi-natural grassland is the only existing natural source to provide the restoration with regional seed mixtures. In recent years, a large number of different harvesting methods and application techniques have been developed for exploitation and application of seed and plant material of regional semi-natural grasslands. To ensure and to guarantee its use according to nature protection targets throughout Europe, binding European guidelines and an approved certification procedure for such material have to be developed.

Introduction
All over Europe, agricultural intensification and, on the other hand abandonment of large areas, led to a strong decrease in biodiversity (Pötsch & Blaschka, 2003). The 1992 Rio de Janeiro Convention on Biological Diversity and the recent EU regulations promote the protection of biodiversity and demote the strong biodiversity decrease in Europe. To implement this aim, the availability of regional, native plant material is of extreme importance. This requirement is not sufficiently met in Europe, where seed of native ecotypes is still seldom available at large amounts. Extensively managed semi-natural grasslands can be regarded as the most important seed source. They are normally rich in species of native provenance and for this reason can be harvested to obtain valuable seeds useful for restoration and revegetation. The typical high diversity of semi-natural grasslands in species and site conditions is their strong point but, at the same time, they pose the main challenge for an economically efficient harvesting. Moreover, the normally used techniques to create forage meadows or to re-vegetate degraded areas with the help of commercial seed mixtures are not comparable with ecological restoration done with seed material from semi-natural grassland.
As a main target, the project "Semi-natural Grassland as a Source of Biodiversity Improvement" (SALVERE) intends to contribute to the practical realisation of EU regulations regarding biodiversity by utilising semi-natural grasslands as potential donor sites of seed to be used for the establishment of HNV areas (SALVERE 2011). Based on experiences made and information gained within this project, the current state of the art in the selection of donor sites, the exploitation of seed material, techniques and know-how for the establishment of semi-natural grassland as well as existing and still necessary regulations is given in the following paper.
Currently, 76 % of grasslands of European interest are assessed as being in an unfavourable conservation status (EU2010 Biodiversity Baseline Report). Therefore, the protection of natural grasslands containing regional sub-species and ecotypes in region-specific compositions is of top priority in nature conservation. To reach this goal, not only the high ecological and aesthetic values of species-rich grasslands should be acknowledged but also their potential as donor sites for regional seed mixtures.
In general, restoration of species-rich grasslands is limited by several abiotic and biotic constraints. The success of restoration measures depends on abiotic factors such as nutrient status, pH-value of soil, and hydrology as well as the availability of appropriate seed sources. Hence, restoration success is impeded by depleted seed banks of restoration sites, decrease or loss of target species in the surroundings and limited dispersal in fragmented landscapes. Early restoration efforts in the 70s and 80s were mostly focused on the removal of nutrients, re-wetting and the re-introduction of an adequate management. In many cases such

measures alone were frustratingly unsuccessful and did not lead to the re-establishment of target communities even after successful lowering of nutrient levels and productivity (Bakker & Berendse 1999). Therefore, the introduction of target species is of decisive importance for restoration success. Seed mixtures directly harvested in genuine, natural grasslands can be used in ecological restoration thereby contributing to the preservation and enhancement of regional bio-diversity. Since the 1990s, different methods for ecological restoration have been used successfully by several working groups all over Europe (Reviews see Walker et al. 2004, Kirmer & Tischew 2006, Klimkowska et al. 2007, Kiehl et al. 2010).

The most important grassland types and their suitability as donor-sites

Seed mixtures should be harvested in species-rich grasslands containing a species composition typical for the selected target community and for the concerned region. It is decisive to choose donor and receptor sites with similar site conditions (hydrology, substrate, nutrient status) to ensure that the plant species are optimally adapted to local climatic and edaphic conditions. Especially hydrology and nutrient status are decisive parameters to determine suitable donor communities:

- dry, nutrient-poor to mesotrophic sites: dry grasslands (Bromion)
- moist, mesotrophic sites: mesic grasslands (Arrhenatherion)
- wet, nutrient-rich sites: eutrophic floodplain grasslands (Deschampsion)
- wet, nutrient-poor sites: oligotrophic floodplain grasslands (Molinion) and fen grasslands

