Exploitation of native plant material for green covers in environmental reclamation

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Introduction

Permanent changes took place in the entire region of the Alps during the course of the last 50 years. Wide areas used for agrarian purposes were reduced or abandoned. On the other hand, the widespread opening of power stations and intensive road building, torrent and avalanche barriers, as well as extensive infrastructural measures especially for winter tourism. All of the measures described lead to intensive building each year, which then requires the restoration of the areas burdened by the intrusion. But at increasing extreme site conditions, restoration is increasingly more difficult due to the rapidly worsening conditions. In most cases, a combination of almost always cheap restoration procedures and cheap and alien seed mixtures are turned to. The resulting ecological and often economic damage is comprehensive: soil erosion, increased surface drainage, inadequate vegetation cover, the high costs of ecologically dubious fertilisation measures and management, and flora falsification are some of the resulting effects that follow.

For fifteen years, intensive research has been carried out by various institutes to break this negative circle of events. In various research projects (e.g. Urbanska, 1986; 1997; Wittmann & Rücker, 1999; Wild & Florineth, 1999; Florineth, 2000; Krautzer *et al.*, 2003) could be proved that a combination of high quality application techniques and site-specific vegetation or seed, lead to stable, sustainable and ecologically adapted populations of high value for nature protection. Fertilisation and management measures can be clearly reduced, which make these methods useful in the medium term, as well as being economical.

The following depictions should offer a brief overview of the possibilities of ecological restoration measures.

Concepts and terms

For a necessary defining, the important terms relative to restoration measures and valid in Austria are exactly defined in the "Guidelines for Site-Specific Restoration" (Austrian grassland federation, 2000). Vegetation is site-specific when after generally extensive agricultural use or non-use it is enduringly self-stabilising, and when the manufacturing of agricultural products is not a prime target for this plant society. This site-specific vegetation, with the exception of finishing and development management, or possible intensive agricultural use, requires no further management measures.

Vegetation created by humans is then site-specific when the following three criteria are fulfilled:

Site adapted: the ecological amplitudes (the "demands") of the applied plant species are in accord with the characteristics of the site.

Indigenous: the plant varieties used are to be seen as "indigenous" when they are found in the geographical region (e.g. Val d'Aosta, Hohe Tauern), but at least in the same region in which restoration takes place, and are evident, or have been evident, at appropriate natural sites.

Regional: the seed or plant material used originates from the immediate surroundings of the project area and from the habitats, which in respect of essential site factors, are appropriate to the type of vegetation to be produced. Due to a lack of availability of regional seed, the "regional" criteria should be aimed at, but is not obligatory.

General criteria for ecological restoration with native plant material

For ecological restoration the following general criteria, which are to be adapted to respective individual cases, are to be given.

1. A state of acceptance is given when restoration shows a condition of development that ensures the achievement of the restoration aims or is appropriate to the same.
2. The sown or planted vegetation must have survived two rest periods and frost phases before being accepted at high altitudes. The acceptance date during restoration must therefore be set for the early summer of the next year but one. In the special case of high altitudes, acceptance should take place following two summer periods and two frost periods. Special agreements are to be made for special cases (e.g. a rehabilitation project).
3. Additional fertilisation should take place only in relation to the nutritional supply of the substrata and the desired restoration aims. Overly rich and thus divergent vegetation created by over fertilisation has no acceptance capacity.
4. Restoration created by seeding should form a uniform cover, which in an uncut state, unless otherwise agreed, must show at least 70% of the projected ground cover (Fig. 1). In cases where restoration has taken place, a divergent ground cover can be brought to agreement. Vegetation-free patches of over 20 x 20 cm are not permitted, whereby vegetation in this sense is to be seen as comprising only vascular plants. The stock must comprise up to 60% of the projected cover with those species given in the seed mixture, or laid down as a restoration target (type of vegetation). The annual state of the plants, according to species, is to be taken into account when mediating the degree of cover. Nursery or alien vegetation does not count among the desired degree of cover. Divergent cover values or acceptance conditions, above all in the restoration of difficult sites, are to be contractually agreed and taken into account during acceptance.
5. The available topsoil should be carefully removed and stored before building begins. The diaspora material it contains, as well as the remaining pieces of vegetation, makes rehabilitation possible with vegetation from the original site. A further possibility is the lifting of grass turf or larger pieces of vegetation for reapplication to the levelled area. The intermediate patches should be restored with a mulch seed. The introduction of a grass sward of forest vegetation is generally not suitable for ski runs cleared within nature.

