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"Ecological Restoration of Ski Runs"

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. 40,000 ski runs amounting to 120,000km in length were built in the last decades in the Alps and used annually by 20 million tourists (Veit, 2002).

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 an increasing altitude restoration is increasingly more difficult due to the rapidly worsening climatic conditions. Due to cost, restoration continues to be relinquished in some areas of the Alps, but 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 restoration problems in alpine environments as well as the possibilities and the necessity of ecological restoration measures, but also the necessary respect given to the limits of what is possible.

Concepts and terms

The following depictions of the ecological restoration of alpine ecosystems relate to the subalpine and alpine zones and are thus limited to the zones between altitudes of 1,300 and 2,400 metres (Ellenberg, 1996). In lower zones, the overcoming of the power of erosion is by degrees easier. At extreme altitudes over 2,400 metres, satisfactory restoration is no longer possible according to the current state of technical awareness.
In the "Guidelines for Site-Specific Restoration" (Austrian grassland federation, 2000) the important terms relative to restoration measures are exactly defined; and means accordingly: 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.

Ski runs and slope areas

Ski runs are emphasised as an independent focus because above all the re-cultivation of bare terrain following the erection of skiing facilities has been and is very often insufficiently carried out. Due to this situation, the important economic and tourism policies have fostered a somewhat negative image. Numerous terrain corrections at high altitudes are recognisable as extensive vegetation-free areas with a high erosion potential after decades of operation, and despite some "restoration attempts" are seen as "wounds" in the landscape. Above all in relation to the re-cultivation of such technological skiing areas is the lack of a definition relative to the latest advances in the field, and the lack of contractual and realisable legal nature-protection criteria and guidelines is especially flagrant. In numerous cases, permanent ecological restoration was brought to agreement in decisions supporting legal nature-protection as well as in tenders, but were never realised. We have unfortunately all too often been satisfied with the argument "We have tried everything, it simply doesn't work better". In this respect, it is to be maintained that there where the sites are beyond restoration, according to the latest advances in the field, terrain-changing measures are to be relinquished. This is above all true at altitudes over 2400 metres and for plant societies that are found within exposed alpine grasslands (e.g. those comprising curved sedge, horst sedge, etc.). Interception in these plant communities, of which there are no seeds currently available, and according to the latest advances in the field cannot be manufactured similar or identical to nature, is to be generally relinquished.

An area used as a ski run in winter is subject to the following special site factors:

- Extended snow cover, generally longer than is natural at the given altitude.
- A relatively dense snow cover, in some cases with deposits of ice layers, which in the six months of winter hinders the exchange of oxygen between the plant cover, the ground and the atmosphere.
- The effect of mechanical disturbance factors, such as the effect of steel edges and the chains on ski-run preparation machinery. These effects can have a destructive influence on vegetation, above all on rounded hills and steep slopes.
- Increased drainage response of surface waters. Because precipitation increases with altitude, a relatively high drainage rate is to be reckoned with in ski run areas, which compared to forests and areas stocked with shrubs, only on runs based on herbal vegetation can disposal take place without danger through appropriate technical measures (diagonally running and open drainage channels).

These points place additional stress factors on the vegetation cover. Above all at increasing altitudes, with the related shortened vegetation period, this is to be taken into consideration in connection with other stress factors (such as grazing). Thus in some high-altitude areas the double burden of skiing and grazing is only possible after several years when the vegetation cover is fully stabilised. There are also cases in which this double burden is to be excluded; that means that before construction begins, one must choose either the construction of ski runs and appropriate re-cultivation measures, or agricultural grazing. Appropriately considerate re-cultivation planning agreements are to be seen as an indispensable part of the project.

General criteria for ecological restoration

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. In cases where restoration has taken place, a divergent ground cover can be brought to agreement. Vegetation-free patches of over 20 x 20cm 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.
6. Exclusively re-cultivation techniques are to be used in most cases because they guarantee sufficient protection of the topsoil. 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 "high-zone mixtures" available on the market mainly comprise high-growing non-site-specific lower plants originally bred for grassland economy in valley locations or as grasses for sporting events. These species are adapted to lower, warmer locations and are generally not suitable for restoration in high zones (Florineth, 1992). 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 because in the short vegetation period, no sufficient decomposition of the additional growth of biomass takes place and the chocking of the vegetation stigma would be the result. In many cases, further use or management of the restored areas is also no longer wished for or possible.

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 500kg per hectare to 80 to 160kg 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.

Fertilisation

Restoration in the area of ski runs is generally only successful with the use of seeds or plants interacting with proper fertilisation. A poor volume of minerals available to plants is mostly shown in areas after levelling. Rapid development of the seeding to a full grass cover is also necessary in site-specific restoration for rapid erosion protection at such sites. A single fertilisation of such areas is generally sufficient with a suitable fertiliser for establishment. If in the second year of vegetation an insufficient vegetation cover is achieved, further fertilisation measures to achieve a sufficient grass density is necessary. These measures can also be combined with seeding-over with a site-specific seed mixture. With the achievement of relatively dense grass cover, the measures can be limited to unsatisfactory patches of the area.