Criteria for the selection of donor-sites

The main obstacle for the implementation of near-natural re-vegetation methods is the identification of suitable donor sites for seed harvesting. For example, in 2003 the first donor site register of Germany was installed in Saxony-Anhalt (www.spenderflaechenkataster.de). The internet-based database comprises open habitats and grasslands with high nature conservation value, suitable for harvesting seeds and seed-rich plant material. The internet-based database offers users multiple research functions for finding suitable donor sites, e.g. a general map and a search module. The donor site register allows a quick assessment of the suitability of potential donor sites according to nature conservation values and economical aspects. Registered donor sites must fulfil specific criterions:

- representative species composition (typical for the vegetation type and the region)
- low amount of problematic species (neophytes, strong competitors)
- not established or modified with standard seed mixtures containing cultivars from propagation
- ± regular management (preferably mowing)
- no change of use expected

Such a data base enables an efficient inquiry about suitable donor sites and facilitates planning and realization of nature-oriented greening measures (e. g. harvesting of seeds via mowing, threshing, brushing, vacuuming). The use of species-rich donor sites in restoration or re-vegetation measures supports habitat protection, protects the biological diversity and preserves the floristic and genetic identity of the region.

Harvesting methods for site specific seed and plant material

The optimal harvesting time is when most target species have set seeds. In Arrhenatherion communities, a first harvest can be done between end of June and end of July. If the site was mown in early May, the harvesting cut can be delayed until the end of August. Bromion communities are harvested best between mid of July and beginning of September. Seed harvest in Molinion and Deschampsion communities should be done between end of August and end of September because of late fruiting target species (e.g. *Cnidium dubium*). An additional harvesting cut in May is recommended to transfer early flowering species (e.g. *Cardamine spp., Ranunculus spp.*). In general, a later and/or second cut favours the transfer of herbaceous species whereas an early and/or first cut favours grasses. If harvesting time and method are different to the normal management regime, the site should not be harvested every year.

A lot of different harvesting techniques, partly well known since centuries, partly developed during the last decades, are used for the exploitation of regional plant and seed material (Kirmer & Tischew 2006, Krautzer & Pötsch 2009, Kiehl et al. 2010). The most common processes and methods are summarised below.

A widely-used method is the mowing of suitable donor sites at the time when most of the desired species are at an optimum stage of seed maturity (June - August). To avoid excessive seed losses, the material is cut preferably early in the morning when it is moist with dew and then immediately taken to the restoration area (receptor site) for distribution. Another possibility is to dry and store the mown material for later use. Nevertheless, this method requires increased manipulation and therefore higher costs. In additional, a large part of the seed material may be lost (ÖAG 2000). The hay-flower sowing method uses seed-rich remains from threshing floors in hay barns, which sometimes keeps sufficient seed quantities and qualities.

With brushing and threshing methods (Jongepierova et al. 2007, Scotton et al. 2009) site-specific seeds can be collected from suitable donor sites. To obtain the greatest possible number of mature seeds from the preferred species particular attention has to be paid to the harvesting time. Seed mixtures with highest species diversity are generally achieved by consecutive harvesting of donor sites according to species-specific seed maturation rates and schedules. In the Alps for example, seed yields are usually between 50-150 kg ha^{-1}. The relationship of donor area to restoration area thus varies from approximately 1:1 to 1:4. If application of threshed seed material is not possible immediately after harvest, it must be dried and stored at a dry location.

A good method that is currently practised in several countries is the nursery or large-area production of seed of suitable species with agricultural and horticultural techniques. Above all, species used often and in large amounts can be produced at comparatively reasonable costs and implemented on appropriately large project areas. This method, for example, has been used successfully in Austria, Germany and Switzerland for restoration projects (Krautzer & Wittmann 2006, Kirmer & Tischew 2006). Similar approaches are now being implemented in the French Pyrenees, in Iceland and latterly in Norway.

In cases of land use change, the transfer of seed- rich top soil (mainly the first 5-max. 20 centimetres) from suitable donor sites is an occasionally used method, especially in case of technical interventions (e.g. road construction, landscaping). Another possibility is the transplanting of turfs, whereat soil-plant segments from donor- to restoration sites are being transferred. Wherever possible the transplanting of turfs should take place as early as possible at the beginning of the vegetation period or after the start of the autumn vegetation pause, thus just after the melting of snow or directly before the onset of winter. With proper planning, grass turfs from building and construction sites can be directly transferred to restoration sites without intermediate storage (Krautzer & Klug 2009).

