# Restoration at high altitudes - Results from European restoration trials in the frame of the EU-Project "SURE"

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## Introduction

This paper shows first results of restoration trials at high altitudes on 6 different sites in Austria (2 sites), Greece (1 site), Italy (2 sites) and Slovakia (1 site). This trials were set up in the frame of the INTERREG IIIB CADSES Project SURE - Successful Restoration and Rehabilitation after Infrastructural Interventions.

The current awareness of technology for the restoration of alpine ecosystems in various neighbouring alpine states is defined very differently and the knowledge of special restoration methods is insufficient.

Therefore, the overall aim of these trials (and among others the whole project SURE) is to compare locally used conventional seed mixtures (widespread commercially available varieties for grassland management) and application techniques with newly developed, site specific seed mixtures and sophisticated application techniques not well known everywhere and thus to distribute and exchange knowledge in the field of ecological restoration.

The first and most important target with restoration at high altitudes is ersosion prevention. To reach this, a vegetation cover of at least 70% is necessary (Stocking and Elwell 1976, Mosimann 1984).

Another points getting more attention during the last years is the possibility to leave restored sites without any further management and keeping or raising to a certain ecological value with an appealing landscape, specially in regions frequently visited by tourists.

## So, the central questions for all trials where:

- Development of cover on species and seed mixture level
- Comparison of perfomance of species and mixtures in the run
- Influence of application technique on the development or ability to establish

The strategic aim of the project SURE was not to find new evidence, but to demonstrate the differences between seed mixtures and application techniques. Therefore the trials where not planned with a „hard" scientific background, but to simulate the practical use, with all problems that may arise from disturbance from outside, being firstly case studies in different regions spread almost all over Central Europe. But only under this conditions, all used methods and materials can show their qualification for daily use and long term sustainability.

## Trial Sites

5 of the 6 trial sites chosen are ski runs which are an important focus at high altitudes, because above all the re-cultivation of bare terrain following the erection of skiing facilities has been, and is often, insufficiently carried out. Due to this situation, the important economic and tourism policies have fostered a somewhat negative image.

The set up was different between trials to take the local situation concerning area, morphology but also local state of the art into account, being the „local" part the most important one, and always taken into consideration when discussing the results.

*Table 1:* **Detailed list of trial sites and site parameters**

| Location | Altitude | Trial | Additional Parameters and remarks | Surroundings |
|---|---|---|---|---|
| Mayrhofen, Austria | 1950 | Comparision of 2 seed mixtures (commercial and site specific), different fertilization | Exposition: North, Inclination 45° pH soil: 6.33 Seeding rate: site specific mixture: 15 g·m$^{-2}$ commercial mixture: 30 g·m$^{-2}$ | The surrounding vegetation consists of patches of a subalpine heath with remains of a larch-stone pine forest. The area is extensively grazed, so plants of alpine pastures (e.g. *Nardus stricta*, *Poa alpina*, *Alchemilla monticiola*, *Festuca* sp.) are also present. |
| Obertauern, Austria | 2150 | Comparision of 2 seed mixtures (commercial and site specific), different application technique, different fertilization | Exposition: North-east Inclination 30° Seeding rate: site specific mixture:15 g·m$^{-2}$, commercial mixture: 30 g·m$^{-2}$ | The surrounding vegetation can be classified as a subalpine heath. The area is quite heavily influenced by the construction and rebuilding of the ski run and the accompanying infrastructure. |
| Varmost 3, Forni di Sopra, Italy | 2015 - 2050 | Comparision of 2 seed mixtures, with different application technique, different fertilization | Exposition: South-West Inclination 7° to 22° Seeding rate: conventional seed mixture 20 g·m$^{-2}$, site-specific 15 g·m$^{-2}$ | The surrounding vegetation is characterised by acidophilous dwarf shrubs (*Rhododendron ferrugineum*, *Vaccinium myrtillus*, *Vaccinium gaultherioides*, *Calluna vulgaris*). Also basiphilous shrubs occur, such as *Erica carnea*, *Dryas octopetala and Juniperus nana*. In the herbaceous layer species of the *Nardus stricta*-mats of the Alps are well represented (*Nardus stricta*, *Carex sempervirens*, *Leontodon helveticus*, *Arnica montana*, *Avenula versicolor*, *Campanula barbata*, *Geum montanum*, *Potentilla aurea*). Besides them, there are also species of the subalpine and alpine grassland on limestone (*Sesleria albicans*, *Anthyllis vulneraria* ssp. *alpestris*, *Pedicularis elongata*, *Helianthemum nummularium* ssp. *grandiflorum*). |
| Cimacuta, Forni di Sopra, Italy | 940 - 975 | Comparision of 2 seed mixtures, different application technique, different fertilization | Exposition: mainly N Inclination: 15° to 21° seed mixture 20 g·m$^{-2}$, site-specific 15 g·m$^{-2}$ | The surrounding vegetation is divided into two parts: The first results from a previous sowing and it is also used for summer grass skiing. Sown grasses as *Poa pratensis*, *Festuca* gr. *rubra* and *Festuca* gr. *ovina*, are accompanied by spontaneous *Carex* spp.; legumes are represented by *Lotus corniculatus*, *Trifolium pratense*, *Medicago sativa*, *Medicago lupulina*, *Ononis spinosa*, *Onobrychis montana* and *Vicia* sp.; among forbs there are *Ranunculus* sp., *Salvia pratensis*, *Leucanthemum vulgaris*, *Pimpinella major*, *Galium mollugo* and *Plantago media*. On the right side of the trial the vegetation is characterised by the presence of a *Picea abies* woodland with a brushwood of *Corylus avellana* at the border. Shade tolerant or sub-heliophilous species as *Anemone nemorosa*, *Listera ovata*, *Orchis maculata* and *Polygonatum odoratum* occur in the underbrush. |
| Paleohori, Central Greece | 1300 - 1350 | Comparision of 2 seed mixtures, different application technique | Seeding rate: 25 g m$^{-2}$ The main problems are: soil slope, acidity and nutrient disorders. Frost, overgrazing and climatic conditions had affected landscape degradation. | Various turf grasses and prairie species, cedar and oak trees. The vegetation cover exceeds 50 % |
| Liptovský Mikuláš, Central Slovakia | 1480 | Comparision of 3 seed mixtures, different application technique, different fertilization | Exposition: North East Inclination: 17°-25° pH soil: 3.0-3.8 Seeding rate: both mixtures 15 g·m$^{-2}$ | Surrounding vegetation: Some 35 species of plants were found in adjacent sward, among them: *Melanpyrum sylvaticum, Vaccinium myrtillus, Vaccinium vitis-idaea, Hypericum maculatum, Rumex acetosella, Soldanella montana, Luzula luzuloides, Hieracium alpinum. Festuca rubra, Nardus stricta, Gentiana aschepiadea, Poa compressa, Agrostis rupestris, Festuca supina, Stellaria graminea, Senecio subalpinus.* |