Fertiliser of a slow and permanent effect should be used, and which promotes the build-up of humus and has good plant tolerance. Attention should be given to achieving a balanced nutritional relationship. To be avoided is the use of roughage-promoting or unhygienic fertiliser. Where possible such organic fertiliser as well-rotted farmyard manure, composted fertiliser or certified biological compost (according to the existing legal regulations) should be used. The use of fluid and semi-solid sewage is to be avoided. The use of organic-mineral fertilisers with the appropriate characteristics (slow, permanent release of nutrition) is possible. Their use should be limited to the necessary degree in relation to the positive additional effects of the organic fertiliser (multiple effect, deposit effect, herb tolerance, build-up of humus).

Fertilising measures should only be carried out to achieve a sufficient degree of cover. 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

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.

Utilisation of ski run restoration is in most cases also necessary in areas not used predominantly for farming. Utilisation takes place in the form of extensive grazing or

annual mowing, with or without the removal of organic material (in only slight amounts of biomass).
Above all, in the first years of seeding accompanied with fertilisation, cultivation of ski areas must take place. Until the achievement of sufficient grass density, at least over the first two vegetation periods, no grazing is to take place on the areas. Annual mowing is necessary following the achievement of appropriately lush growth. This mowing removes biomass and thus hinders the stifling of the growth in winter. Sprouting of the plants is also stimulated and the grass density is promoted. On steep and footfall-sensitive areas, grazing is to be hindered by fencing, if necessary, in favour of mowing.
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 50kg per hectare). When necessary, appropriate improvement work must be undertaken in small areas.

Techniques for establishing site-specific vegetation at high altitudes

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 10g/m² on level areas
up to 18g/m² on steep areas

Cover-crop seeding

This method may 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. For this seeding method winter rye, oats or barley (the latter is only suitable in the spring and summer) is worked into the soil and the remaining seeds sown over them. Due to the rapid accumulation of the cover crop in the soil, a rapid covering of the open areas of earth takes place. Nevertheless, this effect is strongly inhibited by severe climates at high altitudes. The actual restoration seed develops between the cover crop and finally forms the site-specific vegetation. This method is above all suitable for steep ski runs or banks strongly exposed to the sun. At lower altitudes the cover crop must be mowed and cleared on time (at a max. height of 30cm) or it will oust growing and enduring vegetation when dying-off leaves large patches.

Seed volumes: 5 - 10g/m² winter rye/oats/barley
10 - 15g/m² seed

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: to a maximum of 25g/m² of seeds

100g/m² organic fertiliser
80g/m² cellulose, peat-substitute material, very short straw
100g/m² algae products as gluten
(10 - 30g/m² chemical gluten)

Because peat can be replaced in the hydro-seeding method with alternative materials, use of this ecologically questionable raw material is to be avoided for site-specific restoration.

Mulch seeding

In the mulch seeding process, soil and seeds are covered and protected with various organic material. For optimum growth the depth of the layer of mulch should not be more than 3-4cm and pervious to light. The most common mulch materials are hay and straw.

With the simple hay or straw seeding methods, a 3-4cm straw or hay cover is applied over the seeding. The prerequisite for this restoration method are sites that are protected against the wind and are not too steep. The material expenditure is 300 - 600g/m² in a dry state.

The hay mulch seeding method is perfectly appropriate for site-specific restoration. Through the application of well-matured hay from the immediate vicinity, seeding with commercial seed can be avoided insofar a slow vegetation development is possible. The hay cover also acts as additional erosion protection.

At steep points, especially above the tree line, the bitumen straw-cover seeding method is suitable. Seeds and fertiliser are applied into the 3-4cm straw layer and an unstable bitumen emulsion sprayed over it (not to be used in drinking-water protected areas). Hay is not as suitable for spraying with bitumen because it is compressed; due to thinner stalks and better cohesion, hay cover seeding alone is more stable than straw. Hay and straw can also acquire sufficient cohesion through light organic gluten.

Seeding techniques with the use of netting and seed matting

A number of geological textiles are commercially available. This netting of jute, coconut fibre, synthetic fibres or wire can be used for all previously described restoration processes. When possible, use of synthetic fibres and wire netting as a planting aid in site-specific restoration should be avoided. Geological textiles are used predominantly where there is a clear danger of erosion or extreme site conditions (e.g. on very steep ridged banks). They offer the possibility for stronger surface protection and, according to the materials used, are more or less stable in the face of natural forces such as falling rock, snowdrifts, precipitation, etc. According to the material, site conditions and altitude, the netting rots within one to four years with no residue. Galvanised iron and synthetic fibre netting have a lifespan of around 30 years and are not biologically degradable. The danger of residue exists.

Seed matting is filled with wood-wool, coconut fibres, hemp, straw or other natural fibres, which is sewn into finely stepped jute netting. The seeding is mostly contained in the seed matting. This seed matting requires full contact with the soil and can therefore only be attached to flatter and smooth earth surfaces.

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 at the beginning of building work or in the immediate vicinity. 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 - 05m²) 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 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 30% slope 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.

Ready made sward (sod rolls)
Sod rolls with site specific vegetation are already available in small amounts for differing starting substrates. Sod rolls are produced at specialised firms over a period of around 12 months until the sufficient development of site-specific altitude species is ensured. According to need and restoration aims, certain grass mixture can be produced beforehand. The grass is then harvested to order and transported to the restoration area. Thus is the shortest possible time a complete cover of restoration areas is possible. Especially interesting is this method in restorations following small-area interception and in extreme locations.

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