Quality of native seed material

Exploitation, production and trade of regional seeds without any common rules lead to an unmanageable market for consumers. Wild forms compete against cultivars of the same plant-species. Among declared "wild seed products" one will find a wide range of labels as certifications, assertions, documented provenances and qualities. On behalf of nature conservation a system of rules is needed in order to support transparency on an European wild species seed market. On the other hand, seed consumers expect some minimum thresholds for quality aspects related to the composition of harvesting or propagation material, the concentration of pure seeds in harvesting materials and their germination capacity. Therefore, also a sufficient declaration on such quality aspects is important if native seed material is offered on the market.

Quality in terms of nature conservation

The idea of trading wild seeds is due to the consideration of a regional limitation of introducing wild plants as a crucial point of genetically adaptation. The commercial seed market offers several interesting species suitable for restoration, but they are generally to be described as being of non-local provenance. Through negative interaction with still available local provenances their introduction may lead to

undesired results such as hybridisation or displacement (Kirmer & Tischew, 2006). Only harvesting material and seeds collected, propagated and used in the same region ensure ecosystem services which will not be provides by cultivars and non-local propagation material (Blaschka et al. 2008). Therefore there is a need to define biogeographical regions to fulfil those benefits.
However, in Germany, Austria and Switzerland a sufficient definition of seed zones already exists (VWW 2011, REWISA 2011, CPS 2009). One of the most important aspects is the non-conformance of those biogeographical boundaries with political ones! However, a well-defined national system of seed zones is inadequate when transnational trade occurs. Nowadays, the defined regions end at the borders of the member state, even though the physiographic province extents into the neighbouring country. A basis for a (still missing) international definition of European biogeographical regions could be the already existing system at the European Environment Agency (Eea 2009). However, for a functioning European market-system with a regional supply of wild-seed, transnational zones for production and use of native seed material have to be defined.

Quality in terms of consumers' expectations
Contractors are interested to get sufficient information about the quality of sowing material, especially in terms of seed proportion and germination capacity. Corresponding data is particular in demand for large scale restoration projects and trade. The viability or cost-effectiveness of the necessary assessments has to be proven from case to case.
The actual number of seeds in fresh green hay, hay mulch, stripped material or threshings as well as the expenditures connected to the exploitation of the material is dependent on various factors, such as the type of meadow, management, time of day, harvesting time in the course of the year, potential seed production and mechanisation (see Table 1).

Table 1. Share of grasses and herbs, amount of harvested seeds and expenditure of time for differing harvesting methods in Arrhenatherion and Molinion communities (expenditure for drying and cleaning is not included)

Harvesting method	Harvest time	Grasses:Herbs [%]	Pure seeds harvested [kg/ha]	Duration [h/ha]
Fresh green hay	End of June	80:20	100-200	1-2h*
Hay mulch	End of June	70:30	40	3-4h**
Threshing (plot thresher)	End of June	80:20	60-150	5-10***
Threshing (large thresher)	End of June	60:40	50-200	1,5-3*
Stripped seeds	End of June	80:20	20-60	1,5-3***

*depending on technical equipment; **including work processes for the drying of hay; ***depending on vegetation type

The species number and the composition of the harvested material are strongly depending on the type of vegetation. Another influencing factor is the harvesting date. Later harvesting generally deceases the share of grasses in the mixture and thus fosters the establishment of herbaceous species. A harvesting date set too early hinders the full development of the seeds.
The assessment of purity, thousand-seed weight and germinating capacity of seed material harvested on donor sites is very complex and costly. Therefore, such information in practice will only be collected if the material is sold on the market or used at large scale. However, determination of the purity of the harvested seed- and plant materials is important to ascertain the volume of pure seeds that are contained in the material, which then defines the actual seed capacity of the entire material. The composition and quality of hay, hay mulch, stripped material or threshings differs greatly from year to year. The share of chaff and impurities, such as earth, can be very high.
Assessments on the germination capacity of harvested material are still in progress. First results from the SALVERE-project group indicate germination capacities between 40 and 70% from Arrhenatherion meadows. On meadows with a high share of species with seed dormancy (e.g. litter meadows), the actual germination capacity of harvested seed material can decrease notably (Haslgrübler 2011).

