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Analysis of the initial vegetation development on sown sites after landslides in the valley Schwarzenseebach, Nature Park Sölktäler (Styria, Austria)

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Abstract

Heavy rainfall events resulting in landslides and floods are increasing natural hazards in mountainous areas. A fast and sustainable vegetation re-establishment is of upmost importance, especially in regions where agriculture and tourism are the main economic sectors. In this work, I analysed the initial vegetation development on revegetated sites in the valley Schwarzenseebach (Nature Park Sölktäler, Styria) after landslides devastated the mountainous area in 2010. Data was collected on 52 (4x4m) plots concerning vegetation cover, grass cover, legume cover, herb cover and bryophyte cover in 2012. Thereby, the different vegetation measures "straw layer absent" and "straw layer present" were analysed as well as present "lime application" and "farmyard manure application". Additionally, the occurring plant species were determined and their abundance was estimated using a modified Braun-Blanquet scale. The aims were to evaluate the treatments after revegetation and to show how the applied substrate affected vegetation development and plant growth. Furthermore, knowledge was obtained about plant development of sown species after vegetation re-establishment.

My results show, due to the present bare soil with lack of humus and fine-earth fraction, plant growth was mainly inhibited. Hence, vegetation cover was low. The initial plant community was characterized by species from the disseminated seed mixtures dominated by sown grass species and legumes. Straw application decreased vegetation cover significantly. Due to limiting conditions lime application did not increase vegetation development. The work highlighted the importance of revegetation measures and that the application of straw and lime on bare soils has to be avoided. Humus build-up is of upmost importance. However, an overall fertilisation of the pastures in the valley Schwarzenseebach is prohibited due to the Natura 2000 program. The dissemination of commercial seed mixtures need also to be discussed.

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1. Introduction

The likelihood of extreme weather events and disasters with high frequency and magnitude are increasing due to climate change (Mirza 2003). In this context increasing air temperatures and differently distributed precipitation rates raise the probability of extreme weather events outside the tropical regions. That means there will be more heat waves, droughts, heavy precipitation events, floods and wind storms in the future (Beniston et.al. 2006; Groisman et.al. 2004; Mirza 2003). Many European countries experienced such devastating events in higher numbers over the last years. Therefore, the increasing number of insurances against climatic caused hazards is an important value to be considered (Beniston et al. 2006).

In Austria, there have been a lot of extreme weather events over the last years. The alarming trend of more extreme weather events with catastrophic outcome is analysed by the Austrian 'Hagelversicherung'. According to prior years, agriculture suffered major losses due to hail, floods and droughts (Hagelversicherung 2013). Beside cropland and grassland in beneficial regions, mountainous areas experienced enormous damage due to heavy rainfall events and floods. The vulnerability is obviously caused by the steepness of slopes and narrow valley floors, which favour the formation of landslides and log jams followed by floods (Angerer 2005).

One of the most devastating heavy rainfall events happened in the Nature Park Sölktäler in the valley Kleinsölk. An enourmous area was devastated due to landslides and broken log jams in 2010. The affected regions were the valley Schwarzenseebach, the area around Breitlahnalm, the municipality Sölk as well as the village Stein an der Enns. In more detail, the region from the Kesslerkreuz to Putzentalalm was mostly affected by the heavy rainfall and destroyed by landslides (Nerat 2010; Naturpark Sölktäler 2014).

The heavy rainfall event happened on the 17th of July 2010 after 6:00pm. During a time period of three hours 120mm rain and hail felt onto a relatively small area in the Nature Park. The reason for the enormous rain amounts was the circulation of a 70km^2 big thunder-cell in the valley Schwarzenseebach. The formation of that thunder cell was caused by a cold front moving from west to east interrupting a period of very high air temperatures (BMLUFW 2011; Kieninger & Postl 2013).

The rainfall was so intense that 400.000 m³ of mud and boulders slid down to the valley bottom and destroyed a 40.000 m² bank of wood. These factors together resulted in several log jams, which impounded the river Schwarzenseebach and further the river Kleinsölkbach. In summary, landslides blocked the valley on three sites. The Austrian Torrent and Snowslide Control calculated following values: Around the area called Kohlung mud and boulder impounded 210.000m³ water, around the Sachersee 586.000m³ and around the river Stummerbach 80.000m³ water and mud (Nerat 2010; Naturpark Sölktäler 2014). Figure 1 gives a slight overview how intense the heavy rainfall event was on the 17th of July in 2010.

Figure 1: Valley bottom in the Nature Park Sölktäler after the heavy rainfall on the 17th of July 2010. Breitlahn. (Nature Park Sölktäler ©)

Several log jams broke in the evening hours and the village Stein an der Enns was flooded. All of the 12 bridges and small transitions were torn away or damaged. Two kilometres of road in the valley Kleinsölk were completely destroyed. Several farming buildings were damaged too, but fortunately nobody was injured during the landslides and floods. Finally, a mountain area of 220 ha was devastated, at which 150 ha had to be revegetated. The total financial loss was about 15 million Euro (Nerat 2010; Kieninger & Postl 2013; Naturpark Sölktäler 2014).

The enormous rain amount in such a short time (120l in 3 hours) was the main reason for the catastrophe. Rain caused a decline of the static friction between soil particles. In combination of the shallow soil and the steepness of the slopes landslides were formed (Naturpark Sölktäler 2014). However, it has to be considered that landslides are natural processes, which create new habitats and are required for the formation and creation of new landscapes (Schaaf et.al. 2011).

A supporting factor, which affected the formation of several landslides, may be a wind storm in autum 2002. The heavy wind caused numerous trees to break and these conditions were used by the bark beetle (*Scolytidae*), which harmed the development of many trees on the steep slopes. All together the forest lost its protective function and its water retention properties on several sites. During the heavy rainfall in 2010 affected trees were easily washed away (Bieringer 1984; Kieninger & Postl 2013).

Several revegetative actions were carried out to regenerate the landscape in the Nature Park Sölktaler after the 17th of July 2010, especially in the valley Schwarzenseebach. The basis was made by diggers, which worked several months to stabilise the courses of rivers and to clear away coarse material. Help came from the local fire brigades, the Austrian Federal Armed Forces and many volunteers. Afterwards different revegetative actions took place. These treatments are the main point of the study and are described in the methods chapter in more detail.

Due to the loss of pasture area after the heavy rainfall event, the livestock population had to be reduced. During the summer of 2011 only half of the livestock were fed in the valley Kleinsölk. Based on the fast revegetive actions, livestock in normal numbers could be fed on the Alps after three years.

A big problem according to revegetation efforts is the Natura 2000 program. The Nature Park Sölktäler is part of the Natura 2000 program relating to the Niederen Tauern Natura 2000 program. According to this program there are several rules and norms relating to fertilization and humus built-up. It is forbidden to adulterate habitat and living conditions for protected species in the Natura 2000 regions. Besides it is requested to allow natural development particularly „interventions in the natural surroundings and landscape“ are not permitted. More in detail, Natura 2000 prohibits the fertilization in the Nature Park Sölktäler due to natural protection of low nutrient indicator species. Such norms hinder an adequate revegetation and grassland re-establishment. In summary, the Natura 2000 program restricted farmers and the Nature Parkt Sölktäler stuff in their efforts to revegetate the landscape after the rainfall event on the 17^{th} of July 2010 (BMLFUW 2000, Ressel 2003, Pröbstl & Prutsch 2010; Land Steiermark – Amt der Steiermärkischen Landesregierung 2014).

From an agricultural point of view, a fast vegetation re-establishment is essential for pasture yield. Hence, the establishment of high yielding forage grasses has to be favoured. A fast and sustainable re-establishment of landscape and grassland is particularly important in touristical regions such as the valley Schwarzensee. In comparison, natural vegetation built-up due to succession would last decades.

According to agriculture and tourism it is essential for further extreme weather events, especially heavy precipitation causing landslides and floods, to know how to revegetate and regenerate the landscape in mountain regions.

<u>The objctives of this study were:</u>

(1) to investigate which treatment is favourable to revegetate mountain pastures from an agricultural and nature conservation point of view,
(2) to show if the applied substrate affected vegetation development either positively or negatively and
(3) to obtain knowledge about vegetation composition and growth of sown species after vegetation re-establishment.

In this case the hypothesis is that there are differences in growth, vegetative cover and species distribution according to different revegetative treatments: sown area with absent straw cover and sown area with present straw cover and sown area with lime after one year.

In Austria, mountain pasture area composes 25% of total grassland (Grüner Bericht 2014). Only a few publications (Krautzer 2006; Scotton et al. 2012) deal with revegetation measures in mountainous regions. The main part of literature refers to intensively used grassland. This aspect highlights the importance of this work. Therefore, further research has to be carried out to learn more about recultivation of mountain areas under extreme conditions.

2. Methods

2.1. Study Sites

The investigation of sown areas in the Nature Park Sölktäler took place during the vegetation period in 2012 (two years after the heavy rainfall event). All investigated sown areas can be found between the Jagastüberl (N47°19'37', E13°53'38'') and the lake Schwarzensee (N47°17'37'', E13°52'24'') on the valley bottom.

Sown sites both with and without straw cover were used for the investigation. Therefore, 52 homogenous plots with 16m² (4x4 or 1x16) in size were chosen randomly to assure respect of representativeness. To complete the survey, areas where lime or ash were applied, were examined too. Metal nails were inserted into the soil in two opposite corners of each plot for permanent marking. The geographical position and altitude were registered by GPS in the middle of each plot. Further, the exposition of the plots was analysed per compass and the slope angles were recorded additionally. Date and record number complete the description of the site.

2.2. Data Collection

All vascular plant species in the 52 plots were determined using the "Exkursionsflora für Österreich, Liechtenstein und Südtirol" (Fischer et al. 2008). A modified version of the BRAUN-BLANQUET scale (Braun-Blanquet 1964) was used to determine cover and abundance (see table 1). The number of classes was increased for better distinguishability between the abundance of single plant species in the plots. Therefore, the classes 1 to 5 were extended by two subclasses each, which can be seen in table 1. Species only found once in a plot were recorded with r = rarus and two to five individuals from the same species found in one plot were listed with the value +.

The percentage of total vegetation cover was recorded as well as the percentage of bryophyte cover and cover of straw layer for every plot. Furthermore, type of substrate (none, straw, lime, ash and farmyard manure) and the percentage of grass, legumes and herb cover were recorded in each plot with a total of 100%.

Table 1: Modified Braun-Blanquet scale for the investigation of species abundance.

symbol	cover (%)	symbol	cover (%)
r	one specimen	3	33 - 44
+	a few individuals (2-5)	3b	45 – 50
1a	1.0 – 1,9	4a	51 – 56
1	2,0 – 3,9	4	57 – 68
1b	4.0 – 5.0	4b	69 - 75
2a	6 – 11	5a	76 – 81
2	12 – 19	5	82 – 94
2b	20 – 25	5b	95 - 100
3a	26 – 32		

2.3. Vegetation Survey

The collected data was listed in an excel spreadsheet to compare the abundance and dominance of species using the modified Braun-Blanquet scale. In the first rows of the spreadsheet plot numbers, altitude in m, slope angle in °, exposition, vegetation cover in %, bryophyte cover in %, straw cover in %, grass cover in %, herb cover in % and legume cover in % were listed for every plot (see appendices).

Species names were listed in the first column. The species in the seed mixture were listed firstly to show which sown species germinated and established themselves in the plots and how dominant they were. The unsown species were split into several groups, as they were typical grassland species, trees and shrubs, forest and edge species, cropland species, pasture plants and species indicating compacted soils, low-nutrient indicator species, species of higher altitudes, moisture indicator species, nutrient indicator species, pioneer species and species indicating bare ground. Every species was given the number of dominance from r to 5b (modified Braun-Blanquet scale) relating to the plot where it was found (see appendices).