## Results

### Austria: Obertauern

The set up for this site took place on 14 July 2004. Specific to this site were constant disturbances, due to continuing infrastructural interventions as building of an artificial lake and building or renovations of builings in the near surroundings (see also *Figure 1*). Also cattle came into the trial site and caused damage, resulting in patches without vegetation. Therefore, the overall cover is not homogenious, there are even patches found with no vegetation at all in 2006.

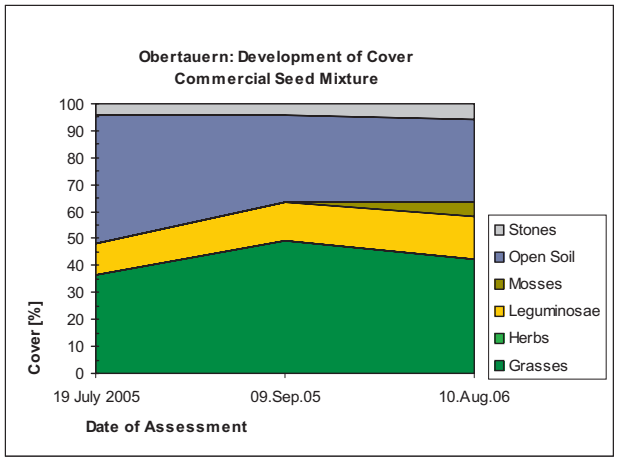
The trial consists of two plots: The first one represents the local state of the art with a commercial seed mixture and as application technique blank handsowing and mineral fertilizer. On the second plot, a site specific seed mixture and a long-term organic fertilizer was used, in combination with the black green system. With this application technique, the bare soil is covered with a mulch layer made of straw after seeding. The mulch layer helps to prevent erosion, as the complete surface is covered and rain can not directly hit the soil.

The development of the cover shows the following trend: All not site specific species show a decline in cover, resulting in a step decline in cover in the variant with the commercial seed mixture, whereas the site-specific species keep growing. In the end, the commercial seed mixture reaches not 70% of cover (see *Figure 3* and *4)*.

If you look at the cover on a species level, is becomes obvious that the cover of the commercial seed mixture comes in 2006 mainly from two species, which are known that they can adapt to high altitudes, namely *Phleum pratense* and *Festuca rubra* (see *Figure 5*).

