Near-natural restoration in surface-mined land (WP 3)

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The general aim of the project is to put basic strategies into practice that guarantee ecological and sustainable restoration of sites with extreme site conditions. Restoration of surface-mined land with alternative restoration methods (acceleration or start of near-natural vegetation development) should enable sustainable vegetation development, and control erosion. The developing areas can be used for nature conservation or recreational use. Based on results obtained during the last years, it is the aim of work package 3 to establish a new state of the art in restoration and integrate alternative restoration strategies (e.g. application of seed-rich plant clipping material, mulch seeding with site-specific species of local provenances) in future restoration schemes.

Introduction

Seeding is most common in traditional recultivation. Standard seed mixtures require mostly a considerable change of the given site conditions (e.g. liming, amelioration). They often promote the development of species-poor plant communities with low aesthetic value. The seeding of ecotypes derived from plant-breeding establishments is not in accordance with the Convention on Biological Diversity. Also, exotic species or garden varieties can be found frequently in seed mixtures (e.g. *Sanguisorba muricata*, *Leucanthemum maximum*). For example the German Federal Act on Nature Conservation demands the use of local ecotypes in restoration of landscapes outside settlements (except agriculture and forestry). The conflict between "new" knowledge and "old" traditional methods of recultivation is not solved until now.

Near-natural restoration methods like application of seed-rich plant clipping material and mulch seeding of site-specific species of local provenances can be used to start or accelerate near-natural vegetation development. They are meant to replace traditional recultivation with standard seed mixtures in areas that are planned for nature conservation and recreational use and they should avoid expensive aftercare. Used in the right way, they effectively prevent erosion and promote sustainable development of species-rich plant communities that are optimally adapted to the given site conditions. The use of local material (hay, fresh plant clipping material) or seeds of local provenances stops the adulteration of the local flora and protects the genetic diversity of the local species pool.

The sites chosen for demonstration projects are located

❶ in the Profen mining site that is part of the Zeitz-Weißenfels lignite mining district (Federal State of Saxony-Anhalt, Germany), where lignite mining can be traced back to the middle of the 18th century. The trials are on a slope site that was built in autumn 2004.

❷ in an industrial area near the towns Ostrava and Karvina (north-eastern region of the Czech Republic) where black coal has been mined since the second half of the 19th century. The trials are on a recultivated slag heap that was built in 1980, recultivated and turned into arable land from 1988 until 1995, and turned into fallow land since 1995, without management.

Material and Methods

Pilot project No. 9

The pilot project No. 9 is situated in the Profen mining site. The trials were established in block design with five variants (see below) at December, 15th/16th, 2004 in the middle and upper parts of the slope site with an area of about 1.2 ha (240 m x 50 m). The location in Gauß-Krüger Coordinates is HW 5666800 - 5667400 and RW 4510400 - 4511300 and the altitude ranges from 161.9 to 177.3 a.s.l.. The slope has a south-western exposition and an inclination in the eastern part of 1:5 and in the western part of 1:4. The substrate of the slope contains of boulder clay and sand mixed with small amounts of topsoil (loess) from arable land. The pH value is around 7. Before the set up, the surface was profiled with caterpillars to reach a structure that enhances and protects germination and establishment of the sown species and reduce erosion on sites without mulch application. In summer 2005 the sites were mown once to suppress species from the soil seed bank of the arable land (mainly *Chenopodium album*).

Standard seed mixture with and without mulch

State of the art is the standard seed mixture No. 7.2.1. without herbs (*Festuca ovina duriuscula* (60 %), *Festuca rubra commutata* (10 %), *Festuca rubra rubra* (10 %), *Festuca rubra trichophylla* (10 %), *Lolium perenne* (10 %). They were sown with a density of 10 g seeds/m² (= about 9700 seeds/m²). In December 2004 for the variant standard seed mixture without mulch three stripes à 1000 m² and for the mulch seeding three stripes à 700 m² were sown by hand (see *Figure 1*).

Afterwards on the mulch seeding variant hay from Mulde dikes was applied by hand with a density of about 1 kg/m².