For comparisons between plots covered with straw and plots without straw cover an additional list was made. Therefore, plants listed before were named a second time to show if there are differences in their abundance according to the substrate. Species, which appeared either on plots with straw or in plots without straw were considered. Did a species occur in both plots, it was not mentioned. According to the application of lime on five sites an additional list was made.

The percentage of sown species as well as unsown species referring to total vegetation cover was additionally illustrated. The aim was to show how the percentage of sown species correlates with recorded total vegetation cover.

Further, comparisons between plots without straw cover (treatment 1) and plots with straw cover (treatment 2) focusing on differences due to the substrate were acquired. In this work, the parameters total vegetation cover, straw cover, grass cover, herb cover and legume cover were the main points listed relating to the two treatments. Species cover of several species found in the plots was recorded. The last point deals with bryophyte cover. This parameter was analysed referring to its means and differences seen during the survey in both treatments.

According to the substrates lime, ash and farmyard manure an analysis was made to consider differences in vegetation cover, species distribution and bryophyte dominance separately from the treatments straw absent and straw present. To compare measures with lime and absent straw cover the sample size was reduced eliminating the highest and lowest values. Hence, lime and absent straw were compared using a sample size of five each.

2.4. Statistical Data Analysis

For the analysis means of all relevant parameters mentioned before were collected and compared. These destrictive statistics were supported by statistical analyses.
The conducted statistical analysis was used to show the correlation between total vegetation cover according to the substrate types. Therefore, the Pearson correlation was used to highlight differences according to present straw cover. Additionally, a t-test was used to show significant differences between the treatments. Furthermore, a Mann-Whitney test was necessary, because data was not normally distributed. The Levene-test of homogeneity of variance was additionally used. If the resulting p-value of Levene’s test is less than 0.05, the obtained differences are unlikely to have occurred randomly. Thus, it is concluded that there is a difference between the treatments. The null hypothesis is rejected.

All results were stated as statistically significant if $p<0.01$ and highly significant if $p<0.001$. The program SPSS version 20 was used. Scatter plots and boxplots illustrate the results.

3. Natural basics

3.1. Study Area

The Nature Park Sölktäler is located in the Styrian district Liezen and extends over the municipality Sölk (see figure 2). The 288 km² big area lies on the eastern end of the Schladminger Tauern, which is part of the Niederen Tauern (Central Alps). A small part of the Nature Park area belongs to the Wölzer Tauern, which is located easterly of the Schladminger Tauern in the Niederen Tauern. The highest summit is the Deichelspitze with 2684m a.s.l. The valley Schwarzenseebach is part of the Nature Park Sölktäler (Resch 1889, Prenner, 2014).

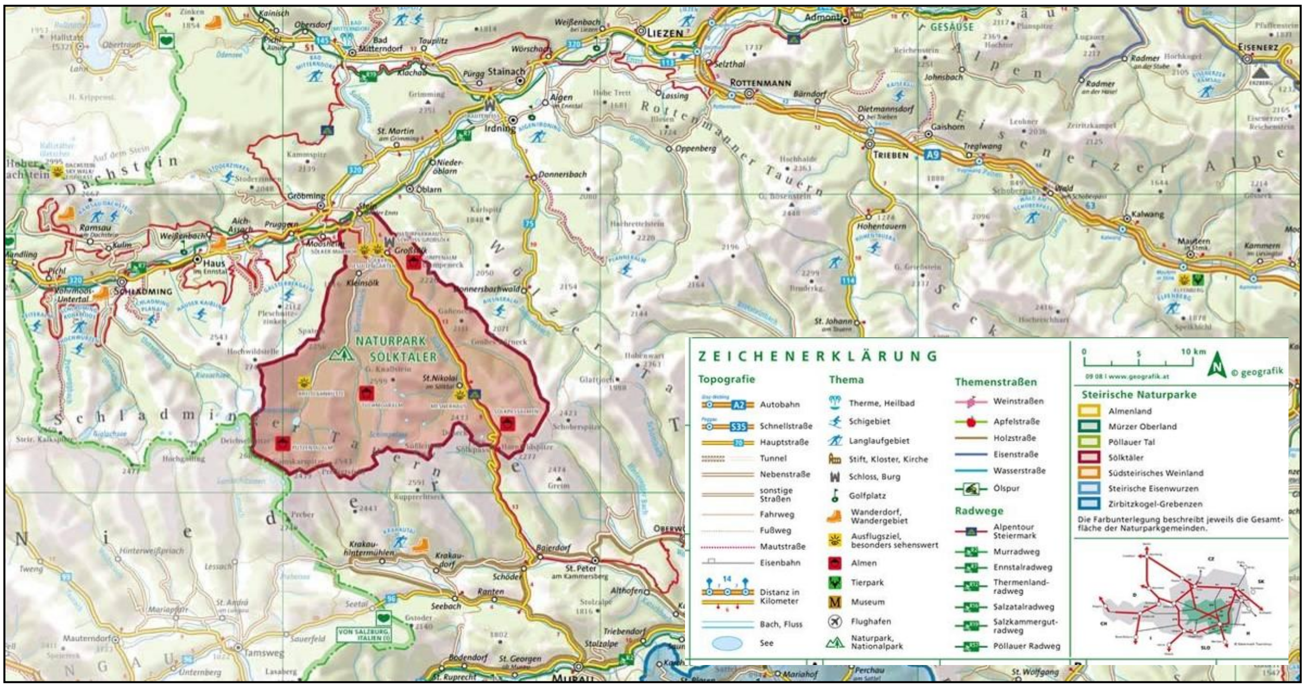

Figure 2: Position of the Nature Park Sölktäler in Styria, Austria. (Adapted from http://naturparke.at/news/map_stei.jpg).

3.2. Geology and Geomorphology

The whole mountainous unit belongs to an old crystalline basement, the so called 'Muriden'. In the Nature Park, the Wölzer crystalline complex makes the major part of the crystalline unit and also builds up a silica based mountain (Becker 1981; Pölzl 2007). The Wölzer crystalline complex is dominated by Wölzer mica schist, gneiss, Sölker marble and hornblende quarzite as well as hornblende gneiss (Becker 1989; Hejl 2006) (see figure 3).

Furthermore, the bedrock can be divided into the gneiss-complex, the amphibolite-complex and the mica schist-complex. Granites and granite gneiss are found in the basis of the gneiss-complex and hornblende and amphibolites are components of the adjacent amphibolite-complex. The mica-schist complex is characterized by phyllitic mica schist as well as granat and quartz mica schist (Becker 1981; Becker 1989; Hejl 2006). Marble is an important unit in the mica schist-complex. It occurs between the Kochofen and the village Großsölk as well as near the summit of the Gumpeneck in different forms and is mined professionally. However, the main part of the occurring marble is fine-grained and banded limestone marble (Becker 1989).

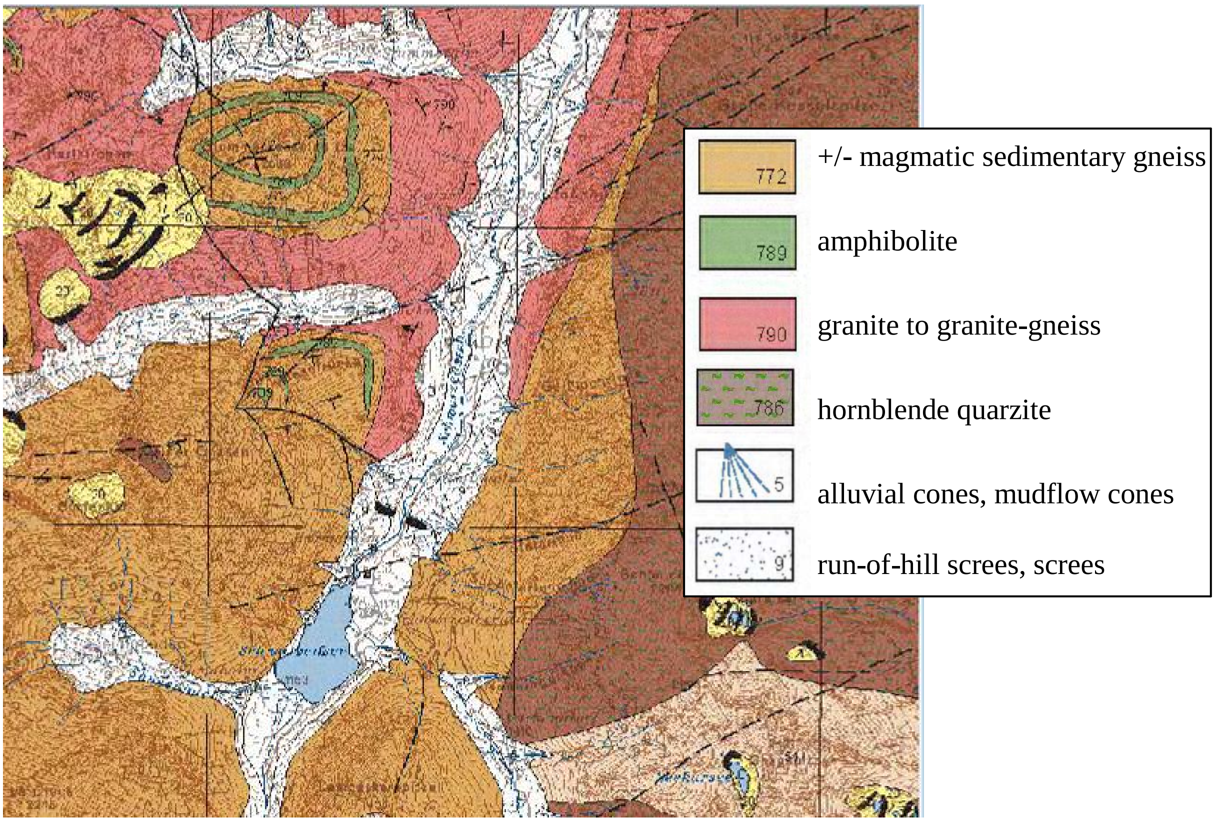

Figure 3: Geological map of the valley Schwarzenseebach. (Adapted from GIS-Steiermark)

The typical U-shaped valley in both Sölk valleys (see figure 4) is the result of the glacial movement during the last ice age. Thereby, an immense ice shield covered today's park area about 20.000 years ago. Warmer temperatures induced the ice‘s movement followed by the abrasion and transport of rock masses. Thus, valleys and cirques were formed over time, which are characterised by flat valley floors and very steep slopes (Husen 1987; Becker 1989).

Bacause of on glaciatation, lakes and waterfalls were formed (Resch 1989). The biggest lake to be mentioned is the Schwarzensee with an area of 23 ha. This relict of the last ice age is located at an altitude of 1150 m.a.s.l. near the valley end in the Upper Valley Kleinsölk (Baumann 1984).

