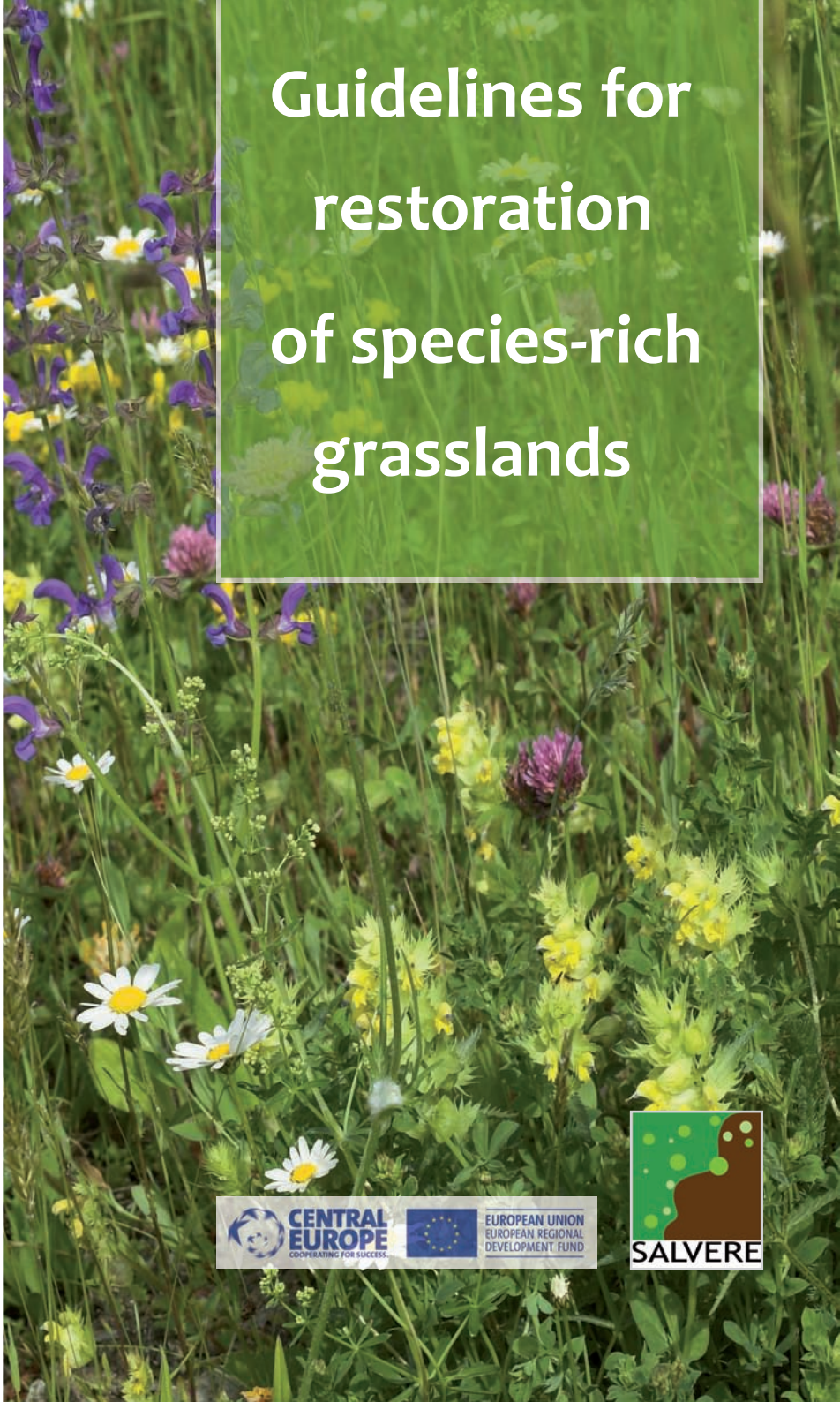
Guidelines for restoration of species-rich grasslands



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Content

Introduction

Restoration of semi-natural grassland has been successfully realized on many differing sites for many years all over Europe. Restoration success strongly depends on different factors: suitable site preparation of receptor sites, selection of the optimal restoration method and target community, and the implementation of a proper management. Using seeds of regional provenance for the establishment of species-rich grasslands contributes to the enhancement of the biological diversity in the region. The developing species-rich grassland can fulfil several ecosystem services such as water retention, carbon sequestration and oxygen production. In addition, species-rich grasslands are an important part of our cultural heritage, enriching the quality of life in the region. For further information see Scotton et al. (2012).