Site specific seed mixture with and without mulch

The sown species were chosen according their ability to grow on dry, sunny sites (species of dry grassland, semi-dry grassland, nutrient-poor ruderal communities and ecotonal communities). They also should satisfy aesthetic demands (e.g. *Coronilla varia*, *Dianthus carthusianorum*, *Linum austriacum*). Additional the establishment of rare species like *Achillea nobilis* and *Tetragonolobus maritimus* should be promoted. Species like *Daucus carota*, *Hypericum perforatum* or *Poa compressa* showed a very high abundance in all mining sites and therefore a very good site-specific suitability. According to the amount of sand in the substrate, eleven additional psammophytic grassland species were chosen that are especially adapted to sandy and dry site conditions (e.g. *Centaurea stoebe*, *Dianthus deltoides Trifolium arvense*). Altogether 51 species were selected (11 grasses, 40 herbs). In December 2004 they were sown by hand on six stripes à 1000 m² (see *Figure 1*) with a density of 2450 seeds/m² or about 3.5 g/m². On three of the stripes a mulch layer was applied by hand with a density of about 1 kg/m². 20 % of the mulch came from a seed-poor grassland (second cut) and 80 % from Mulde dike management measures.

Seed-rich hay

The area where hay mulch was taken is nearby the city of Groitzsch in about 10 km distance to the pilot project. Phytosociolocial, the area belongs to the *Onobrychido-Brometum erecti* Th. Müller 1968 with several species from moist meadows. In June 2004 and July 2005 71 species were recorded (15 grasses, 56 herbs), among them 51 target species of dry and mesic grassland as well as ecotonal communities (11 grasses, 40 herbs: e.g. *Astragalus glycyphyllos*, *Bromus erectus*, *Centaurea scabiosa*, *Ononis spinosa*, *Silene nutans*, *Tragopogon pratensis*, *Trisetum flavescens*). The mowing took place twice in 2004: from July, 19th until July, 27th and from August 30th until August 31st. Due to the delay in finishing of the slope site, the material had to be dried, rolled in bales and stored in a barn until the set up was possible in December 2004. During the storage a part of the fine, seed-rich material got lost, so that the amount of transferred species was lower than expected. The hay was applied by hand on three stripes à 300 m² (see *Figure 1*) with a density of about 1 kg/m².

Data assessment

On all variants complete species lists were compiled in July and October 2005 as well as in May and July 2006. Relevés with percentage coverage of species and layers were made in July and October 2005 and in May and July 2006 on 5 m x 5 m permanent plots with three (site-specific seed mixture without mulch) or nine (all other variants) repetitions.

Pilot project No. 10

The field trials were established on two different localities (Pilnok and Lipiny, see *Figure 2*) at September, 9th 2004. Three variants were applied with Hydrojet seeding (the seeds were applied together with cut straw (80 g/m²) and special adhesive material, without fertiliser). In Pilnok weed was mown on August, 2nd 2005. In Lipiny the variant C "Normal" was fertilised on August 2nd 2005 (30 kg N, 30 kg P_2O_5 and 30 kg K_2O per ha) because of the poor development of the grass sward.

The **Pilnok** site has an extension of 2478 m². The steep slopes (inclination 40-50 %) on both sides of a road were built from slag heap material which was separated from the coal during the mining process. The nutrient-poor, black material is reaching very high temperatures during summer and is prone to a high wind and water erosion. The slopes have a south-eastern and north-western exposition with a pH value of 7.0 (K_{Cl}). The amount of fine material on the substrate is only 13 %.

The **Lipiny** site has an extension of 6150 m². The same material as in Pilnok is covered by soil (about 15 cm) of