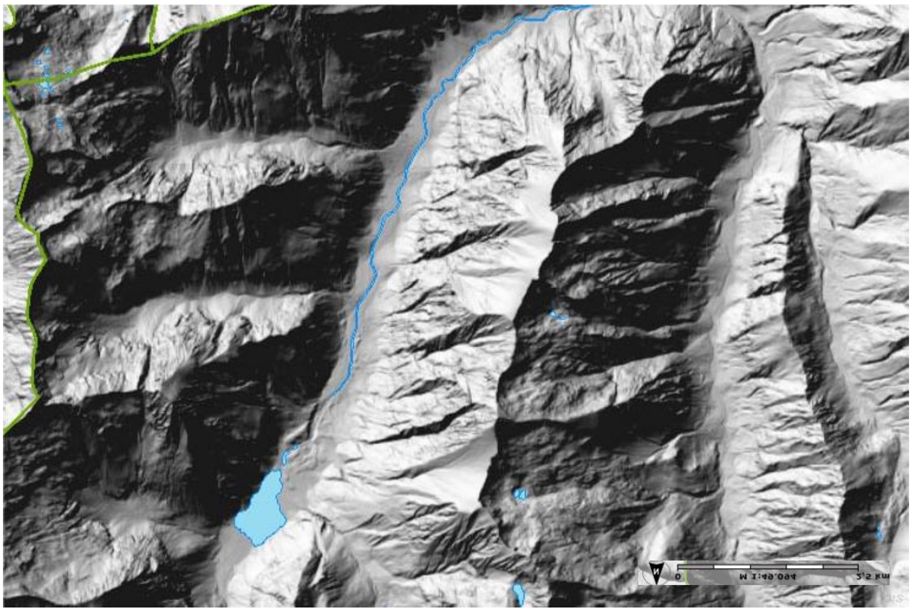

Figure 4: Relief map of the Upper Kleinsölk-valley with the Schwarzensee and the river Schwarzensee as water bodies. (Source: GIS Steiermark)

The movement of the fragments under the ice cover is the reason why coarse-grained material formed moraines, which can be found in both valleys (Husen 1987; Becker 1989).

3.3. Soils

Brown earths (Cambisols) and ranker (Leptosols) are the main soil types in the valley Schwarzenseebach. Soil parent material is composed of different types of crystaline rocks and glacio-fluvial sediments. Therefore, the brown earths and ranker are carbonate-free and soil reaction varies fom acid to slightly acid (pH = 4.6 – 6.5). Soil texture is loamy sand to sandy silt with high coarse fraction. Beside the river Schwarzenseebach an alluvial soil (fluviosol) occurs on the valley bottom (Pölzl 2007).

3.4. Vegetation

In the Nature Park different vegetation types can be found. The valley bottom, located in the montane belt, is dominated by agricultural used pastures and meadows, which feed cattle and ewes. The main vegetation types are the *Festuca rubra-Agrostis capillaris* community and the *Nardus stricta* community. On steep slopes, forests are main vegetation types. In general, pine (*Picea abies*) is the dominant tree species (Höllriegel & Mayrhofer 1989; Pölzl 2007). Magnes and Drescher (2001) describe islands of deciduous forests with the dominant tree species sycamore maple *(Acer pseudoplatanus*) and wych elm (*Ulmus glabra*). These forests are restricted to steep slopes. Further deciduous forests can be found alongside the river Schwarzenseebach dominated by grey alder (*Alnus incana*). In addition, also beech (*Fagus sylvatica*) occurs occasionally in the valley Kleinsölk (Höllriegel & Mayrhofer 1989; Bilovitz 2001).

The forests of the subalpine belt (1500-2000m) are dominated by european larch (*Larix decidua*) and swiss stone (*Pinus cembra*). Knee pine (*Pinus mugo*) and green alder (*Alnus alnobetula*) are widespread at an altitude ranging from 1800 to 2000m a.s.l. (Höllriegel & Mayrhofer 1989).

3.5. Climate

Wakonigg (1978) describes the climate around the lake Schwarzensee as rough with cold winters and cool summers as well as lots of precipitation (1162.4 mm per year). Figure 5 shows the distribution of precipitation and air temperature over the year. In February, the amount of precipitation is 49 mm and in July it is 161 mm on average (ZAMG 2002).

The mean air temperatures vary from -5.3°C in January to 4.7°C in July. A factor influencing temperature is the frequently occurring foehn in the valley Kleinsölk. A relatively short vegetation period of 188 days (21.04.-21.10.) is caused by a long snow cover of about 131 days (Magnes & Drescher 2001; ZAMG 2002).

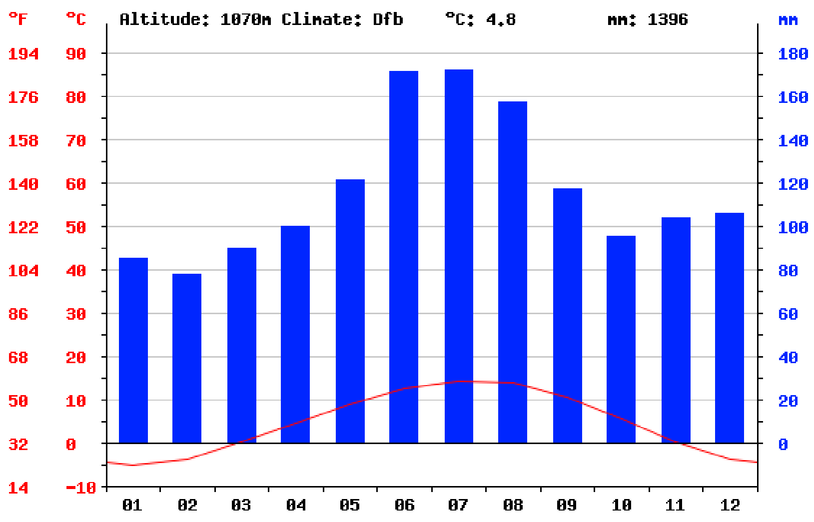

Figure 5: Mean Precipitation rate and mean temperature per year measured in Kleinsölk. (climate data.org)

The Niederen Tauern are characterised by Lee-effect if weather fronts come from north or north-west. This results in higher air temperatures in the small valleys, less precipitation and more direct solar radiation. The narrow valley runs in a south-north direction. Hence, the duration of sunshine is low. The unfavourable climate limits plant growth and increases the abundance of moisture indicator species (Wakonigg 1978; Magnes & Drescher 2001).

3.6. Agriculture and Tourism

Agriculture and forestry are the main economic sectors in the valley Kleinsölk. In addition, mountain farming is the vital branch of production. About 199 agricultural holdings farm the agricultural and forest areas in the Nature Park Sölktäler. The main parts contribute part-time holdings with a high portion of organic farming. Cattle farming for milk and meat production as well as sheep farming play the most important roles. The agricultural holdings are mainly mountain farms with challenging farming conditions. Grassland sites are mown by farmers once or twice a year, but the main part is used for pastoral farming. From the end of May to the middle of September about 1400 livestock spend the summer on 18 Alps (Kleinsölk and Großsölk) in the Nature Park Sölktäler (Ressel 2003; Kieninger & Postl 2013, Naturpark Sölktäler 2014).

Tourism is the second sector, which ensures the livelihood of the local people. The valley is very popular for tourists to find relaxation while hiking or biking. The Schwarzensee is a popular destination for hikers. Several alpine cabins beside the hiking trail offer drinks and food for visitors.

Rooms and appartments are offered in the municipalities in and around the Nature Park with the focus on farm holidays. Daily visitors increase the income as well as the production and direct marketing of agricultural und manual products. A special product produced in the region is the “Ennstaler Steirerkas”, which is sold in the region. The Nature Park is also an important hunting area where game is sold and served regularly. In winter, cross country skiing, luging, ice stock sport and mountain hiking complete the offers for tourists (Resch 1989; Kieninger & Postl 2013).

To inform tourists and guests, the Nature Park Sölktäler established several information paths, like the water path around the Schwarzensee, as well as posters concerning different topics about the forest and the heavy rainfall event in 2010 (Resch 1989; Prenner 2014).

4. Clean-up efforts and revegetation

Approximately 20 landslides destroyed the area in the Nature Park (N.N. 2010). First of all, 28 voluntary fire brigades worked in the disaster area as well as the Austrian Federal Armed Forces. The army flew tourists out of the valley Schwarzenseebach. They also brought food for humans and hay for livestock and game by helicopter. About 236 men of the Austrian Federal Armed Forces rebuilt the destroyed bridges and roads to reach the affected areas by ground (Nerat 2010; Kieninger & Postl 2013). Figure 6 shows a bird's eye view made from the Austrian Federal Armed Forces after the landslides.

Figure 6: The valley Schwarzenseebach after the landslides.(Nature Park Sölktäler ©)

After the immediate aid long-lasting clean-up efforts with diggers took place. Mud and boulder from the landslides were used to flatten the valley bottom, while timber had to be carried away with trucks. Several digger companies worked in the valley Schwarzenseebach. Bigger rocks were used to form and support streambeds and slopes. The owners themselves organised a stone mill to diminish rocks to support further revegetative actions on several pasture areas (Kieninger & Postl 2013; Pitzer 2014; Prenner 2014).

The magazine ‘Ennstaler’ established the platform ’Ennstaler helfen im Sölktal’. Referring to this project, about 900 volunteers in total helped to remove stones and timber from the alpine pastures after the completed digger works in the following year (Kieninger & Postl 2013). A group of 200 people rebuilt barbed wire fences and electrical fences in May 2011 to border the mountain pastures. Freshly sown sites from autumn 2010 were framed with fences to increase plant growth. The fences were also built to keep livestock away from dangerous ditches formed by landslides or water. The group also deployed old hay and straw on numerous sites and disseminated seeds on a mountain pasture area of about 10ha at once (Raumberg-Gumpenstein 2011).

Long straw and hay was used as application to protect the sown seeds on some areas against sweeping off by rainwater. A second aspect was to increase the micro climate concerning moisture content under the straw. On other areas additionally ash, lime and farm yard manure were applied. There were also parts which did not obtain any treatment and were left for natural succession.

The used seed mixtures were “Dauerweide H für raue Lagen” and “Dauerweide G für milde und mitlere Lagen” (see table 2). These mixtures for permanent grassland were disseminated in autumn 2010 and May 2011 (Prenner 2014).

Table 2: Components of the seed mixture “Dauerweide H für raue Lagen” and “Dauerweide G für milde und mittlere Lagen” (after Die Saat 2014)

Species in the seed mixture	Dauerweide H für raue Lagen (% of the species in the mixtures per area)	Dauerweide G (% of the species in the mixtures per area)
Trifolium repens (white clover)	10	15
Trifolium hybridum (alsike clover)	5	0
Lotus corniculatus (lotus)	5	5
Poa pratensis (kentucky bluegrass)	20	25
Festuca pratensis (meadow fescue)	15	15
Phleum pretense (timothy-grass)	15	10
Festuca rubra (red fescue)	10	10
Dactylis glomerata (cooksfoot)	5	10
Lolium perenne (english ryegrass)	5	10
Agrostis capillaris (common bent)	5	0
Cynosurus cristatus (crested dog's-tail)	5	0

According to Die Saat (2014) “Dauerweide H” is appropiate for sites higher than 800 m.a.s.l., whereas “Dauerweide G” is suitable for sites lower than 800m.a.s.l. The recommended seeding rates are the same for both mixtures and correspond to 26 kg per hectare.

The components of the seed mixtures and the proportion of species are listed in table 2. The seed mixture “Dauerweide H” contains more species, as namely *Trifolium hybridum, Agrostis capillaris* and *Cynosurus cristatus* than the seed mixture “Dauerweide G”. *Poa pratensis* is in both seed mixtures dominant, with a percentage of 20% and 25%, respectively. “Dauerweide G” contains a higher portion of seeds from *Trifolium repens, Dactylis glomerata* and *Lolium perenne* compared to “Dauerweide H”.