Site preparation of receptor sites

A first step in grassland restoration and establishment, and an important factor for restoration success, is the site assessment and site preparation of receptor sites. For successful species introduction into **species-poor grassland**, competition with already existing vegetation must be decreased with specialized machinery (e.g. curry comb, harrow, rotary hoe, rotary strip seeder, flail chopper). Complete destruction of the sward can be reached via ploughing. Several assessments showed that the stronger the intervention and disturbance of the sward, the higher the rate of successful species establishment.

Turning of the soil via ploughing or rotary hoeing is a standard method for the restoration of **former arable land**. These soils are generally characterized by a high concentration of soil phosphorous or other nutrients. One simple but time consuming method to impoverish the soil is a one to two years lasting crop production without fertilization. Sites with very high nutrient- and weed-infested topsoil can be very positively influenced by preliminary deep ploughing or topsoil inversion. Nutrient-rich soil layers are buried and at the same time nutrient-poor substrate is turned up. Deep ploughing or topsoil inversion can be restricted by soil protection laws. Timely harrowing of soil under dry conditions fosters the germination of weeds, thus depleting the soil seed bank which can then be controlled mechanically.

Especially on **uniform, exposed areas and raw soil with extreme site conditions** (e. g. in mined areas), restoration success can be improved by the creation of safe sites for germination and establishment. Besides structuring with troughs, a rough surface can be formed with large stones or vegetation fragments (grass sods, bushes, etc.). Sowing of nurse plants or application of a mulch layer can also facilitate colonization and establishment of introduced species.

Selection of restoration method and target vegetation

The selection of a suitable restoration method depends on the given aim (e.g. compensation, nature conservation, erosion prevention, recreation) and the specific starting conditions (raw soil, arable land, degraded grassland). Availability of machines and material, practicality, costs, possible subsequent use and expected maintenance must to be taken into account. The selection of appropriate target vegetation also depends on the specific site conditions, especially nutrient status and hydrology, but moreover on specific restoration targets.

For compensation measures and restitution of Natura2000 sites and nature conservation areas specific plant communities of high nature value must be established. The use of regional material of high quality regarding the number and share of target species is mandatory to develop plant communities with a typical species assembly. For this purpose, directly harvested seed mixtures from nearby donor sites with comparable site conditions are most suitable.

If restoration aims at the restitution of landscape functions (e.g. biotope connectivity, habitats for animals), the developing vegetation must fulfil specific needs (e.g. for target animals), thereby contributing to the enhancement of biological diversity and biotope connectivity in the region (e.g. field margins). To reach this goal, suitable target plant species and communities must be selected, with restoration material coming from donor sites in the region or from regional seed propagation.

If re-vegetation follows infrastructural interventions, it must be ensured that site-specific species from regional provenance and propagation are used to protect regional ecotypes and sub-species and guarantee fast vegetation development and erosion control. In this case, it is not necessary to focus on the establishment of rare and endangered plant species.

If restoration aims on recreation and enhancement of quality of life, the main focus should lay on aesthetic demands (rich in flowers, diverse in structure) and low maintenance costs, but it must be ensured that site-specific species are selected and seeds from regional provenance and propagation are used.

Description of restoration methods

Sowing seeds and seed mixtures

Seed mixtures can be composed of agriculturally produced individual species or mixtures obtained through threshing, stripping or vacuuming directly from natural vegetation. The seed rate (related to the available pure seed in the restoration material) should be between 2 and 5 g m^{-2}. Even with extreme site conditions (e. g. mined areas), the recommended seed rate shows very good results. On extreme sites in high mountains, the sowing rate may be increased to up to 15 g m^{-2}. Impure seed mixtures can be sown with an amount up to 25 g m^{-2}, whereby the actual amount of seeds used should range within 2000 to 5000 seeds per m^2.

Seeds should only be sown on the surface and not worked in. Afterwards, they can be fixed to the soil through final rolling with a corrugated roller (prismatic roller, Cambridge roller, etc.).