Figure 1. Rain simulations on slopes (experimental site Hochwurzen, 1.830 m) showed that a sufficient protection of the soil surface (e.g. by straw, hay) is necessary to avoid erosion the weeks after seeding.

Figure 2. Under extreme site conditions, only a combination of high quality application technique with site specific seed mixtures or plant material leads to successful results (location Piancavallo, 1.435 m).

6. Exclusively re-cultivation techniques are to be used in most cases because they guarantee sufficient protection of the topsoil (Fig. 2). This included seed processes combined by means of covering the topsoil with a layer of mulch, net or seed mat, as well as hay-mulch seed. When using hay-mulch seed and threshed-hay seed, it is necessary for an expert to make the decision for extra cover.
7. Planted pieces of vegetation must be firmly rooted. In the fringe areas of the planted grass swards, no appearance established of drying out or erosion should be apparent.

Seed mixtures

The conventional mixtures available on the Austrian market mainly comprise high-growing non-site-specific lower plants originally bred for grassland economy in valley locations or as grasses for sporting events. The high nutritional needs of these species require long-term, expensive fertilisation measures to achieve the necessary grass density. Also relative is a high biomass production, which again requires regular cutting, grazing or removal of the materials arising. In many cases, further use or management of the restored areas is also no longer wished for or possible.

For high altitude restoration, site specific seed mixtures are already available in Austria (Table 1). Site-specific subalpine and alpine plants are adapted to an optimum degree to the high-zone climate. They produce little biomass, but with an appropriate choice of species, they do produce high-quality feed. Seeding with site-specific seeds generally require only slight amounts of nutrition, and short-term management measures lead quickly to natural, generally extensive self-maintaining grass, which has high persistency against subsequent uses for tourism and agriculture. With the use of site-specific seed mixtures, the required sowing volumes commonly used in practice can be lessened from 200 to 500 kg per hectare to 80 to 160 kg per hectare. Grasses and leguminosae were selected within the sphere of several international research projects, which are suitable for seed production in valley locations and can be used in various site-specific alpine seed mixtures (Krautzer *et al.*, 2003). In the meantime, the ecological species suitable for high zone restoration will multiply over a broad area, graded according to altitude, original rock and usage in high-quality restoration mixtures and brought to the market. The use of such site-specific seed mixtures (e.g. www.saatbau.at) should be obligatory when sowing in high zones.

Table 1. Important characteristics of available site specific grasses and herbs (Krautzer et al. 2004).