5. Results

The altitude of the 52 plots varied from 966m to 1136m a.s.l. The slope angles ranged from 2 to 28°. The exposition was mainly recorded between westerly to northerly. Only 14 out of 52 plots showed an exposition easterly to southerly.

The analysis of 52 plots showed a high variation concerning to species abundance and dominance, vegetation cover and distribution of grasses, legumes and herbs depending on the treatment. For example, total vegetation cover ranged from 5 to 90% grass cover from 20 to 95%, legume cover from 4 to 79%, herb cover from 1 to 3%. Bryophyte cover ranged from 1 to 20% and straw cover from 10 to 80%.

Table 3: Comparisons of species number, mean total vegetation cover and mean species group cover according to the treatment.

Treatment	Number of plots	Number of species	Mean total vegetation cover (%)	Mean Grasses (%)	Mean Legumes (%)	Mean Herbs (%)	Mean Bryothytes (%)
Straw present	19	101	36	48	51	1	2
Straw absent	27	133	56	63	35	1	5
Lime	5	43	58	47	52	1	10
Farmyard manure	1	19	75	35	64	1	1
Total numbers and means	52	147	mean: 49	mean: 56	mean: 43	mean: 1	mean: 4

Table 3 shows differences in number of species (vascular plans), mean total vegetation cover, mean grass cover, mean legume cover, mean herb cover and mean bryophyte cover according to the treatment. Plots with ash application were not included.

In the 27 plots without straw application, total vegetation cover showed a mean of 56%. In the 19 plots with straw application, mean total vegetation cover was 36%. The difference was 20%. Straw cover correlated highly significant (p= <0.001) and negatively with total vegetation cover (r= -0.91) and herb cover (r= -0.92) (see table 7). Due to the closure to -1, the values indicate a negative effect of the parameter straw. The boxplots in figure 7 illustrates this relationship. In plots with absent straw cover the median and the standard deviation was 70% and 24%, respectively. Plots with present straw showed a median of 30% and a standard deviation of 19%. Three outlier were analysed in the boxplot. For comparison, plots with lime application showed a median of 60% and a standard deviation of 12% referring to total vegetation cover.

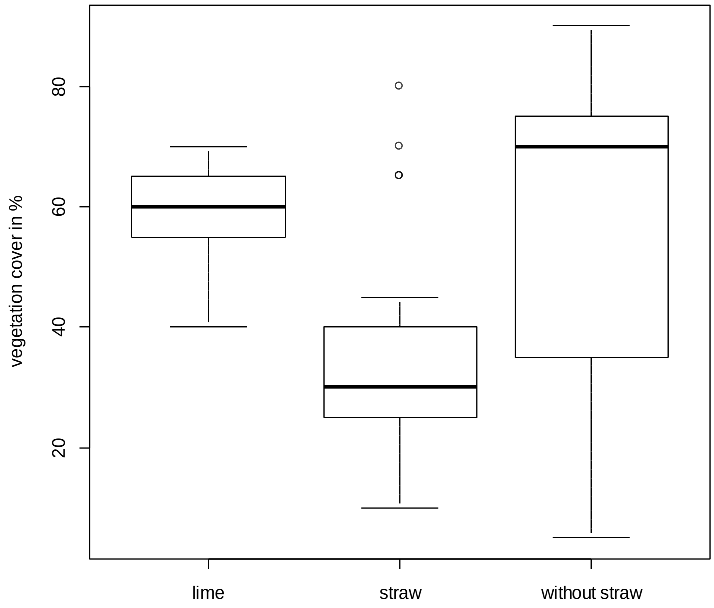

Figure 7: Boxplots of total vegetation cover according to present lime, straw and absent straw cover (N=52).

In plots without straw application, mean grass cover was 63%. In comparison, mean grass cover in plots with straw cover was 48%, which illustrated a difference of 15%. Grass cover was also highly significantly correlated ($p= <0.001$) to plots with different treatments. Due to the different treatment, the median in plots of present straw cover was 13% (standard deviation: 11%) and 35% (standard deviation: 14%) on plots without straw application (see figure 8).

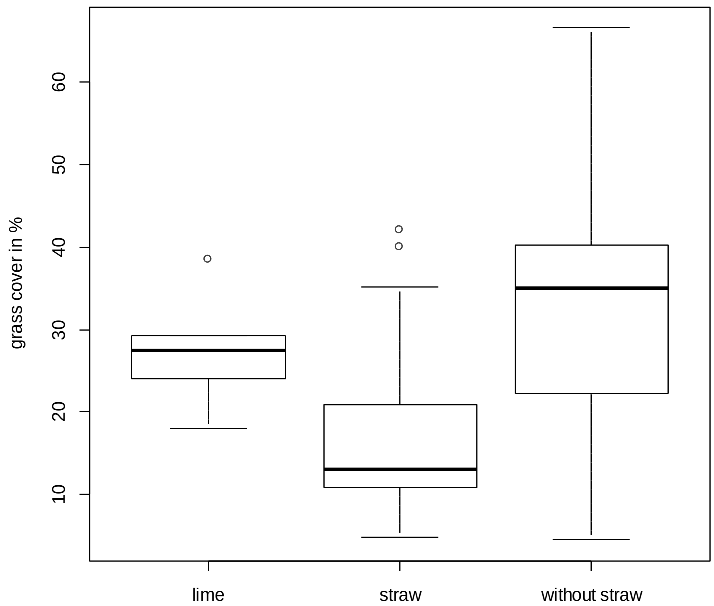

Figure 8: Boxplots of grass cover according to present lime, straw and absent straw cover (N=52).

On the other hand, legume cover was higher on plots with straw application (mean: 51%) compared to plots without straw (mean: 35%). The difference averaged 16%. There were no significant differences (p= >0.4) between legume cover and plots with straw and without straw application. Figure 9 shows this correlation. The meadian is 18% each. Herb cover was significantly differnet according to present substrate (p=0.002). A mean value of 1% was found on plots without straw and on plots with straw. The median is 0.30% on plots with straw application and 0.70% on plots without straw cover (see figure 10).

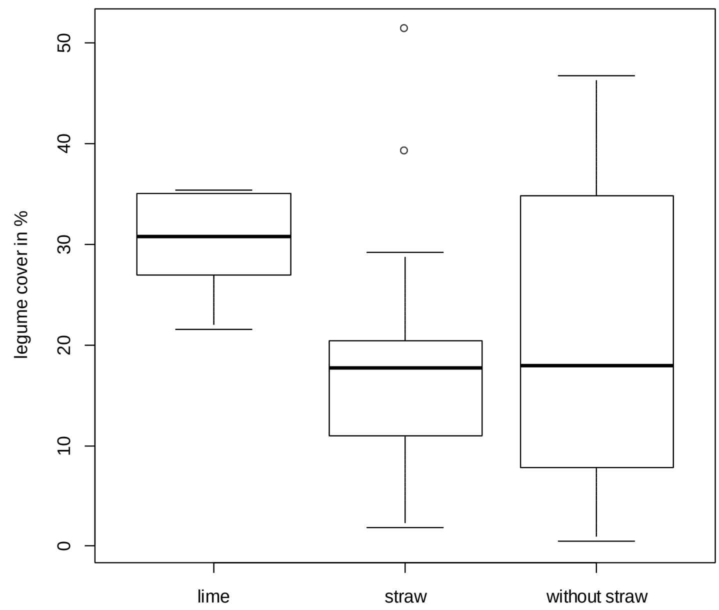

Figure 9: Boxplots of legume cover according to present lime, straw and absent straw cover (N=52).

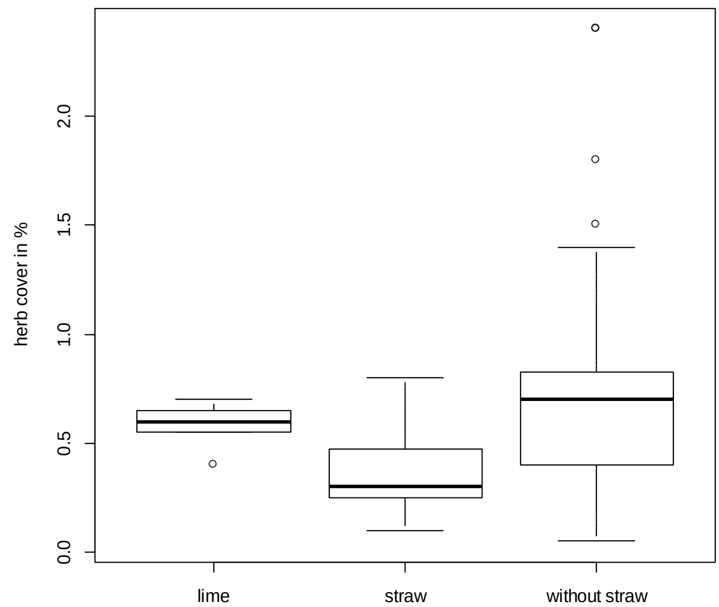

Figure 10: Boxplots of herb cover according to present lime, straw and absent straw cover (N=52).

A small difference was recorded concerning bryophyte cover. On plots without straw application a mean bryophyte cover of 5% was registered, wheras on plots with straw application a mean cover of 2% was observed (see figure 11). In summary, the treatments plots with straw and plots without straw correlated significantly positive with vegetation cover, herb cover as well as with the parameter species in the seedmixture. The treatments correlated highly significant with grass cover (see table 4). There were no statistical differences found between treatments and legume cover.

Table 4: Results of the t-test between plots with straw cover and plots without straw cover.

		Levene's test for homoscedasticity		**t-test for averaging equality**		
		F	**Sig.**	**t**	**df**	**p-value**
vegetation cover in %	Variances are equal	4.18	0.047	2.93	44.00	0.005
	Variances are not equal			3.04	43.05	0.004
grass cover in %	Variances are equal	0.90	0.348	4.10	44.00	0.00
	Variances are not equal			4.28	43.42	0.00
herb cover in %	Variances are equal	8.12	0.007	2.87	44.00	0.006
	Variances are not equal			3.32	33.01	0.002
legume cover in %	Variances are equal	3.52	0.067	0.76	44.00	0.451
	Variances are not equal			0.79	42.96	0.435
species in the seed mixture in %	Variances are equal	9.75	0.003	2.60	44.00	0.013
	Variances are not equal			2.80	43.75	0.008

Additionally, the effects of lime and farmyard manure application were listed in table 3. Plots with lime application show a mean proportion of grasses, legumes and herbs like plots with present straw cover. Mean total vegetation cover was 58% and the average bryophyte cover was 10%. Highly significant differences (p= 0.010) were found between legume cover and plots with lime and plots without straw application.

The single plot with applied farmyard manure showed more vigorous plants resulting in higher vegetation cover of 75%. Grass cover was 35%, legume cover 64%, herb cover 1% and bryophyte cover 1%.

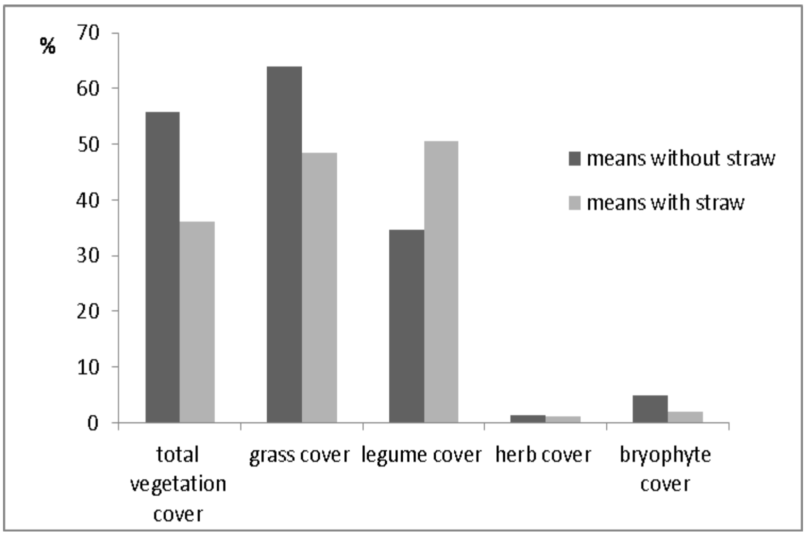

Figure 11: Comparison of means of total vegetation cover, grass cover, legume cover, herb cover and bryophyte cover on plots without straw and sites with straw application.