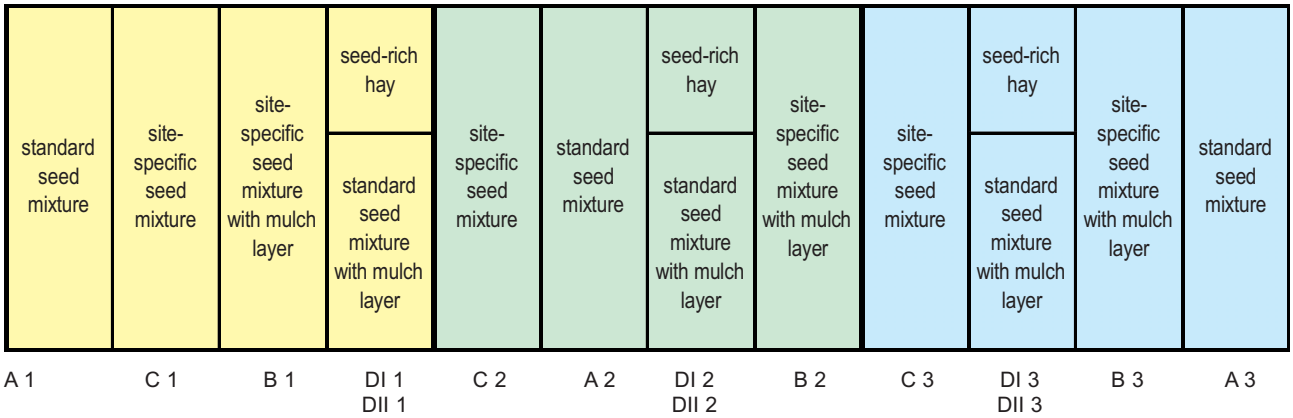


Figure 1: **Design of pilot project No. 9 in the mining site Profen (Germany).**

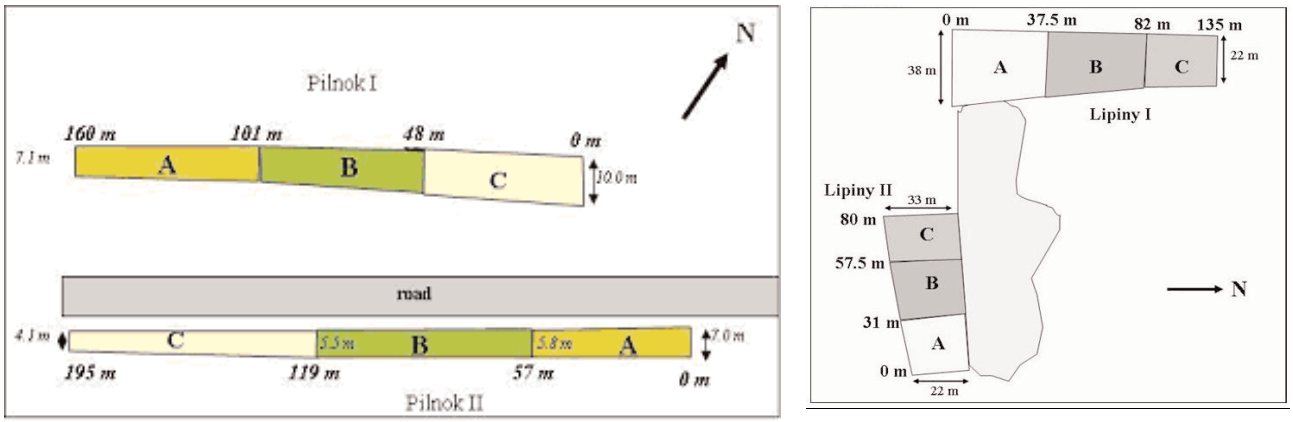


Figure 2: **Design of pilot project No. 10 in the Czech Republic: Pilnok I and II (left) and Lipiny I and II (right).**

different quality. The slopes showed an inclination of 10-30 % and a pH value between 4.7 and 5.6 (K_{Cl}). They are threatened by water erosion. The fine material that consists of clay loam and sandy clay loam has a share of 42 % on the substrate.

Mixture A "Spoilslope"

The mixture contains 44 site-specific of different species groups (dry and mesic grassland, ecotonal communities, nutrient undemanding species of ruderal communities: e.g. *Anthyllis vulneraria*, *Bromus erectus*, *Euphorbia cyparissias*, *Genista tinctoria*, *Hypericum perforatum*, *Lotus corniculatus*, *Oenothera biennis*, *Origanum vulgare*, *Thymus serpyllum*, *Vincetoxicum hirundinaria*). They were sown with a density of 2.35 g/m² (= 2930 seeds/m²).