*Figure 1:* **In the second year of the trial (2005), interventions continued at the trial site, for example storage pond was built in direct vicinity to the trial site**

*Figure 2:* **The trial site Obertauern in September 2005: The influence from ongoing construction work is obvious. On the left side, it is the construction work of the storage pond (see *Figure 1*)**



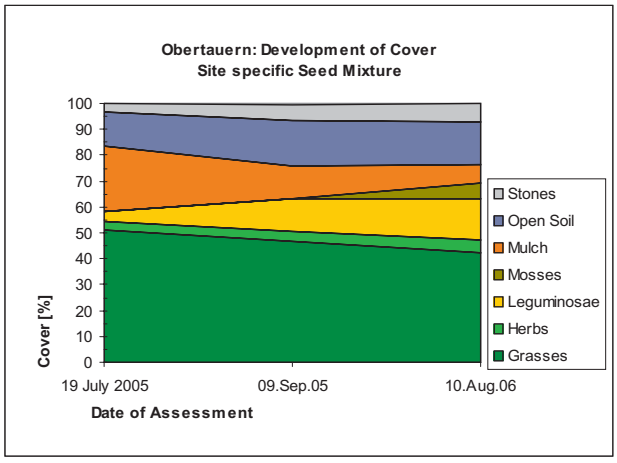




*Figure 3 (left):* **Development of overall cover at the trial site Obertauern, commercial seed mixture: 70% percent of cover for erosion prevention are not reached**

*Figure 4 (right):* **Development of overall cover at the trial site Obertauern, site specific seed mixture: 70% percent of cover for erosion prevention are reached at the end, but only with the help of mosses and remaining of the mulch layer applied (black green system). Further explanations in the text**

Species of the site specific mixture show (after a gap in 2005) an increase in the year 2006, whereas the species count from the commercial seed mixture show a constant decline.

Additionally, the different *Festuca* species in the site specific mixture (*Festuca nigrescens*, *Festuca pseudodura*, *Festuca supina*) could only be registered as *Festuca* sp., they started only at the end of the second vegetation period (2006) to differentiate. Therefore we have in the site specific seed mixture more or less all species from the mixture.

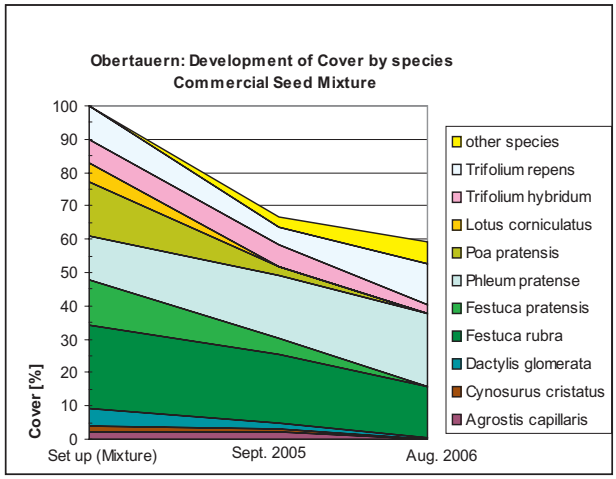
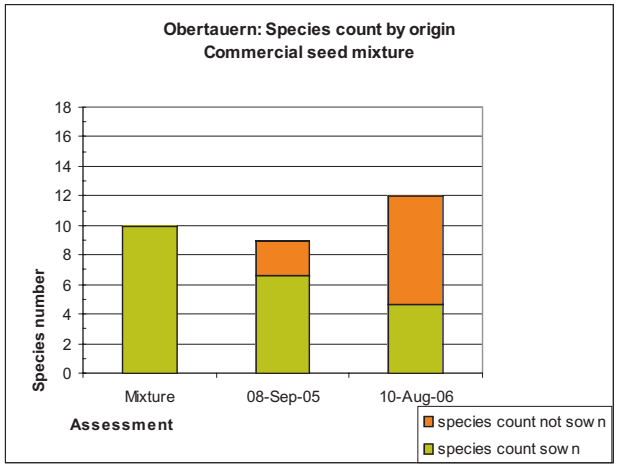



*Figure 5:* **Development of cover of species at the trial site Obertauern, commercial seed mixture. The main part is taken by only to species: *Phleum pratense* (light green) and Festuca rubra (dark green)**