In the case of manual or hydro-sowing, corrugated rollers also can be used before sowing to create a structured surface. Sowing of seeds and seed mixtures can be realized with the following techniques:

- Manual sowing
- Sowing by means of sowing and spreading devices
- Over-sowing
- Rotavator sowing
- Wet sowing or hydro-sowing

Spreading seed-rich biomass

Apart from spreading a layer of mulch for the purpose of erosion protection, the main aim here is the transfer of seeds contained in hay. Thus, the volumes necessary for restoration are calculated primarily according to the seed content of the fresh or dried hay. Assessment is not easy especially with fresh cuttings, because the amount of seeds is dependent on the type of vegetation, time of harvesting and seasonal weather conditions. Additional sowing with a mixture of site-specific seeds from regional propagation is recommended when the seed content is low or target species are missing.

The ratio of the donor area to the application area is dependent on biomass production, seed content and erosion risk. It varies between 1:2 (e.g. vegetation with high biomass production and high seed content) to 8:1 (low-growing vegetation with low coverage, e.g. dry grasslands). On areas endangered by erosion or desiccation, 1-2 kg of fresh biomass per m² (= application height 5-10 cm) is recommended.

Because the seed potential in green hay is usually very high, the amount can be reduced to 0.5-1 kg of fresh biomass m^{-2} (application height 3-5 cm) on areas not endangered by erosion. If fresh material is used, it adheres to the surface when it is drying. Hay on the other hand must first absorb moisture (rain, dew) and subsequently dry on the surface. In general, fine material should be spread in shallow layers, because putrefaction processes can otherwise set in. Differently harvested seed-rich material can be used in restoration:

- Green hay
- Hay
- Hay-flowers
- Raked material

Special techniques for protection against erosion and drying out

Sown areas can be protected against wind and water erosion as well as desiccation with various organic materials, such as green hay, hay or straw, that are as seed-free as possible. A significant protection effect is the reduction of the kinetic energy of raindrops.

The quality of the mulch materials, especially the carbon/nitrogen (C/N) ratio, plays a decisive role for plant development. Above all on nutrition-poor soils, structurally-rich, long-stalked material with a similar C/N ratio (e.g. herb-rich meadow cuttings) is more favorable than, for example, straw, because nitrogen is used by micro-organisms when the straw decomposes and is not available to the developing vegetation. With the use of straw layers on nutrition-poor soils, the addition of a slight amount of organic fertilizer is thus recommended to enable optimum vegetation development. If on the other hand fresh green hay or hay is used, the establishment of the germinating seedlings is fostered through nutrient release through decomposition. Moreover, microorganisms and small animals are transferred, which promote the organic material cycle and development of the soil.

For optimum growth, the depth of the mulch layer should not exceed 3-5 cm. Thick mulch layers enhance the growth of grasses and impede the development of many herbs. The ideal spreading volume is 500-700 g dry weight m^{-2} in dry climates, and 300-500 g dry weight m^{-2} in moist climates. In general, the following methods can be recommended as protection against erosion and drying out:

- Mulch sowing (cover sowing)
- Mechanical mulch sowing
- Cover-crop sowing, nursery sowing
- Mulch sowing with the use of organic biodegradable geotextiles
- Winter sowing

Restoration with site-specific plant materials

Planting of individual species or the use of turfs and overburden is generally more extensive and therefore cost-intensive than, for example, hay transfer or mulch sowing. But with critical site conditions, it offers the advantage of a shortened development time and skips the especially sensitive germination and juvenile stages:

- Planting of individual species
- Grass sods/turfs
- Sod rolls
- Spreading of seed-rich topsoil

Natural succession

Areas not endangered by erosion and connected to potential seed sources are colonized depending on site conditions and spontaneous successional processes. Important is the selection of suitable areas, which in respect of size, location, substrate and relief heterogeneity, as well as spatial and/or functional connection to seed sources, permit a specific degree of influence on the direction and speed of development. On nutrient-rich sites with appropriate contact vegetation, it must be constantly ensured that problem species (e.g. invasive neophytes, strongly competitive ruderal species) are not allowed to spread uncontrolled into the areas. Through a combination of active species introduction and spontaneous colonization processes (“free power of nature”), structure- and species-rich vegetation can develop, especially on nutrient-poor or raw soil.