Mixture B "Claycover"

The mixture contains 26 site-specific species of different species groups (dry and mesic grassland, ecotonal communities, nutrient undemanding species of ruderal communities: e.g. *Agrostis capillaris*, *Campanula glomerata*, *Daucus carota*, *Hypericum perforatum*, *Leontodon hispidus*, *Lotus corniculatus*, *Trifolium montanum*, *Trisetum flavescens*). They were sown with a density of 2.35 g/m² (= 3300 seeds/m²).

Mixture C "Normal" (OSEVA PRO, Ltd.)

The state of the art mixture contains two *Lolium perenne* varieties (Numann and Taya, each 20 %), two *Festuca rubra* varieties (Engina and Tatjana, each 20 %) and two *Poa pratensis* varieties (Baron and Enprima, each 10 %) with a sowing density of 20 g/m² (= c. 26500 seeds/m²).

Data assessment

Species lists with percentage coverage of species were made on 5 m x 4 m plots with three repetitions in June 2005, August 2005 (Pilnok), September 2005 (Lipiny), May 2006, and August 2006. Complete species lists were compiled in May 2006 and August 2006 from the whole variants. Additional on each variant ground coverage and percentage coverage of botanical groups (grasses, herbs, legumes) were estimated in November 2004, May 2005 (Lipiny), June 2005, August 2005 (Pilòok), September 2005 (Lipiny), May 2006, July 2006, and August 2006.

Results

Pilot project 9

Regarding total coverage, the amount of target species on the coverage, species number, and number of target species (*Figure 3* and *4*) the variant site-specific seed mixture with mulch was most successful. On the variant site-specific seed mixture without mulch the vegetation development was delayed but a gradual approach to the mulch variant could be detected in the second year. Already in the first year 65 % (without mulch) respectively 80 % (with mulch) of the sown species had been established on the sites. The establishing rate remains the same in the second year. If all observed species during the whole observation period were considered, the germination rate amounts to 75 % (without mulch) respectively 88 % (with mulch). Some species (e.g. *Poa annua*) were out-competed very soon because of the fast vegetation development.

Concerning the share of target species on the number of species and on the average coverage all near-natural methods are more successful than the two standard variants (*Figure 3* and *4*). Here, the vegetation is dominated by *Festuca* ssp., but high competition between innumerable small tussocks of *Festuca* led to a decrease in coverage during the observation time. *Lolium perenne* (mesic grassland group) reached a coverage of about 5 % until 2006.

The success of the variant seed-rich hay is hampered by the partly loss of the fine, seed-rich material during storage. In July 2006 the total average coverage reached only 50 % with a low amount of psammophytic and dry grassland species (*Figure 3*). The average species number is comparable to the site-specific variants (*Figure 4*).



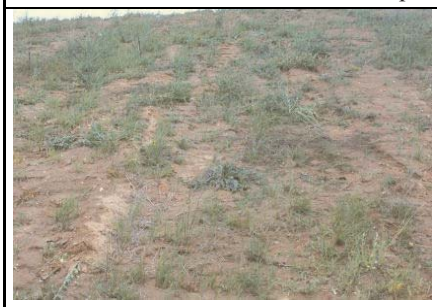
July 2005 May 2006 July 2006

standard seed mixture without mulch on pilot project No. 9 in the mining site Profen (Germany)



October 2005 May 2006 July 2006

standard seed mixture with mulch on pilot project No. 9 in the mining site Profen (Germany)



July 2005 May 2006 June 2006

site-specific seed mixture without mulch on pilot project No. 9 in the mining site Profen (Germany)



July 2005 May 2006 June 2006

site-specific seed mixture with mulch on pilot project No. 9 in the mining site Profen (Germany)



July 2005 May 2006 July 2006

seed rich hay on pilot project No. 9 in the mining site Profen (Germany)