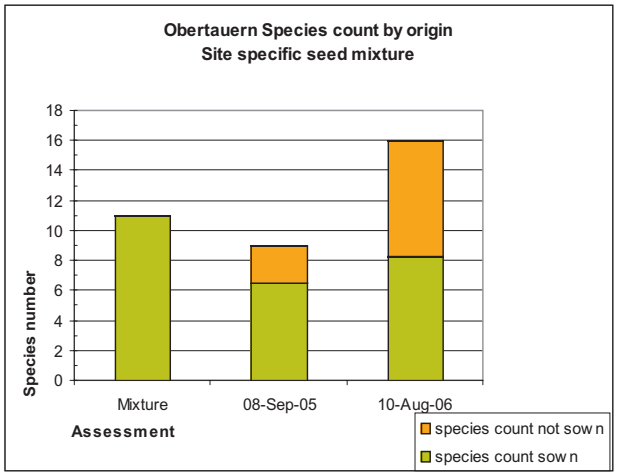



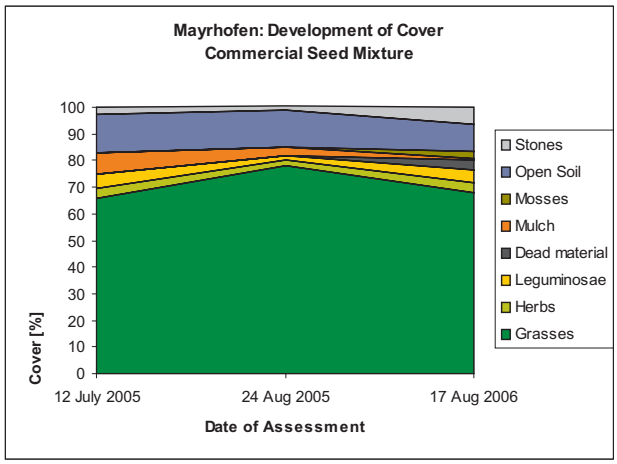

*Figure 6 (left): and Figure 7 (right):* **Species count (average of three replication) by origin (sown and not sown).**

## Austria: Mayrhofen

*Figure 8 (left): and Figure 9 (right):* **The trial site Mayrhofen immedeately after setup in July 2004 (left) and in July 2006 (right).**

The setup took place on 22 July 2004. The trial looks similar to the one in Obertauern, with one difference: On both parcels, the black green system was used, as the slope is very steep, with up to 45° to 50° (*Figure 8*). Also here disturbances took place, in the form of cattle grazing several times during all vegetation periods, and causing severe damages from trampling. This trampling had a relatively high impact, favoured by the steepness and wet conditions when the cattle broke in (*Figure 10*).

*Figure 10 (right):* **Damages caused by trampling of cows at Mayrhofen**



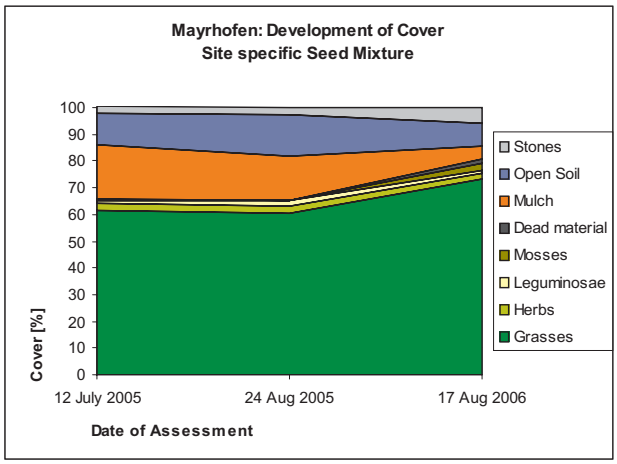




*Figure 11 and 12:* **Overall cover at the trial site Mayrhofen, split in main groups (grasses, herbs, legumes...). Both mixtures reach the necessary 70%, but the commercial seed mixture show already a decline in cover in August 2006.**

At this trial both mixtures perform satisfactory up to now (August 2006), but a decrease with the commercial mixture is already apparent (see *Figure 11* and *12*).

If you look at the cover on species level (*Figure 13*), also here, just like at the trial site Obertauern, *Phleum pratense* takes the biggest proportion, followed by *Festuca* species (most probably most of it *Festuca rubra*) and *Lolium perenne*. *Festuca rubra* and *Phleum pratense* are both known to adapt to high altitudes.

Seen from the perspective of origin, the site specific species show a continuous increase. Species number coming from the commercial seed mixture is in the first as high as in in the second full vegetation period. The low species number of the site specific species comes partly again from the not differentiated *Festuca* species in the mixture (*Festuca nigrescens*, *Festuca pseudodura*, *Festuca supina*) and even maybe some *Bellardiochloa variegata* may have fallen under this category - see *Figure 14* and *15*. Species not sown are all coming from the tall herb communities, where a stand is neighbouring.