Species	Distribution	Vegetation belt			Parent rock		Moisture	
		Montane	Subalpine	Alpine	Siliceous	Calcareous	Dry	Wet
Grasses								
Anthoxanthum odoratum	Europe	+	(+)	-	+	+	+	(-)
Avenella flexuosa	Worldwide	+	+	+	+	-	+	(-)
Bellardiochloa variegata	Middle/south Europe	-	+	+	+	(-)	(+)	(+)
Briza media	Europe	+	(+)	-	+	+	+	(+)
Bromus erectus	Middle/south Europe, North Am.	+	(-)	-	(-)	+	+	-
Bromus inermis	Europe, Asia, North America	+	(-)	-	+	+	+	(-)
Cynosurus cristatus	Euroasia, North America	+	+	-	(+)	+	(+)	(+)
Deschampsia cespitosa	Worldwide	+	+	+	+	+	(-)	+
Festuca nigrescens	Europe	+	+	+	+	+	+	+
Festuca picturata	Middle Europe	-	+	+	+	+	+	(+)
Festuca pseudodura	Middle Europe	-	(+)	+	+	(-)	+	(-)
Festuca supina	North/middle Eeurope	-	+	+	+	(-)	+	(-)
Festuca varia s.str.	Central Europe	(-)	+	+	+	(-)	+	-
Koeleria pyramidata	Europe	+	+	-	(-)	+	+	-
Phleum hirsutum	Middle/south Europe	(+)	+	+	(-)	+	+	(-)
Phleum rhaeticum	Middle/south Europe	(+)	+	+	+	(+)	(+)	+
Poa alpina	Europe, Siberia, North America	(+)	+	+	(+)	+	+	(+)
Sesleria albicans	Europe	+	+	+	(-)	+	+	-
Leguminosae								
Anthyllis vulneraria	Middle/south Europe	+	(+)	-	(-)	+	+	-
Anthyllis vulneraria ssp.alpestris	Middle/south Europe	+	+	+	(-)	+	+	-
Trifolium alpinum	Middle/south/west Europe	-	(+)	+	+	-	(+)	(+)
Trifolium badium	Europe, Siberia	(+)	+	+	+	+	+	+
Trifolium pratense ssp.nivale	Middle/south Europe	-	+	+	+	(+)	(+)	+
Herbs								
Achillea millefolium s.L.	Europe, Siberia	+	+	(+)	(+)	+	(+)	(+)
Leontodon hispidus s.L.	Europe	+	+	+	(+)	(+)	(+)	(+)

Species	Distribution	Tolerance against			Nutritional Value	Sward Density
		Fertilization	Cutting	Trampling		
Grasses						
Anthoxanthum odoratum	Europe	(-)	(+)	(+)	(-)	-
Avenella flexuosa	Worldwide	(-)	-	(-)	-	(-)
Bellardiochloa variegata	Middle/south Europe	(+)	(+)	(+)	(-)	(+)
Briza media	Europe	(+)	+	(+)	(+)	+
Bromus erectus	Middle/south Europe, North America	+	+	(-)	(+)	-
Bromus inermis	Europe, Asia, North America	+	+	(-)	(+)	(+)
Cynosurus cristatus	Eurasia, North America	+	+	+	+	+
Deschampsia cespitosa	Worldwide	+	(+)	+	-	(+)
Festuca nigrescens	Europe	+	+	+	(+)	+
Festuca picturata	Middle/south Europe	+	+	(+)	(+)	+
Festuca pseudodura	Middle Europe	(+)	-	(+)	-	(+)
Festuca supina	North/middle Europe	(+)	(-)	+	-	+
Festuca varia s. str.	Central Europe	(-)	-	-	-	(+)
Koeleria pyramidata	Europe	(+)	(+)	(+)	(-)	(+)
Phleum hirsutum	Middle/south Europe	+	+	+	(+)	+
Phleum rhaeticum	Middle/south Europe	+	+	+	+	+
Poa alpina	Europe, Siberia, North America	+	+	+	+	(+)
Sesleria albicans	Europe	(-)	(-)	(-)	(-)	(-)
Leguminosae						
Anthyllis vulneraria	Middle/south Europe	(+)	(-)	(+)	(-)	-
Anthyllis vulneraris ssp.alpestris	Middle/south Europe	(+)	(-)	(+)	(-)	-
Trifolium alpinum	Middle/south/west Europe	+	+	+	+	-
Trifolium badium	Europe, Siberia	(+)	+	+	+	(-)
Trifolium pratense ssp.nivale	Middle/south Europe	(+)	+	+	+	(-)
Herbs						
Achillea millefolium s.L.	Europe, Siberia	+	+	+	(+)	(+)
Leontodon hispidus s.L.	Europe	(+)	(+)	+	(+)	(-)

+ = very good; (+) = good; (-) = poor; - = very poor.