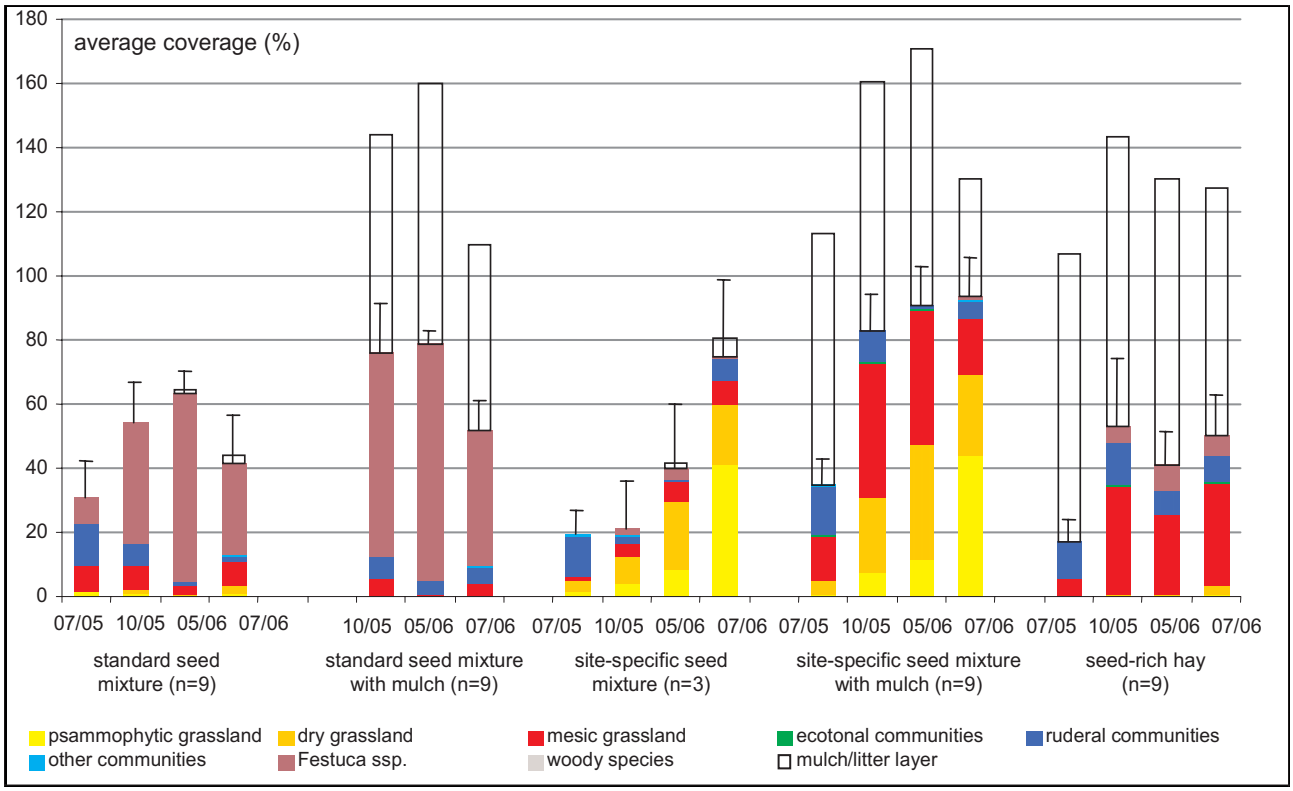


Figure 3: **Development of the average coverage on pilot project No. 9 with standard deviation for total coverage.**

The transmission rate amounted to 50 % (all species) respectively 58 % (only target species). In comparable studies the transfer of the whole material resulted in higher transmission rates (examples in KIRMER and TISCHEW 2006 [1]). Nevertheless, on the pilot project a sufficient vegetation development and erosion control could be obtained. Transfer of species-rich plant clipping material or seed-poor mulch should be made preferably with fresh material because during the drying process the mulch layer stick to the soil surface and therefore can not be blown away by wind. Additional the fine, seed-rich material will fall out during storage. If it is necessary to use dry material (e.g. hay), the fine material must be gathered for application and the mulch layer must stay at least one night on the site so that the nightly dew formation enables adhesion to the soil surface. Therefore the application of dry material should be avoided during windy weather (e.g. winter storms).

Pilot project 10

On all sites spontaneously developed vegetation could be observed before set up of the trials. In *Figure 5* and *6*, the development of the spontaneous vegetation is marked in yellow colour. Due to the extreme site conditions at the Pilnok locality, vegetation cover reached only about 40 % until the second year on all variants. On the variants Spoilslope and Claycover the increase of the coverage of sown species is slightly higher than on the variant Normal. Comparable to other extreme sites (e.g. natural dry grasslands) it can be assumed that below-ground competition hampered the increase in above-ground coverage (e.g. STOLLE 2000 [2]). Intensive root development as it can be observed under extreme site conditions (mainly draught or nutrient-deficiency) can inhibit erosion processes.