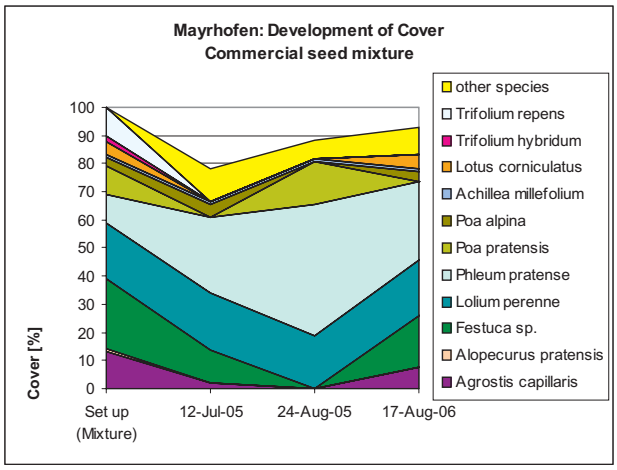
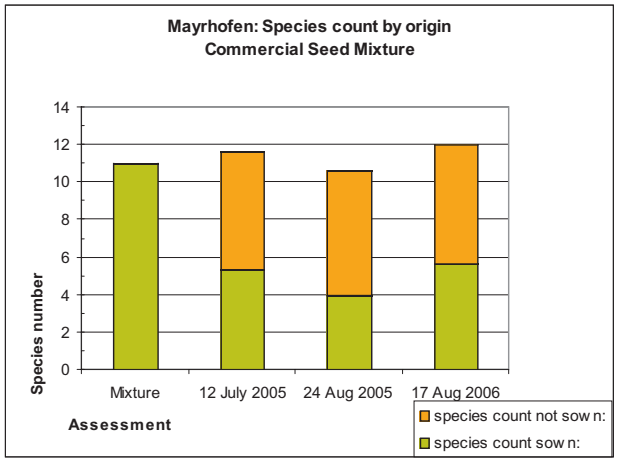



*Figure 13:* **Development of cover of species at the trial site Mayrhofen, commercial seed mixture.**

Also remarkable on the species level are the changes within the commercial mixture (see *Figure 13*), which may be an indication for further severe changes within the composition of species.



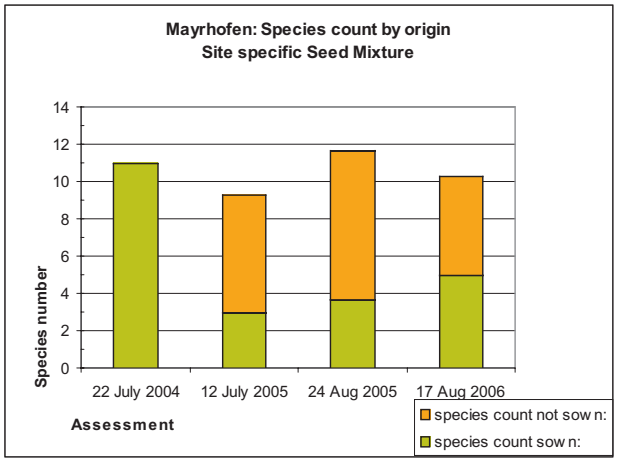
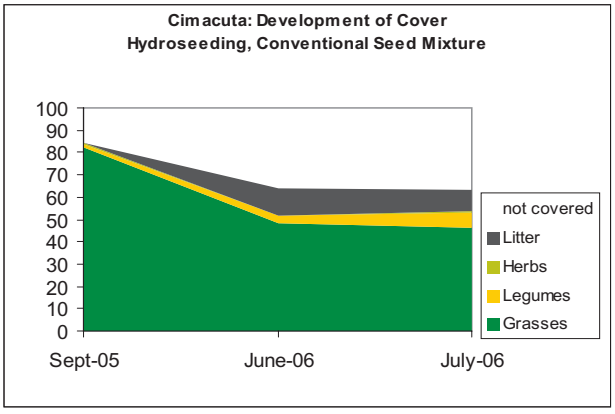




*Figure 14 (left) and 15 (right):* **Species count (average of three replication) by origin (sown and not sown).**

## Italy: Cimacuta Ski run, Forni di Sopra

In Italy, also trials on two different ski slopes were made, but only results from the one at Cimacuta are presented. The trial is constituted by the combinations of three application techniques (improved hydroseed with wood fiber mulch; conventional hydroseed with hay mulch; hydroseed with a bonded fiber matrix) with two seed mixtures (commercial and site-specific) for a total of 6 treatments without replicates. In the following, results only from selected variants (with and without mulch layer, both mixtures) are shown. Observations are concentrated on differences between application techniques.