Site preparation on receptor sites

A first step in grassland restoration and establishment and an important factor for restoration success is the site assessment and site preparation on receptor sites, thus creating optimal conditions for germination and establishment of introduced species. The special demands and threats of the habitat to be created in terms of soil properties, nutrient supply, erosion tendency, competition phenomena with other plant species, sowing- and planting time, availability of the seed- and plant materials, etc., are to be determined as exactly as possible (ÖAG 2000). Therefore, the choice of proper techniques for harvesting and application of species rich grassland requires an assessment of the main factors of natural geographic region, climate, soil, erosion risk and other possible restoration targets (e.g. agricultural utilization, use as recreational area).

Site preparation in terms of regenerative measures

For successful species introduction into species poor grassland, the sward has to be cut down to a height of 3-5 cm, if necessary. Afterwards, the sward has to be opened subsequently. For large area treatment, the use of curry comb, harrow, rotary hoe or flail chopper is recommended. During the last years, different specialised machinery for grassland regeneration has been developed and is available in grassland dominated areas. Several assessments showed that the stronger the intervention and disturbance of the sward, the higher the rate of successful species establishment (Walker et al. 2004).

Site preparation of arable land or ploughed grassland

The turning of the soil via ploughing or rotary hoeing is the standard method for the restoration of former intensively utilized grassland or arable land. Those soils are generally characterized by a high concentration of plant available nutrients. One simple but time consuming method to impoverish the soil is a one- to two years lasting crop production without any fertilization.

Especially restoration areas formerly used as arable land can potentially contain an enormous amount of weeds. Timely harrowing of soil under dry conditions fosters the accumulation of annual weeds which can then be combated mechanically with several times of harrowing or grubbing before sowing. In humid regions, dry weather conditions are especially necessary for success when using these measures. In more continental regions with low precipitation, the germination of weeds from the soil seed bank may depend on moist conditions after grubbing. If those recommended methods of mechanical weed control are not applicable, the use of low persistence herbicides (e.g. Glyphosate) could be considered (Pyvell, 2007).

Sites with very nutrient- and weed-infested topsoil (above all soil from arable land) can be very positively influenced by preliminary deep ploughing or topsoil inversion. To be used here could be a so-called trench excavator (deep plough), which requires a very powerful tractor. Thus the soil will be turned over to a depth from 40 to a maximum of 80 centimetres. Nutrient- and seed-rich layers are replaced and nutrient-poor substrate is turned up. The use of a trench excavator is not always permitted (e.g. Federal Soil Protection Act in Germany).

Site preparation after technical intervention

Many receptor sites requiring subsequent restoration are created through infrastructural interventions. Ground work (soil removal, intermediate storage and creation of an appropriate substrate layer) must only be carried out when the soil is suitably dried and during appropriate weather conditions. Soils with a clay content of over 30 % are especially prone to soil compaction and are to be handled accordingly with care. The general decision on the re-use of the topsoil-layer respectively its thickness will depend on the content of nutrients and/or seeds of weeds and unwanted species. The extent of the applied soil layer, the space in which roots can penetrate, the water-storage capacity and the nutrient content of the substrates can be appropriately assessed during planning and adjusted according to the desired type of vegetation (or vice versa).

Establishment of semi-natural grassland

Practically relevant restoration of semi-natural grassland has been successfully realised on the most differing sites for many years in different European countries (examples given in Kirmer & Tischew 2006, Donath et al. 2007). The selection of a suitable method depends on the given aim (e.g. erosion prevention, development of extensive vegetation, compensation measures) and the site conditions of the receptor site. To be generally selected is the restoration method with which the desired target community can be developed with the least possible expenditure. Availability, practicability, costs, possible subsequent use and maintenance are to be taken into account. Fundamentally the method should be adapted to the particular areas of origin to take into account climatic conditions and also the life cycle of insects, which are adapted to the regional blossoming period and special content material of plants local to an area. A lot of successful techniques and strategies for the establishment of semi-natural grassland have been developed during the last years. The use of seed-rich top soil or plant material from donor sites is in practice reduced to the rare situations where valuable donor sites are destroyed during construction work.

Under moist climate as well as in mountainous areas, restoration with seeds or seed mixtures should take place at the beginning of the vegetation period to make optimum use on the one hand of the winter moisture on dryer sites, and on the other hand to guarantee development of the seedlings into plants capable of surviving the winter during the vegetation period. But in principal the application of extensive grassland areas throughout the entire vegetation period is possible, whereby persistent dry periods (e.g. in high summer) can lead to failures. In practice the time of restoration is generally in late summer to early autumn because in that period construction measures are to a great extent completed. According to the author's experience, moist conditions and deep topsoil applications favour the development of grasses whereas herbs have an advantage on nutrient-poor and dry sites.