Regular techniques used in Austria for establishing site-specific vegetation

Simple dry seeding

This method may only be used when combined with a covering of the topsoil by means of a layer of mulch, netting or seed matting. One sees simple dry seeding as the introduction of seeds and fertiliser in a dry state with no additional support substances. It is very suitable for level terrain (use of diverse sowing machines), but can also be used on banks with a rough topsoil.
Degree of seeding: up to 10 g/m² on level areas, up to 18 g/m² on steep areas.

Wet seeding or hydro-seeding

This method can only be used at high altitudes when combined with a covering of the topsoil by means of a layer of mulch, netting or seed matting. In this seeding method seeds, fertiliser, mulch

material, soil adjuvant substances and gluten are mixed with water in a special spray container and sprayed over the areas to be restored. Even steep banks with a smooth surface can be restored in this way, whereby the rapid emergence of the seeds has above all proved to be advantageous against erosion processes. On steep slopes, the seed-fertiliser mixture can be sprayed over an affixed jute net. In extreme cases, this method can also be undertaken with a helicopter.
Material expenditure: 6 g/m² to a maximum of 20 g/m² of seeds

Hay-mulch seeding

With the availability of appropriate areas, the "seeds" can also be won through special mowing in suitable "donor areas". The areas to be mowed should generally bear site-specific vegetation, which is appropriate to the aims of the areas to be restored. Mowing is undertaken at staggered intervals (two to three mowing dates) to include the broadest possible spectrum of species in a mature state. These mowing dates should be determined by an expert. The plants to be harvested should not be in an overly ripe state because a slight loss of seed can take place. With the intermediate storage of the hay, which often requires the recommended selection of several mowing dates, sufficient drying is unavoidable to hinder the attack of mould. The relationship of winning and restoration areas is generally 1:1 to 1:2. The hay won in this way, and the seeds it contains, is to be applied to the restoration area in a uniform layer to a maximum depth of 2cm. Over-intensive application is to be avoided to prevent anaerobic decomposition processes in the distributed seed.

Figure 3. Hay flower seeds from appropriate donor sites, a valuable material for ecological restoration.

Hay-flower seeding

Required for this method is the availability of the seed-rich remains on threshing-floors in hay barns, which above all at high altitudes is still mostly of sufficient quality (Fig. 3). This material should come from hay that is not older than one year or a maximum of two years. A further prerequisite is that the hay must be cut sufficiently late, which promotes the forming of mature seeds in many field grasses and herbs. Sieving is often recommended to acquire an appropriately high seed concentration. The hay-flowers (0.5 – 2 kg/m²) are sown with their stalks to a maximum depth of 2 cm. An additional layer of mulch is only necessary when sieved material has been used. To hinder loss through being scattered by the wind, seeding should only take place on wet soil, or if the hay-flowers are watered after seeding. At high altitudes, seeding weighted with steel building grids, wire netting or coconut netting, which can be removed after a few weeks, has proved successful A certain degree of protection of the soil against mechanical interference is achieved through the mulch layer and microclimatic conditions are improved. The additional use of a cover crop has proved useful. If the

germination capacity of the hay-flowers is insufficient, important seed components can be additionally purchased and sown.

Sod clippings

Shoots or rosettes (mostly mechanically separated vegetation turfs) are loosely distributed. Distribution can take place mechanically in areas that can be driven on. In this way, a much larger area can be restored with well-established vegetation than with grass swards. Restoration, however, is significantly more sparse, and the danger of erosion higher. Grass pieces lacking a share of fine soil or lack re-stabilisation can dry out.

Grass turfs

Available and natural vegetation is above all the best substance in the alpine zone for enduring restoration identical to nature. Therefore, extreme care should be taken when using such vegetation because destruction or a lack of reuse must be strictly avoided.
Grass turfs (also known as grass swards) or larger pieces of vegetation won during levelling or path construction are grouped together following completion of the work. They are very suitable for the rapid and site-specific restoration of damaged areas (Fig. 4). On steeper banks, the grass turfs must be fixed with wooden nails. Wherever possible the planting of grass turfs should take place before shooting or after the start of the autumn vegetation pause, meaning just after the melting of snow or immediately before the beginning of the coming of snow in winter. At these points in time the success of planting, even in extreme high zones, is extremely good.