Figure 12 shows the percentage of grass cover of all 52 plots. A huge variation was found due to differing treatment. Legume cover describes a mirror inverted graph relating to grass cover (see figure 13). Herb cover was overall low (see figure 14). Herb cover was mostly 1%. Seven peaks with higher herb cover than 1% were found.

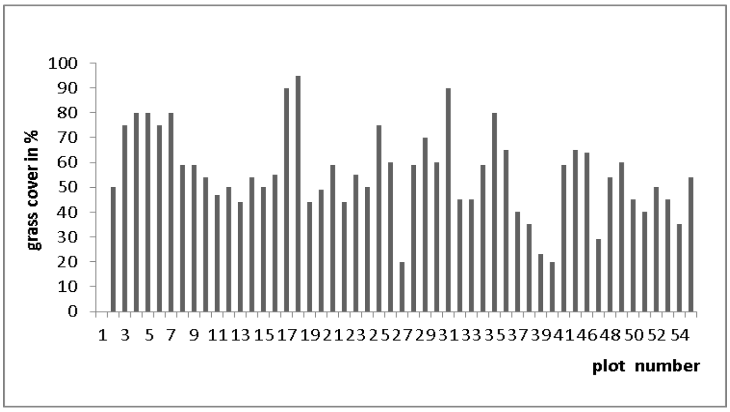

Figure 12: Percentage of grass cover of all 52 plots..

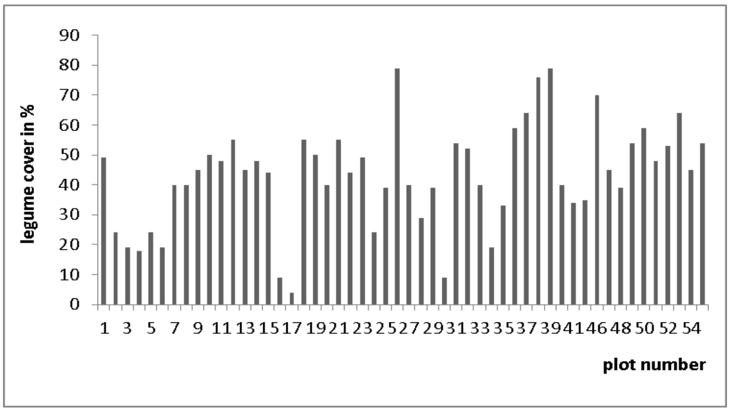

Figure 13: Percentage of legume cover of all 52 plots.

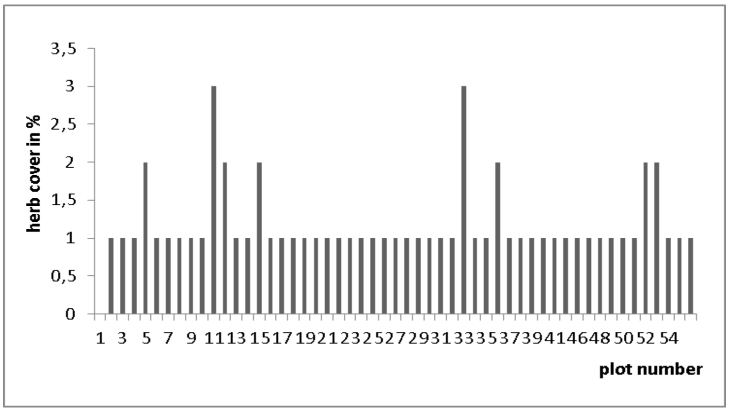

Figure 14: Percentage of herb cover of all 52 plots.

In all plots, 147 plant species were recorded - mainly typical grassland species, low-nutrient indicator species and species of higher altitudes. The application of straw increased slightly species richness, because cereals and cropland weeds appeared. Tree and shrub seedlings occurred in higher numbers. In terms of vascular plant species, at a plot size of 16m², an average of 22 species were recorded (minimum: 11, maximum: 43). In all permanent plots, invasive neophytes were missing.

As expected, species from the seed mixture dominated the examined plots. Species from the seed mixture showed the highest cover on plots with applied farmyard manure. Plots with absent straw, present straw and lime did not differ significantly, but on plots with straw application the correlation of species in the seed mixture was highly significant according to the treatment ($p = 0.008$).

Table 5: Mean cover of species from the seed mixture according to treatment.

species	**absent straw (%)**	**present straw (%)**	**lime (%)**	**farmyard manure (%)**
Poa pratensis	0,08	0,18	0,30	0,5
Festuca pratensis	2,1	2,0	1,4	4,5
Phleum pratense	1,4	1,8	1,4	3,0
Festuca rubra agg.	12,6	15,7	18,3	15,5
Trifolium repens	16,6	19,0	29,0	38,5
Cynosurus cristiatus	1,0	1,8	0	3,0
Dactylis glomerata	1,3	1,8	1,60	4,5
Lolium perenne	6,8	2,3	2,1	15,5
Agrostis capillaris	13,7	3,3	3,0	1,5
Trifolium hybridum	4,1	7,7	2,4	22,5
Lotus corniculatus	6,5	5,8	7,4	15,5
sum	**64**	**60**	**67**	**121**

In general, the cover of sown species was higher than the percentage of non-sown species. On the plot with applied farmyard manure, sown species grew more vigorously due to a better nitrogen supply. Sown species in the plot with farmyard manure were twice as dominant compared with the other treatments. The appearance of non-sown species was inhibited due to the competition of fast-growing and high-yielding forage grasses and legumes. Furthermore, non-sown species were found in higher numbers on plots without straw application (see table 6).

Table 6: Mean sown species und mean non-sown species referring to mean total vegetation cover.

Treatment	Number of plots	Number of species	Mean total vegetation cover (%)	Mean sown species (%)	Mean non-sown species (%)
straw present	19	101	36	60	34
straw absent	27	133	56	66	53
lime	5	43	58	67	15
farmyard manure	1	19	75	134	7

The statistical analysis showed a highly significant effect of straw cover to total vegetation cover (p= <0.001). With increasing straw cover total vegetation cover decreased. This linear relationship is illustrated by figure 15. For the analysis of this correlation the Pearson correlation and the Spearman correlation were used. Both statistical instruments showed a highly significant correlation (p= <0.001) indicating a negative effect of straw to the analysed parameter (see table 7).

Table 7: Pearson correlation of straw cover.

		total vegetation cover	grass cover	herb cover	legume cover	species in the seed mixture
Straw cover	Pearson correlation	-0.91	-0.77	-0.92	-0.75	-0.87
	significance (two-sided)	0.000	0.000	0.000	0.000	0.000
	N	19	19	19	19	19

With increasing straw cover total vegetation cover decresed. Referring to figure 15 the relationship was nearly linear. The correlation of grass cover, legume cover, herb cover and bryophyte cover to straw cover showed a tendencially decline with increasing straw cover (see appendices).

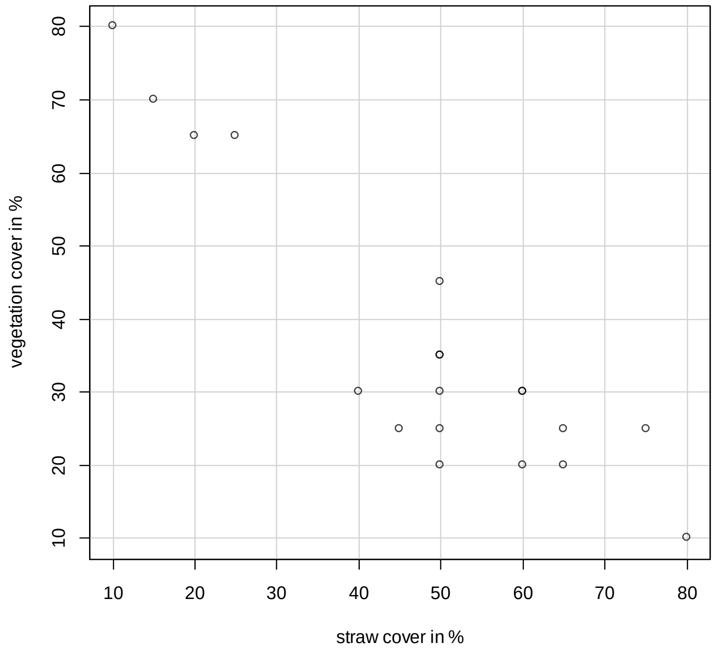

Figure 15: Relationship between total vegetation cover and straw cover.

Concerning to the results, it seems favorable to avoid straw application. This would result in higher vegetation cover and increased grass ratio.

5.1. Straw layer absent

In all plots with absent straw cover, total vegetation cover varied considerably and ranged from 5 to 90% (mean: 56%) (see figure 16). The average cover of grasses, legumes and herbs was 63% (44 to 95%), 35% (4 to 55%), 1% (1 to 3%), respectively (see figure 17). Bryophyte cover ranged from 1 to 20% (mean: 5%).

In all 25 plots investigated grasses dominated the vegetation, but also legumes reached a high cover. Herbs were found rarely, but increased species richness. A total of 133 species were recorded on plots without straw cover. Among these species, 46 species were restricted to plots without straw cover.

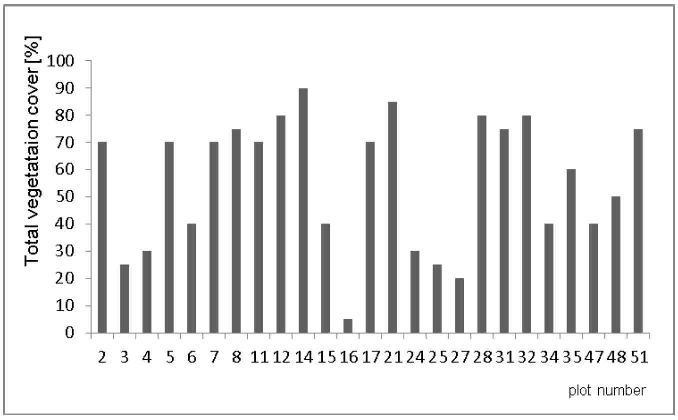

Figure 16: Total vegetation cover in % relating to plots with absent straw cover.

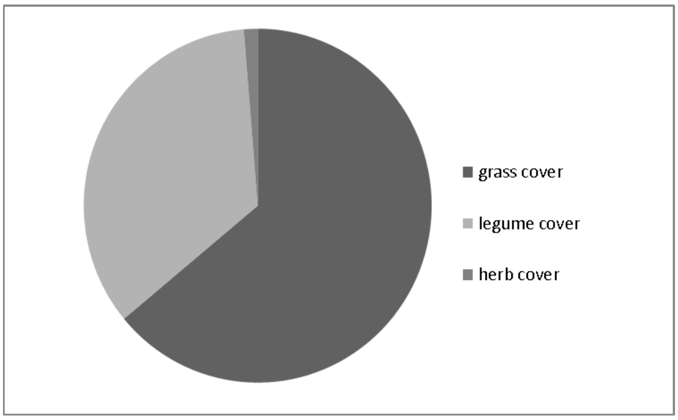

Figure 17: Ratio of plant groups grasses, legumes and herbs referring to plots with absent straw cover.