*Figure 16:* **The trial site Cimacuta before set up**



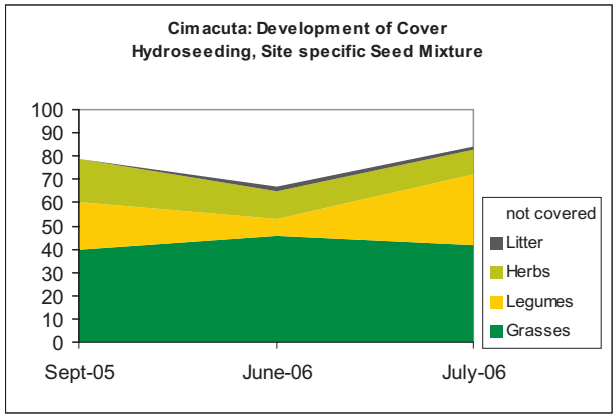
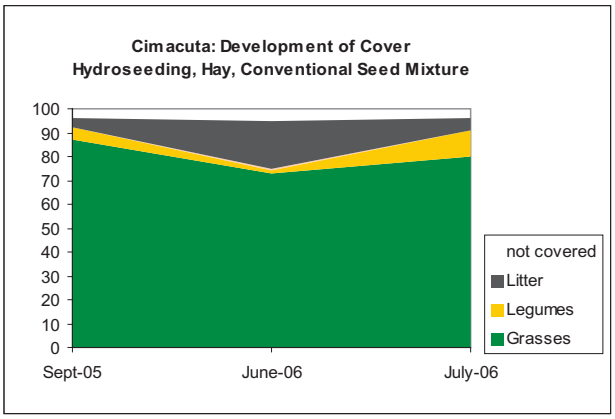




*Figure 17 (left) and Figure 18 (right):* **Development of cover, hydroseeding, but no mulchlayer in comparison of the conventional seed mixture (left) and site specific mixture (right).**



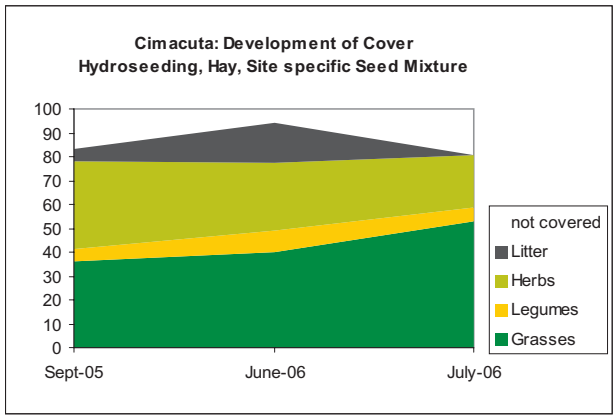
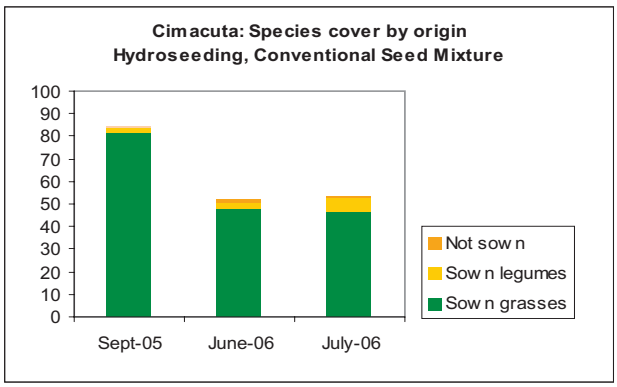




*Figure 19 (left) and Figure 20 (right):* **Development of cover, hydroseeding with a hay mulchlayer in comparison of the conventional seed mixture (left) and site specific mixture (right).**



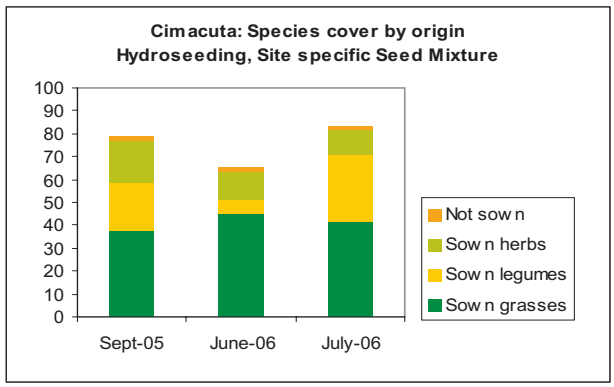
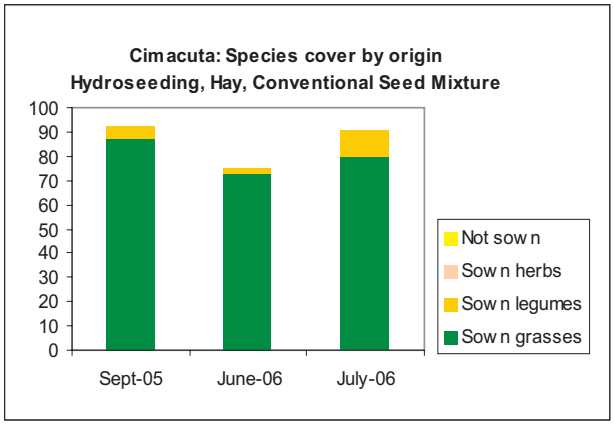