Many species of the extensive litter meadows (fen meadows, litter meadows, etc.) are so-called frost germinators. Therefore with these types of vegetation sowing in winter has proved successfully, whereby the seed must be sown from the middle of November to the beginning of December as long as the soil has no snow cover (Krautzer & Klug 2010).

Restoration success

Semi-natural, species-rich grasslands are generally created over a very long period through extensive forms of use. Achieving the strived for target state is therefore only possible through appropriately adapted utilization over a long period, sometimes after a decade or even longer. It is important that in the first year following the application as many grassland species as possible are regularly germinated and young plants are to be recognised. Some types of grassland species will appear only in the second or third year after the application or become visible even later because their seeds have a distinct dormancy or the young plants are very difficult to find. But on no account a high share of problematic species, such as common couch grass, creeping thistle, dock species or white clover should be visible. The cover of grasses should generally be not too high, and before the first cut not exceed 40 % to 60 %. The share of various functional groups should also be in a balanced ratio (grasses, legumes, other herbs). For most vegetation types, the vegetation cover should have achieved 40 - 60 % after the first vegetation period, depending on vegetation type, to guarantee a receptor state. If this is not the case, subsequent sowing is required

With increasing development time, the degree of cover derived from target species and the increasing similarity to the reference- or target state is decisive for success of the measures. The success of sowing (restoration) is decisively influenced by conditions on the receptor area. In the first year after the application, according to vegetation type (moist meadows, litter meadows, semi-dry grassland) the transfer rate is about 30-50%. On raw soil the transfer rates are generally higher and can reach 60% in the first year after the application. The transfer rate is dependent on differing factors e.g. quality of the seed, soil preparation, site conditions, weather after the application, natural seed potential of the soil (weeds) and restoration method

Regulations and implementation in Europe

To protect the market for licensed varieties, the important fodder plant directive was launched in 1966 (EEC 1966). With some amendments it is today the main directive, which causes problems between many national nature conservation laws and those for seed breeding protection. In 2010 a new Commission directive has been passed, which approves the trade of a small amount of 5% of "wild" seeds among the cultivars. The European member states have to implement the directive until the end of November 2011 (EEC 2010). This moment at the latest is the start of a competition in trade between wild seeds and cultivars. There are only few points in the new directive supporting the use of wild forms but many formal conditions, like detailed registrations and declarations of every single mixture which will hamper the development of a wild seed market. To improve the situation of semi-natural grassland in all European member states, it is inescapable to start activities according to those directives, like carefully implementation in national laws to protect initiatives dealing with native seeds in the process of emerging. Member states as well should start to influence the lately started process of a review of the European seed legislation. On national level, only Germany adapted its nature protection law in view of the harvest, propagation and trade of native seeds (BNatSchG 2010).

Prospects for the future

Semi-natural grasslands are the most important category of High Nature Value Farmland and provide a high level of bio-diversity. Due to land abandonment and intensification this type of grassland is strongly endangered, the maintenance and development of semi-natural grassland has therefore become a special concern of agrarian- and environmental policy. Semi-natural grassland can also be used as a natural source of bio-diversity for different purposes and can itself contribute to the development and restoration of High Nature Value Farmland.

Ecological restoration of semi-natural grassland is a relatively new field of activity, and as a result there are still considerable gaps in our knowledge and know-how. Approaches to the technical aspects vary considerably, and the development of special restoration methods, especially for extreme site conditions, is partly far from sufficient. The legal standards and requirements also vary greatly from one country to another. What is commonly accepted or promoted in some countries is strictly forbidden in others. Above all, despite prohibitions and restrictions written into various nature-protection laws, the use of non-native plant species is often ignored or overlooked due to lack of the knowledge about alternatives or ability to properly identify plant material being offered for sale or used on site. There is also a considerable lack of information among the authorities concerning what became technically possible during the last years. According to the subject, the European environmental legislation seems to bet the right address to implement rules for seed supply intended for use in nature conservation. If there is no political majority for being taken over into a European directive, there is at least practical use to launch just a recommendation for a regional wild seeds market on the European level.

However, the drawing up of binding European rules for the origin, quality, exploitation and establishment of semi-natural grassland as essential part of the High Nature Value Farmland concept is urgently needed.

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