Figure 18 shows a small section of a fenced area without straw application. There was no humus layer, but numerous stones covered the soil surface. Grasses from the seed mixture established successfully under these stony and nearly humus-free conditions.

Figure 18: Plot 24 with no straw cover in a fenced area near Breitlahnalm.

5.1.1. Grasses

On average, plots without straw application showed a higher grass cover than plots with straw application. Mean grass cover was 63% and ranged from 44 to 95%. Although grasses dominated the plots, numerous grass individuals did not grow vigorously.

The dominant grass species were *Festuca rubra agg.* and *Agrostis capillaris,* which occurred in each plot. *Festuca pratensis* and *Phleum pratense* were also abundant. *Dactylis glomerata, Lolium perenne* and *Cynosurus cristatus* did not achieve such high values as *F. rubra agg.* and *A. capillaris,* but established themselves successfully. In contrast, *Poa pratensis* occurred rarely.

Non-sown grass species, which occurred in the 25 plots without straw cover were *Bromus hordeaceus, Carex remota, Danthonia decumbens ssp.decumbens, Glyceria notata, Holcus lanatus, Nardus stricta* and *Poa alpina.*

5.1.2. Legumes

Among sown sites without present straw cover legumes were abundant. This plant group varied from 4% to 55% (mean: 35%).

Especially *Trifolium repens* was very dominant followed by *Lotus corniculatus* and *Trifolium hybridum*. All three species were present in the applied seed mixtures. Several non-sown legume species were also recorded. Their cover value was *Trifolium pratense* > *Trifolium dubium* > *Medicago lupulina*.

5.1.3. Herbs

Numerous non-sown herb species were recorded. Their cover varied from 1% to 3% on sown sites without straw cover (mean: 1%).

The main species only found on sites without straw layer were *Anthemis arvensis, Arnica montana, Bellis perennis, Cardaminopsis halleri, Carduus personata, Carum carvi, Danthonia decumbens ssp. decumbens, Daucus carota ssp.carota, Euphrasia picta, Galium pumilum, Hieracium lactucella, Hypericum maculatum, Juncus alpinoarticulatus, Juncus articulatus, Juncus bufonius, Leontodon hispidus, Luzula multiflora, Luzula pilosa, Maianthemum bifolium, Myosotis nemorosa, Ranunculus montanus, Rhinanthus minor, Rorippa palustris, Rumex acetosella ssp. acetosella, Rumex obtusifolius, Sanguisorba minor, Saxifraga stellaris ssp.robusta, Silene vulgaris ssp.vulgaris, Tripleurospermum inodorum* and *Veronica fruticans.*

5.1.4. Bryophytes

The cover of different bryophyte species ranged from 1% to 20% (mean: 5%).

5.2. Straw layer present

Beside the group 'plots with absent straw layer' a group of 20 plots with straw cover was investigated. The cover of straw layer ranged from 10 to 80% (mean: 48%). Total vegetation cover varied from a minimum of 10% to a maximum of 80% (mean: 36%).
Of the 147 species recorded, 101 species occurred on plots with straw cover. Among these species 14 were present exclusively on plots with straw cover.

The variation of total vegetation cover in plots with present straw cover was not as extreme as in plots without straw cover. The lowest total vegetation cover was 10% and the highest was 80% (see figure 19). Grass cover ranged from 20 to 90% (mean: 48%), legume cover varied from 9 to 79% (mean: 51%) and herb cover from 1 to 2% (mean: 1%). Grasses and legumes were more uniformly distributed on plots with straw cover. The ratio grass cover and legume cover was nearly 50%, whereas herb cover was negligible (see figure 20).

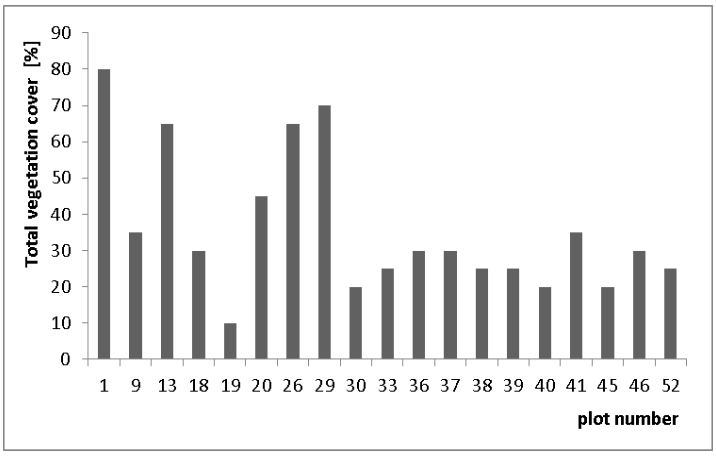

Figure 19: Total vegetation cover in % relating to plots with present straw cover.

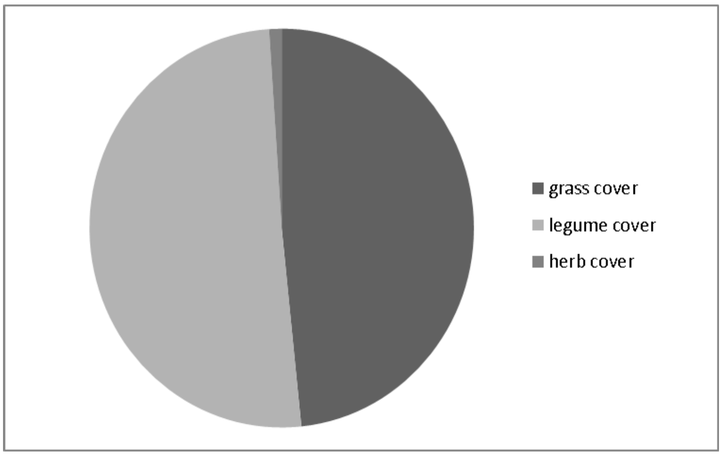

Figure 20: Ratio of plant groups grasses, legumes and herbs referring to plots with present straw cover.

Straw cover correlated highly significant (p= <0.001) with total vegetation cover, grass cover, legume cover and herb cover. Figures 21 to 23 show that with increasing straw cover grass cover, legume cover and herb cover decreases, respectively.

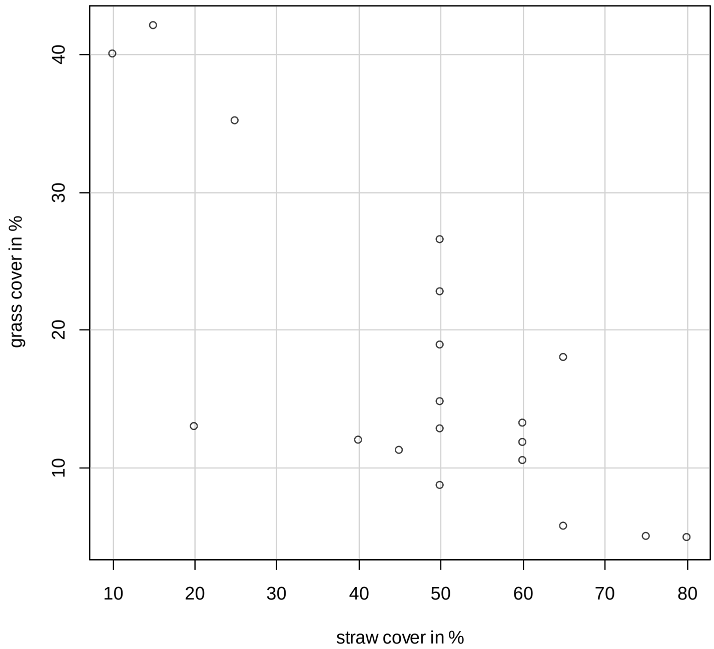

Figure 21: Correlation of grass cover and straw cover.

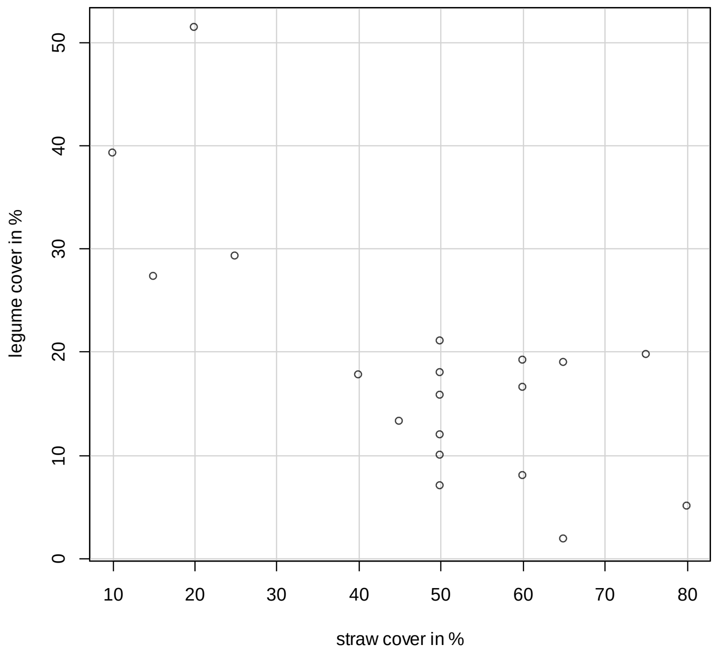

Figure 22: Correlation of legume cover and straw cover.

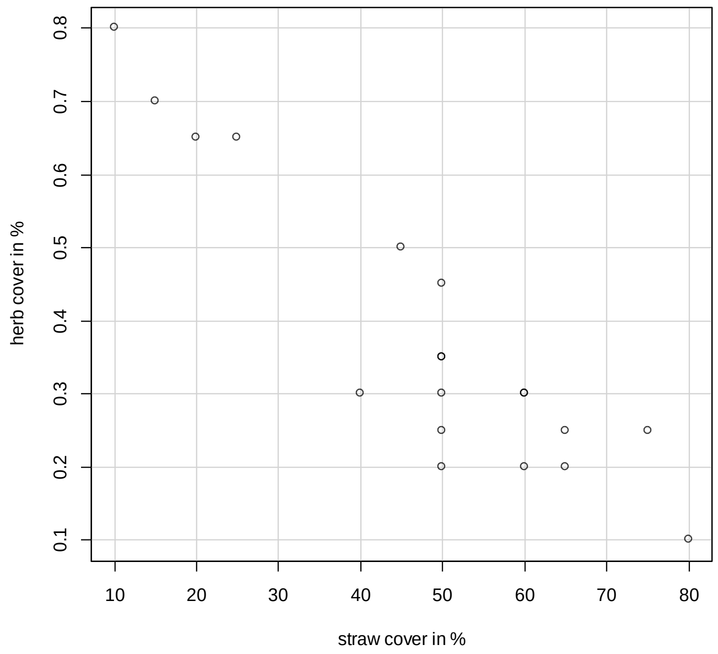

Figure 23: Correlation of herb cover and straw cover

Figure 24 shows a plot where straw covered the soil to a great extent and depressed vegetation growth. Grasses from the seed mixture dominated the area. *Trifolium repens*, *Lotus corniculatus* and *Trifolium hybridum* were the most abundant legume species in plots with straw cover. Total vegetation cover was low as well as bryophyte cover.

Figure 24: Plot number 30 with a straw cover of 65% and a total vegetation cover of only 20%.