*Figure 21 (left) and Figure 22 (right):* **Proportion of cover of not sown species,application technique hydroseeding, no mulchlayer.**



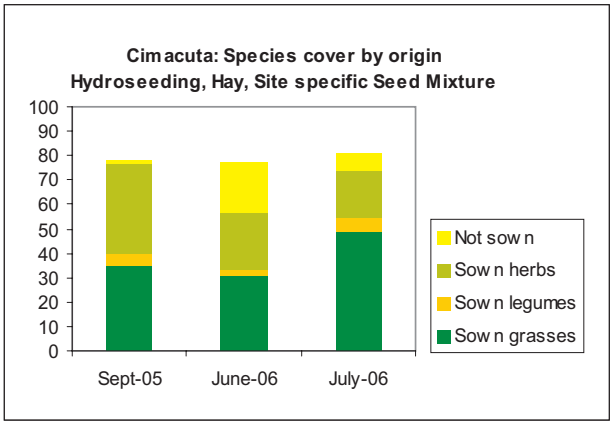




*Figure 23 (left) and Figure 24 (right):* **Proportion of cover of not sown species, application technique hydroseeding, hay mulchlayer.**

Without a mulch layer, only the site specific seed mixture reaches the critical 70% of cover, the conventional mixture is just over 50%.

With a mulch layer of hay, the conventional seed mixture reached even a higher cover (around 90%) than the site specific seed mixture (around 80%).

So, both mixtures are well above the 70% mark - see *Figure 19* and *20*.

## Greece

The set up took place at the end of March 2005.

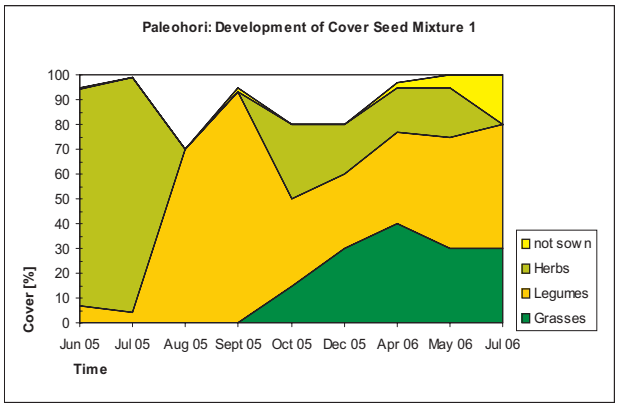
The set up contains three different application techniques with two different seed mixtures: Mixture 1 is the widely used mixture with 7 species, mixture 2 is an enhanced version with more and better adapted species (13 species). For this compilation only the variant "Conventional sowing by hand and fertilizer" are presented.

As it is visible from *Figure 26* and *27*, specially the legumes and herbs from mixture 2 are better adapted to the dry climate during summer.

The overall performance is satisfactory from both mixtures.

What is also remarkable are the changes in cover of the different groups, therefore further changes are to be expected. Additionally, as immigrating species from the surroundings are also remarkable.

*Figure 25:* **The trial site at Paleohori, Greece during the set up**



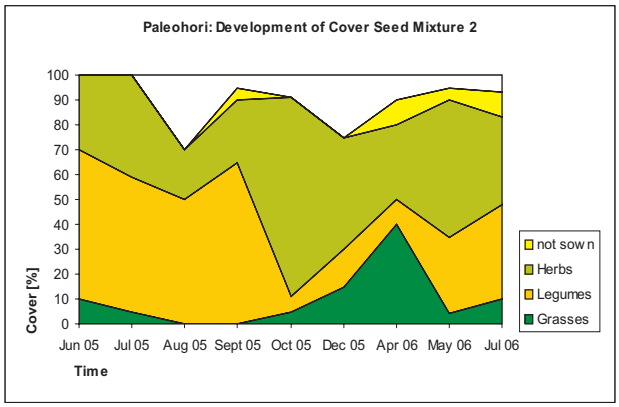




*Figure 26 (left) and 27 (right):* **Development of overall cover for from June 2005 (three month after setup) until July 2006**

## Slovakia

Three mixtures were compared: 2 different site specific mixtures, one originating from Slovakia (named GMAI), the other one coming from Austria and a Slovakian commercial mixture. With the site specific mixtures a straw mulch layer and fertilization was applied, the commercial mixture was sown by hand, without any fertilization.

Results from botanical surveys confirmed a very slow development of all mixtures. First observations in June 2005 showed the development of plant cover only in the bottom part of the trial plots. Probably some seeds were taken with the melting snow to the lower part of the slope.

In July 2005 the best plant coverage was found at GMAI variant (75%), to a lesser extent at the Austrian variant (65%) and the lowest plant coverage was at state of the art variant (50%). The differences between the first two variants were erased at the end of the growing season (in October, 2005), when the bare ground percentage of Austrian and GMAI variants was 12 and 16%, respectively. The state of art variant still showed 25% of the bare ground.

