Ecological restoration in Alpine environments

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1. 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 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.

2. Concepts and terms

Appropriate to the climatic changes at specific altitudes, vegetation in the Alps and many other landscape elements and processes are divided into altitudinal zones. The change of these factors, according to altitude, leads to a vertical sequence in various climatic areas. The high zones are separated by fairly easily recognizable borders - the montane from the subalpine zone by the forest line, the subalpine from the alpine zone by the tree line, the alpine from the subnival zone by the grassland border.

The following depictions of the 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. 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.

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”. 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.

3. Alpine climate

Plants at high altitudes are often subject to an often and partly rough change of the climatic factors. The transition of the seasons takes place very quickly. With increasing altitude, the vegetation period takes around one week less per 100 metres of altitude. The differentiation of the macroclimate to the microclimate dependent on altitude and broad location is important. The most important difference to sites in valley locations can be briefly characterized by the following factors:

1. Temperature decreases in the air and in the deeper levels of the earth by an average of 0.6°C per 100 metres of altitude. Frost is a possibility at all times of the year in high zones, at the beginning and end of the vegetation period an interchanging frost climate generally predominates. The climatic-vegetation period with average daily temperatures of over 10°C, is around 67 days at an altitude of 2,000 metres, which is a third of the vegetation period in the valley.
2. The deep ground temperatures in the mountains strongly reduce the activity of micro-organisms. Reduction of dead organic mass and thus the provision of basic mineral nutrition is inhibited. The subterranean habitat is thus limited, contrary to the grasses in warmer, lower zones, to the most strongly warmed, humus-rich and generally acidic and intensively rooted upper layers of the ground.
3. Precipitation increases with altitude, on the fringes of the Alps it is 800 to 1,000mm more than in the heart of the Alps. Evaporation rises. Critical situations in the water balance of plants, however, are rare, other than in special locations (strong radiation, high temperature and high wind).
4. Wind increases in frequency and strength with altitude. This strongly influences the distribution of snow in winter and thus the length of the snow-free period and the water balance, which makes a strong erosion effect possible in exposed locations. Various inclinations of the sun's radiation create differing degrees of heat.
5. The difference between a north and south aspect is increasingly greater with altitude. The microclimate, however, can surpass the influence of the macroclimate and altitude.

4. General criteria for ecological restoration with seeds and 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. 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.

5. 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. 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. 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.

6. Techniques used for establishing site-specific vegetation in alpine environments

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. An additional protection of the soil surface with mulch (straw, hay, geo-textiles) is necessary to avoid erosion on steeper slopes.

Degree of seeding: up to 10g/m² on level areas, up to 15g/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: 6g/m² to a maximum of 20g/m² of seeds

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. To avoid the inclusion of undesired seed, in principle only hay of the second or third cut should be used.

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.

At steep points, especially above the tree line, the 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.

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.

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. 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.

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 0.50m². If required they can be stored in pits or stacked on pallets (maximum of 1m wide and 0.6m 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. 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.

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 specialized 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 a complete cover of restoration areas is possible in the shortest possible time. Especially interesting is this method in restorations following small-area interception and in extreme locations.

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 - 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 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.

7. Fertilisation and Utilisation

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

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 50kg per hectare). When necessary, appropriate improvement work must be undertaken in small areas.

8. Failures

Restoration can easily fail in extreme locations or at extreme altitudes. The most common causes for such a lack of success are listed as follows:

False restoration methods

The more extreme the conditions, all the more specific must be the planning of the restoration or rehabilitation measures. The securing of valuable pieces of vegetation, the gathering, restoration, intermediate storing and expert reapplication of the topsoil, subsequent prevention against erosion, use of special restoration methods, to the choice of donor areas for the combined seed-sward technique or for hay-mulch seeding require planning by appropriately experienced experts. Successful high-location restoration at over 2000 metres has always been planned and maintained by trained experts.

False seed

A common mistake, even in less than extreme conditions, is the choice of unsuitable seed. Not only the use of lowland seed in the subalpine and alpine zones, but also the lack of attention given to decisive criteria, such as degree of acidity of the soil, or the availability of nutrition are causes for insufficient restoration success. Also valid here is the maxim: the more extreme the conditions, the more unavoidable is the use of trained experts.

False fertilization

As already mentioned, fertilization at the restoration target and the restoration method are to be mutually adapted. 'Too little' as well as 'too much' hinders the success desired. In this way, with the combined seed-sward technique, heavy fertilization can destroy vegetation of the replaced swards and the natural seed slumbering in the soil. The slightest failure in this respect can be caused by small doses of slowly and long-term working fertilizer.

Inexpert work

The grass swards as well as the seed are 'living' materials and appropriately careful handling and expert work is therefore indispensable. Falsely stored grass swards, inexpert fixing of the sward on the soil, a lack of adequate bedding in and the connected drying-out phenomenon can even destroy restoration undertaken with high expenditure. Above all, under difficult conditions one must call in a competent restoration expert.

Lack of subsequent management

In many cases, a certain degree of subsequent management is required for the success of restoration: when mowing is to be undertaken an exactly dosed post-fertilization, additional seeding or necessary fencing against grazing animals is required for the achievement of the projected level of restoration. All of these measures are essential elements of restoration, which must not be forgotten if one wishes to achieve appropriate success.

9. Related literature

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