5.2.1. Grasses

On plots with straw cover mean grass cover was 48% (20 to 90%). *Festuca rubra agg.* and *Agrostis capillaris* occurred in each plot and can be seen as the dominant grass species. Also abundant were *Festuca pratensis,* as well as *Phleum pratense, Dactylis glomerata*, *Lolium perenne* and *Cynosurus cristatus* in decreasing order. These species did not achieve such high cover values as *F. rubra agg.* and *A. capillaris*, but established themselves successfully in the examined plots.

Of the sown grasses, *Poa pratensis* was the only species which did not establish successfully. This species was only present on seven plots - each with few individuals.

5.2.2. Legumes

On average, the plots with straw cover showed a relatively high cover of legumes. The percentage of legume cover ranged from 9 to 79% (mean: 51%).

Similar to plots without straw cover *Trifolium repens*, *Lotus corniculatus* and *Trifolium hybridium* were the dominant legume species. All three species (*T. repens* > L. corniculatus > *T. hybridum)* were present in the applied seed mixture. *Trifolium pratense* occurred in several plots, but did not establish successfully.

5.2.3. Herbs

Herb cover ranged from 1 to 2% (mean 1%). Similar to plots without straw cover herbs increased vascular plant species richness.

The non-sown species exlusively found on plots with present straw cover were: *Avenella flexuosa, Campanula barbata, Campanula patula, Campanula scheuchzeri, Digitalis grandiflora, Epilobium alsinifolium, Galium album, Geranium robertianum, Hypochoeris radicata, Mycelis muralis, Senecio ovatus, Sideritis montana, Stellaria media* and the fern *Thelypteris limbosperma.*

5.2.4. Bryophytes

With a mean cover of 2% bryophytes were less dominant on plots with straw cover than on plots without straw cover. The lowest and highest cover values were 1% and 15%, respectively.

5.3. Treatment with other substrates

On five plots lime, on one plot ash as well as on one plot farmyard manure was applied. These plots are described in more detail due to differences in total vegetation cover and plant group ratio.

5.3.1. Lime application

Total vegetation cover on plots with lime application ranged from 40 to 70% (mean: 58%). Grass cover varied from 40 to 55% (mean: 47%), legume cover varied from 44 to 59% (mean: 52%) and herb cover showed a value of 1% in each plot. The plots with visible lime treatment showed a bryophyte cover of 10% (see table 8). In total, 43 plant species were recorded.

Table 8: Means referring to lime application.

Plot	vegetation cover (%)	grass cover (%)	legume cover (%)	herb cover (%)	bryophyte cover (%)
22	70	55	44	1	10
23	55	50	49	1	10
49	65	45	54	1	10
50	60	40	59	1	10
55	40	45	54	1	10
	mean: 58	**mean: 47**	**mean: 52**	**mean: 1**	**mean: 10**

The species from the seed mixture were relatively abundant on plots with lime application. *Trifolium repens* was the most dominant species in all five plots. The second dominant species was *Lotus corniculatus* followed by *Festuca rubra agg*. The other species from the seed mixture reached low cover values. *Poa pratensis* was either missing or occurred rarely.

Among plots with lime application no cropland species or nutrient indicator species were abundant. In contrast, pasture plants and species indicating compacted soils were relatively abundant.

Figure 25 shows an area where lime was applied. All in all, liming did not show any positive effect, concerning total vegetation cover and plant species composition.

Figure 25: Plot 49 with a visible lime application.

Table 9 shows mean cover values on plots with lime and plots without straw application using a sample size of five each. Significant differences (p=0.01) were found between lime application and legume cover. Total vegetation cover, grass cover and herb cover were not significantly different to the application of lime and plots with absent straw cover.

Table 9: Means of lime application and absent straw cover (N=5).

	Lime (N=5) in %	Absent straw cover (N=5) in %	p-value
Total vegetation cover	58	64	0.3
Grass cover	47	34	0.3
Legume cover	52	18	0.01
Herb cover	1	0.7	0.1

5.3.2. Farmyard manure application

Farmyard manure was applied on a relatively small area (see figure 26). On this plot total vegetation cover reached 75% despite a straw cover of 20%. 19 species were recorded. The legumes *Trifolium repens*, *Trifolium hybridum* and *Lotus corniculatus* dominated the area with 64% legume cover, followed by 35% grass cover. *Festuca rubra agg.* and *Lolium perenne* were the dominant grass species. *Dactylis glomerata*, *Festuca pratensis*, *Phleum pratense*, *Agrostis capillaris* and *Poa pratensis* established successfully. Also *Arrhenatherum elatius* and *Cynosurus cristatus* grew vigorously.

Herb cover was recorded with 1% and bryophyte cover reached a value of 1%.

Figure 26: Area with farmyard manure and straw application (plot 53).

Figure 27 shows a snapshot of the species composition and total vegetation cover of plot 53. Obviously, legumes dominated the area and total vegetation cover was higher than on most plots. Moreover, plants grew more vigorously.

Figure 27: Legumes dominated the area with farmyard manure application.

5.3.3. Ash application

Only one plot was recorded to show the effects of ash application. No difference was observed concerning total vegetation cover and plant species composition.

5.4. Non-sown species

All non-sown species were listed in different groups according to their habitat preference. This chapter gives an overview, which species could establish successfully due to seed dispersal. There was no effect of differing treatments.

5.4.1. Typical grassland species

This group contains 22 common and widespread grassland species. *Achillea millefolium agg.* and *Cerastium holosteoides* showed a high degree of presence in more than 30 plots. *Trifolium pratense, Arrhenatherum elatius, Plantago lanceolata* and *Achillea millefolium agg.* were recorded. Furthermore*, Arabidopsis halleri, Campanula patula, Carum carvi, Cerastium holosteoides, Galium album, Holcus lanatus, Leontodon hispidus, Leucanthemum ircutianum, Lolium x boucheanum, Medicago lupulina, Poa trivialis, Prunella vulgaris, Ranunculus acris ssp.acris, Silene dioica, Taraxacum officinale agg., Trifolium dubium, Veronica chamaedrys ssp.chamaedrys* and *Veronica serpyllifolia ssp.serpyllifolia* were recorded with a few individuals.

5.4.2. Trees and shrubs

Ten tree and shrub species were recorded in 52 plots. *Acer pseudoplatanus* and *Alnus alnobetula* showed a high degree of presence, at which *A. pseudoplatanus* was the dominant tree species. According to vegetation cover, *A. alnobetula* reached high cover followed by *Salix myrsinifolia* and *Picea abies*. *Abies alba, Alnus incana, Betula pendula, Betula pubescens, Larix decidua* and *Vaccinium myrtillus* occurred rarely.

5.4.3. Forest and edge species

Due to the near to the forest, 25 forest and edge species could be found. *Luzula luzuloides* showed the highest degree of presence within this plant group. Additionally, the herb *Anemone nemorosa* was present in 17 plots, but barely with more than one individual per plot. All other species occurred only in a few plots with a few individuals. The following species were recorded: *Athyrium filix-femina, Cardamine flexuosa, Cardamine impatiens, Carduus personata, Digitalis grandiflora, Epilobium montanum, Fragaria vesca, Galeopsis speciosa,* *Hieracium murorum, Homogyne alpina, Lamium sp., Luzula pilosa, Luzula sylvatica ssp.sylvatica, Lysimachia nemorum, Maianthemum bifolium, Moehringia trinervia, Petasites albus, Rubus idaeus, Mycelis muralis, Scrophularia nodosa, Senecio ovatus, Thelypteris limbosperma, Verbascum densiflorum* and *Viola riviniana*.

5.4.4. Cropland species

Several cropland species were found in 13 plots. The cereal *Hordeum vulgare* was present in six plots and showed the highest abundance within this plant group. *Secale cereale* and *Triticale rimpauli* were the other cereals found in the examined plots, but with a low degree of presence. The recorded cropland weeds were *Anthemis arvensis, Cyanus segetum, Equisetum arvense, Stellaria media* and *Tripleurospermum maritimum subsp. inodorum, at which C. segetum* is classified as endangered.

5.4.5. Pasture plants and species indicating compacted soils

Several different pasture plants and species indicating compacted soils were recorded. The species, which reached a higher degree of presence were *Sagina procumbens* followed by *Plantago major ssp. major. Bellis perennis, Leontodon autumnalis, Poa annua, Poa supina* and *Ranunculus repens* occurred only rarely in the examined plots.

5.4.6. Low-nutrient indicator species

24 low-nutrient indicator species were recorded. *Potentilla erecta* was found in 31 plots, but reached only low cover values. In contrast, *Carex pallescens* was recorded in 25 plots, but showed comeratively higher cover values. *Anthoxanthum odoratum, Carex leporina, Carex pilulifera, Euphrasia officinalis ssp.rostkoviana, Luzula campestris* and *Veronica officinalis* reached also a higher degree of presence. The other low-nutrient indicator species, *Avenella flexuosa, Danthonia decumbens ssp.decumbens, Euphrasia officinalis ssp. picta, Galium pumilum, Gnaphalium sylvaticum, Hieracium lactucella, Hieracium pilosella, Hypericum maculatum, Hypochoeris radicata, Luzula multiflora, Nardus stricta, Ranunculus nemorosus, Sanguisorba minor, Silene vulgaris ssp. vulgaris, Stellaria graminea* and *Thymus pulegioides,* established a few individuals each.

5.4.7. Species of higher altitudes

The examined sown sites in the valley Schwarzenseebach were located at an altitude ranging from 966m to 1136m. 13 local alpine species from the surroundings established themselves on the examined areas in relatively short time. *Ajuga pyramidalis* was the most abundant species of this plant group. The next dominant species was *Viola biflora* followed by *Potentilla aurea* and *Rumex alpestris*. Other species, such as *Arnica montana, Campanula barbata, Campanula scheuchzeri, Crocus albiflorus, Peucedanum ostruthium, Poa alpina, Ranunculus montanus, Veratrum album ssp.album* and *Veronica fruticans* established only a few individuals in the examined plots.

5.4.8. Moisture indicator species

A relatively high number of moisture indicator species were found during the survey. The reasons are the long snow cover and the cool and precipitation-rich climate. In total, 16 moisture indicator species were found. The most abundant species was *Cirsium palustre*. Further species with relatively high degree of presence were *Galium uliginosum* followed by *Deschampsia cespitosa* and *Juncus effuses*. All other species showed low abundance. These were *Cardamine pratensis, Carex remota, Epilobium alsinifolium, Glyceria notata, Juncus alpino-articulatus, Juncus articulates, Juncus bufonius, Myosotis nemorosa, Pinguicula alpina, Rorippa palustris, Saxifraga stellaris ssp.robusta* and *Veronica beccabunga.*

5.4.9. Nutrient indicator species

Only three typical nutrient indicator species were found during the survey. *Rumex obtusifolius* established itself in three plots. The other nutrient indicator species found during the survey were *Geranium robertianum* and *Urtica dioica.* A few individuals of both species were found in one plot each.

5.4.10. Pioneer species and species indicating bare ground

The bare ground conditions were used by seven pioneer plants. *Silene rupestris* and *Rhinanthus minor* occurred in eight plots each, at which *S. rupestris* was the dominant species. Both species showed a relatively high degree of presence. However, *Daucus carota ssp.carota* occurred only in one plot, but reached there the highest abundance within one plot.

Bromus hordeaceus, Cardamine hirsuta, Sideritis montana, and Rumex acetosella ssp.acetosella complete the list of pioneer species and species indicating bare ground.