More hospitable site conditions at the Lipiny locality lead to a vegetation cover of 60-80 % until the second year (*Figure 5*). On all variants, sown species increased their coverage during the observation period up to 50 %. Due to the fertilisation in autumn 2005, the variant Normal eventually reached the same coverage than the variants Spoilslope and Claycover. Slightly denser canopy was formed only by the mixture Claycover (80 %).

The species increased in number especially in the second year after seeding (*Figure 6*). As for the percentage of species found, both site-specific mixtures are quite similar. During the last observation of the mixture Claycover, six species at the Pilnok locality (23 % of the mixture) and nine species at the Lipiny locality (35 % of the mixture) were recognised. From the mixture Spoilslope nine species were recorded at the Pilnok locality (20 % of the mixture) and 14 species at the Lipiny locality (31 % of the mixture). In the species-rich mixtures, *Daucus carota* and *Festuca ovina* are most successful on all sites. At the Lipiny locality, the following species were present during the whole observation period: *Agrostis tenuis*, *Bromus erectus*, *Holcus lanatus*, *Lotus corniculatus*, *Poa compressa*. At the Pilnok locality *Festuca pallens* and *Pimpinella saxifraga* could be observed.

Spoilslope: Pilnok I 04/05

Spoilslope: Pilnok II 05/06

Spoilslope: Pilnok I 08/06

Pictures of pilot project No. 10

Claycover: Pilnok II 10/04

Claycover: Pilnok II 06/05

Claycover: Pilnok I 08/06

Normal: Pilnok I 10/04

Normal: Pilnok II 05/06

Normal: Pilnok II 08/06

Claycover: Lipiny I 04/05

Claycover: Lipiny I 10/05

Spoilslope: Lipiny I 04/05

Spoilslope: Lipiny I 10/05

Normal: Lipiny II 04/05

Normal: Lipiny II 10/05

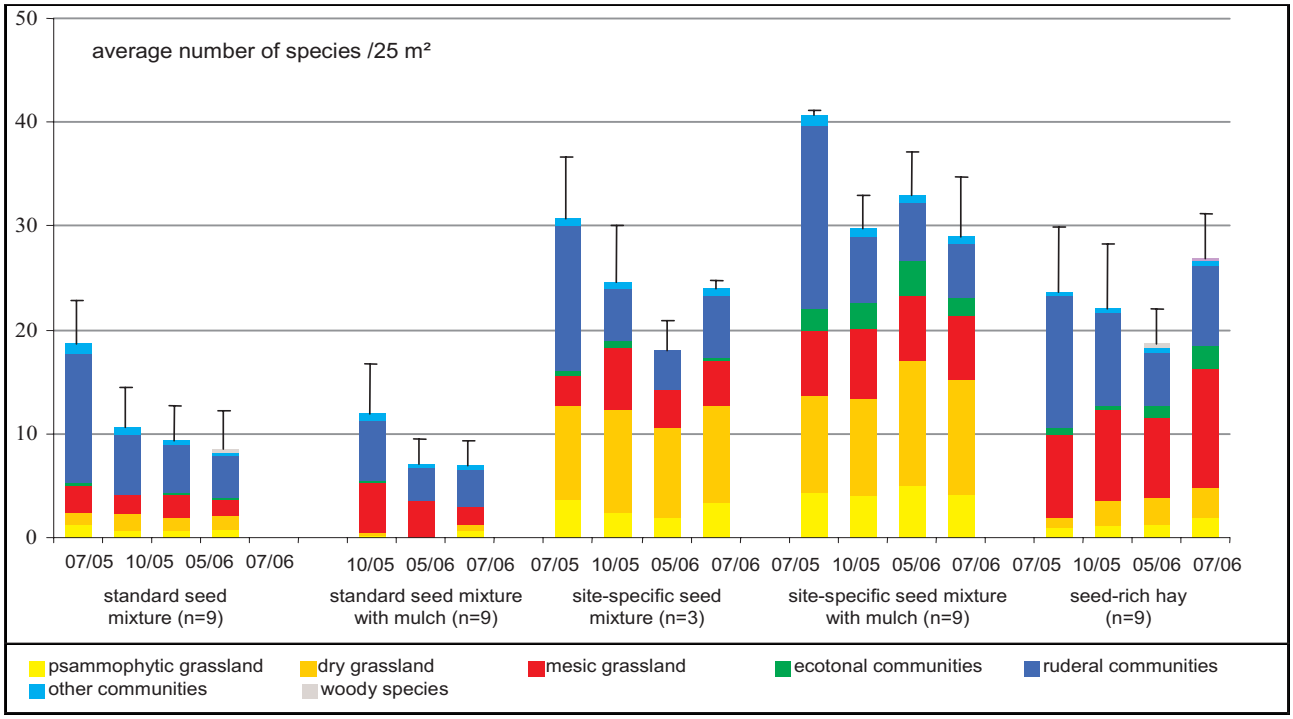


Figure 4: **Development of the average number of species on pilot project No. 9 with standard deviation for total species number.**

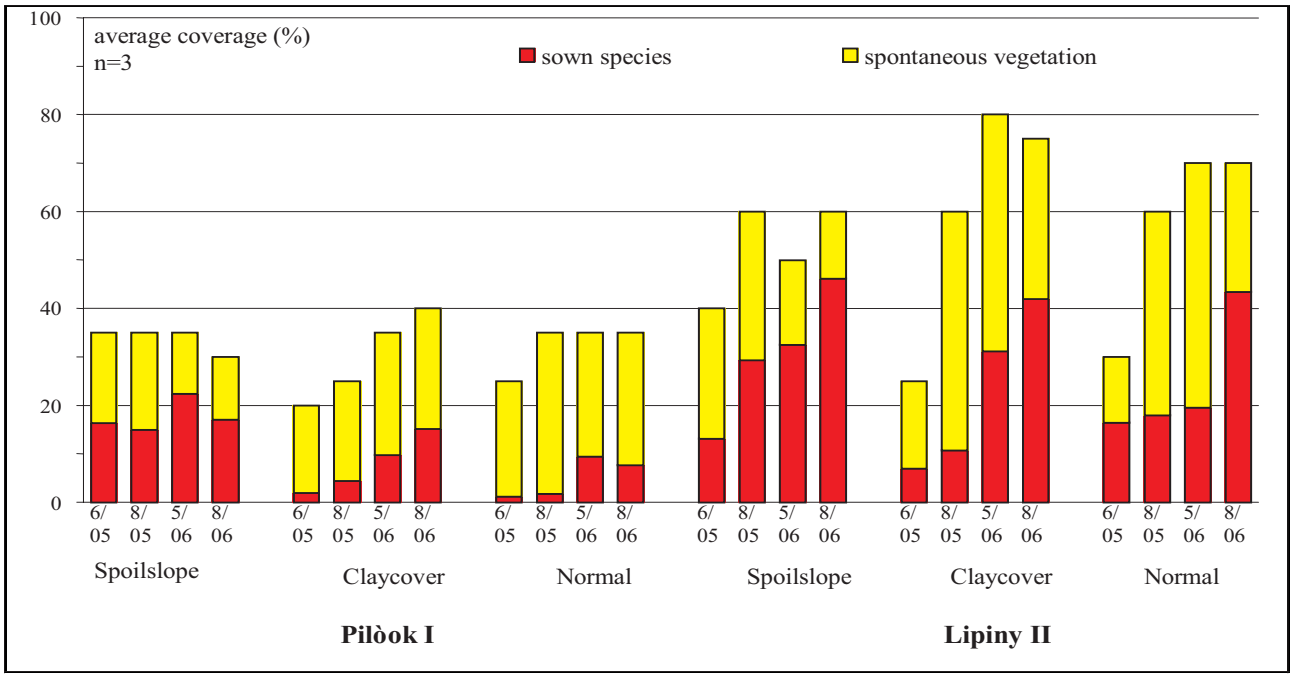


Figure 5: **Average coverage on pilot project No. 10**.