Management after restoration

Restoration is not only the initial set of interventions on the surface to be restored, but a more or less lasting, active process. In general, we have to distinguish between the establishment phase and the regular management of the sites. Proper management during the establishment phase is mandatory for restoration success. During the first months/years after the initial intervention, management must aim at facilitating establishment and spread of species sown and on achieving an effective anti-erosion cover on sites prone to erosion.

Management during the establishment phase

During the establishment phase, a combination of mowing and subsequent grazing, as well as year-round grazing, can enhance establishment and spread of target species. On newly created grassland sites, grazing must wait until sufficient soil consolidation is reached. This may be 1-2 years after implementation depending on site conditions and weight of the grazing animals. If invasive neophytes (e.g. *Impatiens gladulifera*, *Solidago canadensis*, *Fallopia sachalinensis*, *Bunias orientalis*) or other unwanted plants are immigrating into the sites, specific management is necessary: single plants can be removed by hand, small patches e.g. by covering with a black foil. Ultimately, selective spraying with an herbicide (glyphosate) may be taken into consideration.

In establishing species-rich grasslands on **nutrient-poor raw soils**, management efforts at the beginning of development are usually low compared to nutrient-rich and weed-infested former arable land. Mowing is recommended only if problematic and competitive species are immigrating into the sites.

Especially on sites with mulch cover, pioneer woodland species in the close vicinity may colonize quickly, thus requiring management in the second year. If nutrient-rich grassland topsoil is spread on raw soils with thicker layers, mowing once or twice a year may be necessary for weed control.

On **former arable land and fallows**, management is mandatory already in the first year after restoration (implementation in spring) or the following year (implementation in autumn). Especially on former arable land, the germination of weeds from the soil seed bank as well as the immigration of invasive species from adjacent sites can hamper the establishment of target grassland species. The first cut is necessary as soon as the vegetation is closed and the ground is not visible any more. Depending on the productivity of the sites, cutting frequency can be increased up to three or four cuts per year. At this time, target species are mostly in a rosette or juvenile stage and will not be damaged by mowing. Even if target species are already flowering at the time of cutting, the cut enhances their vegetative and root development. Weeds are not resistant to mowing, so that the management will constrain their development very effectively.

For restoring **degraded grasslands**, disturbance of the grass sward is most important. Management during the establishment phase should focus on combating the spread of re-growing grasses and germinating weeds from the soil seed bank. On highly productive sites, biomass removal is recommended to lower competition as well as to decrease the nutrient level of the site. A cutting height of approximately 10 cm avoids disturbance of the developing target vegetation.

Transition to regular management

When development leads in the direction to the intended target community, regular management can be started in the second or third year. The management type must be chosen according to the productivity of the site and the intended target vegetation.

Mowing is often the best option to maintain a species rich semi-natural grassland. The frequency and time of mowing and fertilisation must be selected according to the standard management of the target vegetation. On nutrient-rich soils, a low cutting frequency and too late cuts should be avoided in order to prevent grass dominance. Traditional hay-making without fertilization is best suited for maintaining a high species diversity on these sites, as it tends to decrease the soil nutrients content and, at the same time, favours target grassland species. As mowing is non-selective, it also better controls unpalatable invasive species than grazing.

Grazing is an important management tool for keeping grassland free of shrubs and trees and to maintain biodiversity in steep or irregular sites. Under favourable climate conditions, all-year megaherbivore grazing with low stocking density is an effective tool to develop species-rich plant and animal communities. Extensive grazing has positive impacts on semi-natural grasslands and, as post-restoration management, has other important benefits, such as cultural and aesthetic values. Above the timberline, where the rough climate prevents shrubs and trees colonisation and the low fertility slows down plant growth, no management and exclusion of domestic herbivores can also be a good solution, as grazing can further slow down or damage the development of vegetation and enhance erosion.

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Impressum

Further information about restoration of species-rich grasslands as well as a comprehensive literature review about this topic can be found in:
Scotton M., Kirmer A. and Krautzer B. (eds.) (2012) Practical handbook for seed harvest and ecological restoration of species rich grasslands. Published by Cleup, printed by Wallig Austria, 116 p.
The book and downloads are available under **www.salvereproject.eu**
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