Figure 4. Grass turfs are very suitable for the rapid and site specific restoration of damaged areas.

Before levelling begins, the available grass or pieces of vegetation are lifted together with the rooted soil and laid again after levelling. Depending on whether the turfs are cut manually, or lifted mechanically, their size is 0.15 to 0.50 m^2. If required they can be stored in pits or stacked on pallets (maximum of 1 m wide and 0.6 m high) to hinder drying out, stifling and rotting. The storage period should not exceed a maximum of two to three weeks in summer. Following the end of levelling the grass turfs or pieces of vegetation are again laid out and lightly pressed in.
With appropriate planning of the building process, the direct use of vegetation turfs is possible without intermediate storage.

Potted plants

The plants and seeds are pre-cultivated in nurseries and planted with a well-developed root stock at the restoration site. Site-specific species with a good vegetative growth are used for this (Grabherr & Hohengartner, 1989). One can also turn to mother plants or seeds taken directly at the site by experts. With the appropriate choice of species, excellent results can be achieved at extreme sites in this way.

The supporting use of this method as a post-improvement measure against sparseness in the restoration area is favourable.

Vegetation transplantation – combined seed-sward process

In this special restoration technique, the covering with grass swards, or other pieces of vegetation, is combined with dry or wet seed. The grass swards used must be appropriate to the desired site-specific type of vegetation and are generally acquired in the project area or in the immediate vicinity at the beginning of building work. There can therefore be cases of an interception in the vegetation sphere beyond the immediate project area to achieve optimum success through the "division" of available vegetation. The area to be restored is therefore often larger than the original project sphere.

The grass swards (02 – 05 m²) are placed in groups in dry locations to prevent them from drying out and grid-like in areas subject to high precipitation in the area to be restored. Site-specific seed is applied to sparse patches between the swards. This seed has a stabilising effect on the vegetation-bearing layer. Due to the short distances between the covered grass swards, it is possible for well-established vegetation to move into the intermediate spaces. In this way, these patches will also be restored and inhabited in a natural way by species that are not available as seeds.

The conception of this restoration technique, and above all the selection of grass-donor areas, is only to be undertaken by appropriate experts. In steeper areas (over a 30% gradient), and in terrain endangered by erosion, the use of geological textile matting or similar is planned for securing the covered vegetation or for the protection of the topsoil against erosion.

Figure 5. Without steady fertilisation, site specific seed mixtures (left) reach significant better vegetation cover compared to commercial seed mixtures (right).

Fertilisation

Fertilising measures should only be carried out to achieve a sufficient degree of cover (Fig. 5). "Too little" as well as "too much" hinders the success desired. Only slow, permanently effective and ecologically safe fertiliser that promotes the build-up of humus is to be used for restoration. This requirement is above all fulfilled by organic fertilisers (home-produced commercially available fertilisers), which are also authorised for biological farming. To be especially recommended is well-rotted farmyard manure. The use of fluid and semi-fluid sewage as fertiliser is unsuitable and to be avoided.

Utilisation

In many cases, a certain degree of subsequent management is unavoidable for the success of restoration: when mowing is to be undertaken an exactly dosed post-fertilisation, additional seeding or necessary fencing against grazing animals is required for the achievement of the projected level of restoration. Following our Austrian experience with native plant material, constant utilisation is not obligatory or necessary following the use of site-specific seed mixtures. With the appropriate composition of the seed mixtures or the use of appropriate plant materials, a restoration area can be left to itself, which is greatly desired for the restoration of areas prone to erosion, constructions for the regulation of torrents and avalanches, etc.
With a slight degrees of cover (< 50%) the year following restoration, further necessary measures are to be laid down, such as reseeding with a site-specific seed mixture (30 to 50 kg per hectare). When necessary, appropriate improvement work must be undertaken in small areas.

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