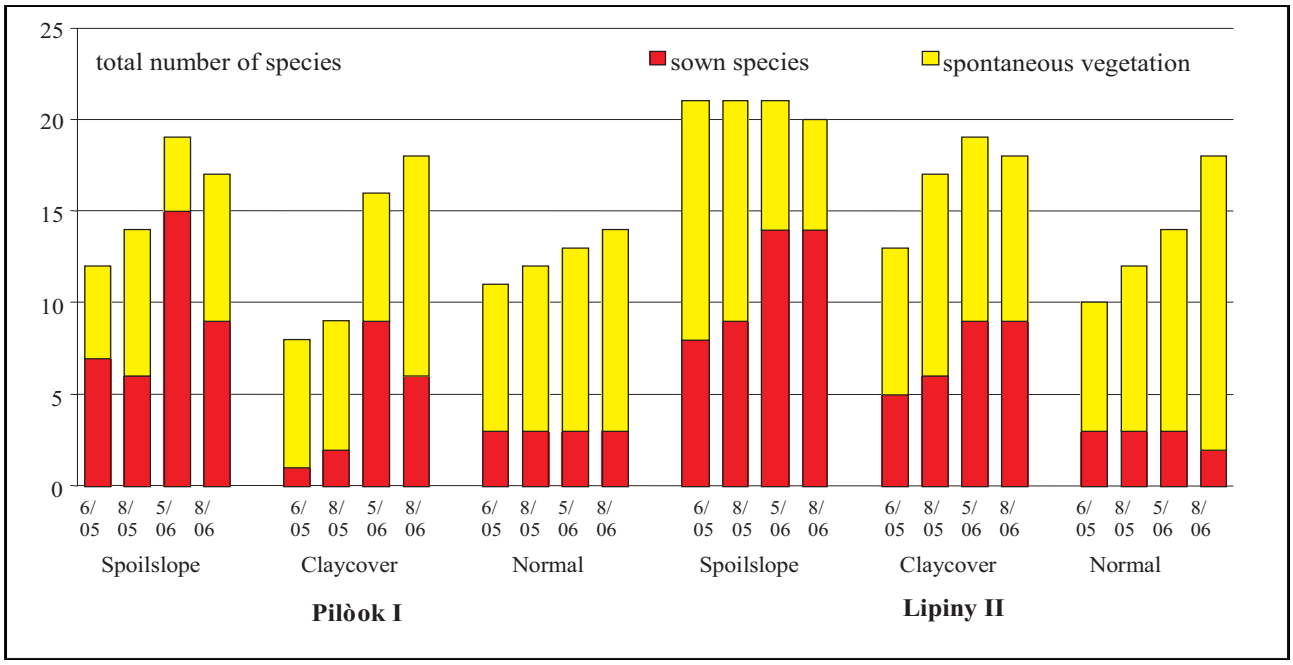


Figure 6: **Total number of species on pilot project No. 10.**

Vegetation development of the trials in Pilnok was affected by the absence of a protective layer which would have reduced summer heat and improved moisture conditions on the site. The amount of straw in the Hydrojet seeding was not sufficient.

Additional, the decomposition of straw needs nitrogen and therefore increases the stress for the establishing vegetation.

In spring, a favourable effect of autumn hay mulch was evident but during the subsequent drought in summer a large number of the emerged plants died (personal observation). This lead to the conclusion that almost all niches for establishment are already taken by the existing vegetation.

Conclusions

Near-natural restoration methods are very successful in acceleration of vegetation development on raw soil if the method chosen is appropriate for the given site conditions. On extreme sites, a hay mulch layer gives protection against drought and summer heat and it releases a small amount of nutrients during decomposition. Additional, the application of a mulch layer ensures an effective and immediate erosion control. For the survival during extreme summer draughts an extensive root system is required. Only a sparse vegetation cover (30-40 %) with less competitive stress ensures the development of extensive root systems. If the existing sparse vegetation cover prevents erosion the development of a dense sward is not necessary and because of extreme site conditions anyway not possible. On less extreme sites the vegetation cover on variants with site-specific seed mixtures reached 50-80 % after two years of development. For long-term prognoses of the vegetation development on the sites further examinations are necessary.

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