The development of GMARI and Commercial mixture was more rapid in the summer of 2005, allthough the results of botanical surveys in 2006 showed comparable development considering cover and percentage of bare spots. Surrounding plant species are penetrating into all mixtures. Site-specific species were not so strong in their development and coverage in the first year (2005), but their coverage strongly improved in the second year. The percentage of bare spots in June 2006 was in the Austrian, GMARI and Commercial mixture 17.5, 14.5 and 21.5 %, respectively (see also *Figure 27* and *28*).

As the growth dynamics of the variants showed differences, it is necessary to continue observation, no final conclusions are possible with the available data.

## Discussion

Advantages of the use of site specific seed mixtures for ecological restoration at high altitudes, specially in combination with advanced application techniques, are already well documented and demonstrated on a wide area (Peratoner 2003, Krautzer and Wittmann 2006, Kirmer and Tischew 2006). Also the results shown here from demonstration sites fit in general into this pattern.

The use of advanced application techniques, especially the application of a mulch layer shows advantages: The bare soil is immediately protected against erosion and the seedlings get better conditions for germination and growth. In alpine environments, only a combination of high-quality site-specific plant or seed material with the optimum restoration technique will bring permanent success.

*Figure 26:* **The trial site in Slovakia in October 2005**

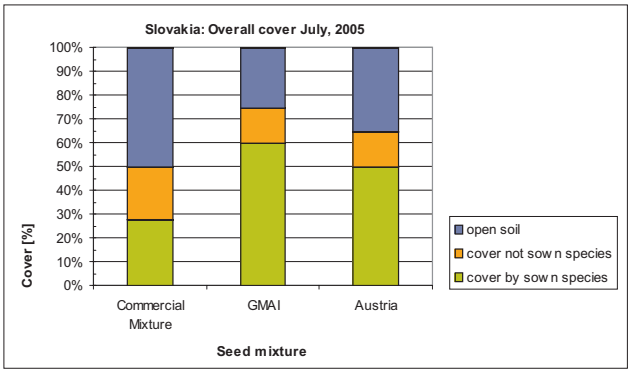



*Figure 27:* **Cover in comparison at the beginning of the first vegetation period, divided by origin.**

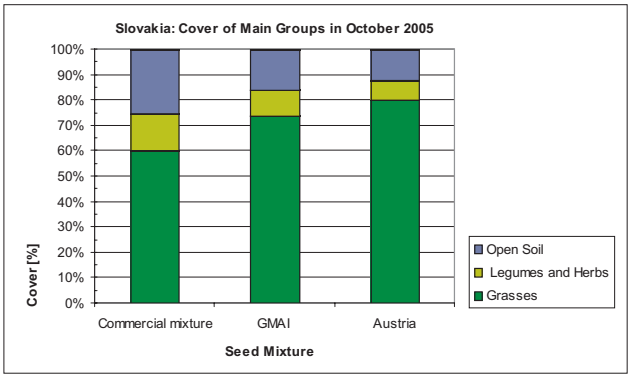



*Figure 28:* **Cover of main groups in comparison at the end of the first vegetation period.**

Problems did occur specially on the Austrian sites with severe disturbance happening during the whole trial period. But on every trial site, the site specific seed mixture performed at least as well as the commercial counterparts, in most cases and variants better. As the example from Austria shows, even those mentioned disturbances can be at least partially compensated, because despite of harsh climatic conditions at the sites, the site specific species are able to reproduce and make up a self-sustaining vegetation cover (Blaschka et al. 2005). Many of the commercial variants showed only after two growing seasons symptoms of nutrient deficiency, whereas the site specific species showed increases in cover and biomass.

Good perfomance of both mixtures (commercial and site specific) up to now at Mayrhofen (Austria) comes most probably from two reasons: a relatively high amount of fine material and, specially in the area of the commercial seed mixture a for this altitude good supply of nutrients in the soil. In direct neighbourhood, there is a tall herb community with alder. Those tall herb communities are known for higher nutrient content in the soil. But during the last assessment in August 2006, a decline in cover was remarkable, in contrary to the site specific seed mixture, where an increase in cover was obvious. Another important question, in this compilation only a sidenote, is fertilization: Varieties from lowland grassland farming need a high amount of nutrients, specially in comparsions to species from high altitudes, with are in general communities with a low demand on nutrients.

This considerations lead also to the conclusion that ecological restoration at high altitudes is in general more or less a long term process, a final success can only be evaluated after at least two vegetation periods. Specially the lowland species, mostly pushed with mineral fertilizer, show a quick development, but soon start to deteriorate when the effect of fertilization is gone.

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