6. Discussion

New created surfaces caused by landslide deposits are often characterized by nearly humus- and vegetation-free soil surfaces, so called bare soils. These conditions emerge as a result of the removal and burial of the humus-rich topsoil layers (Sidle & Ochiai 2006). The combination of different grain sizes originating from landslide deposits and low fine earth fraction is the reason for a lack of humus and hence, for a low plant available nutrient content in the initial soil. However, landslides are natural processes, which create new habitats and are required for the formation and creation of new landscapes (Schaaf et al. 2011).

From an agricultural point of view, a sufficient nutrient supply is essential for the growth of high-yielding forage grasses. Humus is the main nitrogen supply of the soil. All sown areas and unsown sites in the valley Schwarzenseebach were characterized by low nutrient contents due to a lack of humus and fine earth. The soil surfaces were mainly covered by gravel and stones, at which fine-earth fraction was missing mostly on all examined plots. Due to missing nitrogen on the valley bottom, the valley Schwarzenseebach can be described as a nitrogen-limited ecosystem. This factor caused the bad vegetation development and inhibited growth of several plant species. In summary, revegetation was less successful on areas with particularly high content of coarse fragments than on areas with higher content of fine-textured substrate and humus.

Additionally, the reason of the poor plant development may be the degeneration of seedlings caused by the low nutrient content in the soil. The fast emergence of particular plant species also surpressed the development of slow emerging plant species (Dietl & Lehmann 2004, Dierschke & Briemle 2008).

Other revegetation projects show that a sufficient content of fine-textured substrate favours vegetation development. Using the example of the flooding event in the valley Hollersbach in the National Park Hohe Tauern (Salzburg) in 2005, the revegetation measures were highly successful as they used fine-grained deposits from the barrier lake (Scharler 2014). However, the heavy rainfall event in the Nature Park Sölktäler was an unparalleled catastrophe and cannot be compared with the flooding in the valley Hollersbach. But the results showed that fine-earth fraction and humus are of utmost importance for a sustainable and successful grassland re-establishment. The lack of humus and hence the lack of nitrogen is still a big problem in the valley Schwarzenseebach.

Festuca rubra and *Agrostis capillaris* were the dominant grass species on the examined plots. They occurred on every plot due to their adaptation rate to the specific site conditions. Both species can grow on bare ground (Bohner et al. 2007). Either *F. rubra* or *A. capillaris* were the dominant grass species. Furthermore, both species are characteristic species of the main vegetation type in the valley Schwarzenseebach, the so-called *Festuca rubra-Agrostis capillaris* community (Pölzl 2007, Bohner 2014).

Due to the nitrogen deficiency as a result of a lack of humus, growth of several other grass species was reduced. Particularly *Lolium perenne* and also tall-growing grasses such as *Dactylis glomerata*, *Festuca pratensis* and *Phleum pratense* have a high nitrogen requirement (Bohner, 2014). Grass cover was highly significantly correlated ($p = <0.001$) between plots with straw and without straw application.

All species occurring regularly in higher numbers have the ability to grow on bare soils characterised by humus-free and stony site conditions. The following species from the seed mixture were most successful: *Trifolium repens* (mean cover of all 52 plots: 19%), *Festuca rubra agg*. (mean:14%), *Agrostis capillaris* (mean: 9%), *Lotus corniculatus (*mean:7%), *Trifolium hybridum* (mean: 6%), *Lolium perenne* (mean: 5%), *Cynosurus cristatus* (2,6%), *Festuca pratensis* (mean: 2%), *Phleum pratense* and *Dactylis glomerata* (both mean:1.6%).

In nitrogen-limited ecosystems, nitrogen-fixation used by legumes is the key factor for a successful establishment. Legumes benefit from their nitrogen fixation ability and hence do not depend on the nitrogen supply of the substrate (Lloyd & Pigott 1967). Therefore, the legume *Trifolium repens* reached a relatively high cover on all studied plots. The cover ranged from 0.5 to 38%. The cover of other nitrogen-fixing legumes, such as *Trifolium hybridum* and *Lotus corniculatus*, was also relatively high. In case of *T. hybridum*, its vigorous growth was unexpected, because it naturally occurs in wet meadows. *T. repens* is characteristic of intensively used grassland, whereas *L. corniculatus* is a typical species of extensively used grassland indicating nutrient-poor soils. All legumes achieved a high cover on many sown sites due to their competitive advantage over grasses. This could cause a gradual increase of the nitrogen content in the immature soil in the future. To reduce legume abundance cattle grazing is a suitable method (Jewell 2002; Deutsch 2007).

Species from the surrounding areas were able to invade the plots. Seeds were dispersed either by grazing, farmyard manure, straw application or wind. Particularly pioneer species benefited from vegetation-free and bare ground conditions. Such species are able to establish successfully on bare soils due to their competitive properties. Many plants invaded from neighbouring sites. These were all species, which tolerate humus-free soil conditions with low fine-earth fraction. Most successful were the following species: *Rumex obtusifolius, Sagina procumbens, Trifolium pratense, Plantago major ssp.major* and *Arrhenatherum elatius*. In case of *A. elatius* the relatively high degree of presence might be attributable to the import of hay immediately after the heavy rainfall event to feed cattle and sheep.

In the study area, the meadows belong to the *Festuca rubra-Agrostis capillaris* community (Bohner et al. 2014). The mountain pastures are dominated by the *Homogyno alpinae-Nardetum* community (Winter, 2005). Only a few characteristic species of the *Homogyno alpinae-Nardetum* community could be found on the studied plots (e.g. *Nardus stricta, Ajuga pyramidalis, Carex pilulifera, Carex pallescens, Hieracium pilosella)*. The absence of other characteristic species may be associated to their low ability to grow on humus-free, bare surfaces (Dullinger et al. 2001; Pölzl 2007).

On the sown plots, numerous low-nutrient indicator species were also able to establish. These species seem to benefit from the low competitiveness of the sown species. Especially *Potentilla erecta, Euphrasia* species as well as a few *Carex* species and *Veronica officinalis* were successful invaders on sown sites. All species showed low individual numbers, but their successful establishment within two years highlights their high immigration rates. Such invaders originate from the surrounding pasture area. Disturbance is the key factor for pioneer plant species invading vegetation-free areas. They are the first species establishing on bare soils. It seems that numerous local plant species naturally invaded the vegetation-free areas (Fahrig 2003).

The plants are not competing about light, because the stony soil conditions do not allow narrow growing. However, bryophytes used these conditons and occurred in higher numbers on several plots ranging from 1 to 20%. A higher bryophyte cover may be depressed due to lime application.

Species of higher altitudes also occurred in the investigated plots. *Ajuga pyramidalis, Epilobium montanum, Viola biflora, Potentilla aurea* and *Rumex alpestris* were the main species. In this context, extensive cattle grazing increases seed dispersal. Some non-sown species including *Arnica montana* are under nature protection. Their establishment is desirable from a nature conservation point of view.

Poa pratensis, a typical species in permanent grassland seed mixtures, occurred rarely in the 52 plots. This species favours humus-rich soils, but its absence on many sown plots can mainly be explained by the slow germination rate of its seeds (Bohner et al. 2013).

Sites with present straw cover showed high covering effects due to the applied substrate. With increasing straw cover total vegetation cover decreased highly sigificantly (p= <0.001). Long straw was used to cover the seeds. The application should prevent avulsion of the seeds and improve the micro-climate due to its protective effect against incident solar radiation, low temperatures and wind. On humus-rich soils this would be the normal treatment, but on bare grounds with lack of humus and fine-earth this method is not appropiate. In more detail, nitrogen was bound due to present straw. The reason is nitrogen immobilization. Thus, nitrogen remains plant unavailable in the soil. In nitrogen-limited ecosystems, microbes require additional nitrogen to metabolize material with high C content relative to N. This results in a wide C-N ratio in the soil. If additionally straw was applied, microbiotic activity increases nitrogen immobilization due to nitrogen requirement for the decomposition of the substrate (Barrett & Burke 2000; Kirmer & Tschew 2006; Wanek et al. 2010).

Rainfall swept off straw and accumulated it on several sites. This seems to be the reason for a high variance of straw cover ranging from 10 to 80% (mean: 18%). Furthermore, low microbial activity due to a lack of humus induces a very low decomposition rate and causes a longer retention time of straw on the soil surface. In case of grassland re-establishment on mountain areas the application of hay seems to be more successful. Hay decomposition is faster and grassland seeds are imported.

On several sites, only legumes were able to establish successfully due to their nitrogen fixation ability. But there was no significant difference (p=0.4) found between plots with straw and plots without straw application. Nitrogen indicator species were absent or present only with a few individuals. The nitrogen deficiency is a result of a lack of humus and hence limits the establishment and development of grasses. Especially on areas with straw cover, seed germination was inhibited (Dierschke & Briemle 2008). Legume cover was too high, especially *Trifolium hybridum* reached unfavourable cover values in all plots.

Furthermore, cereals such as barley or triticale and several cropland weeds occurred in the plots. These species increased floristic diversity for a short time. Some weed species were rare and endangered plant species, such as *Cyanus segetum.* Barley and triticale as well as cropland weeds occurred only on plots with straw cover, indicating that they were introduced by straw application. But there was no correlation between the occurrence of cropland species and straw cover.

All in all, straw application to ecosystems with nitrogen deficiency, like on humus-poor landslide deposits, should be avoided. Seed germination is inhibited, nitrogen is immobilized and legumes are favoured. The vegetation development was more inhibited than increased. Straw application correlated highly negative with total vegetation cover ($p= <0.001$).

The inhibited plant growth of the sown species enabled herbs from the local species pool to invade the sown areas. Although herbs were underrepresented, they increased species richness. The main portion of invaders was common and widespread grassland and forest species. A high portion of tree seedlings and shrubs found in the sown areas is an indicator of a fast succession towards forests (Borsdorf & Bender 2007). Tree seeds used the vegetation-free conditions to establish themselves. *Acer pseudoplatanus* and *Alnus alnobetula* were highly successful, but also *Picea abies* and *Salix myrsinifolia* seedlings were able to grow on several sites. If vegetation is missing, the establishment of trees is favoured (Dierschke and Briemle (2008).

In this context it may be favourable to use a hayflower seed mixture originating from the local meadows and pastures. Local seeds can be introduced and humus built up. This method can be used to obtain low cost seeds. One of the problems is that the harvesting efficiency is low with 10 - 20% of standing seed yield (Scotton et al. 2012).

Lime and ash application did not show any effects on vegetation cover, plant species composition and distribution of grasses, and herbs. Lime application correlated significantly with legume cover ($p=0.01$). In case of low pH values, application of lime is a possibility in the future. Up to now, nitrogen is a limiting factor and this causes the ineffectiveness of lime application.

Low soil nutrient content increased the establishment of bryophytes. Under these conditions, bryophytes used the increased light conditions to grow vigorously (Humer 2014). In general, high-yielding forage grasses prefer a neutral to slightly acid soil reaction and they have a high nitrogen requirement. Due to the lack of nitrogen, lime application did not show any effect. The application of farmyard manure or compost would be a better method, because it increases pH and additionally produces humus. But according to the Natura 2000 programe the application of external substrates on Natural Park areas is prohibited (Ressel 2003).

The application of local farmyard manure favoured vegetation development. Total vegetation cover was higher and plants grew more vigorously compared to unmanured plots. Obviously, the application of farmyard manure on bare surfaces enhanced plant productivity and should be applied continuously. Furthermore, higher plant productivity increases humus formation.

An additional study, which investigated primary succession, was carried out by the University of Natural Recourses and Life Sciences. Bohner et al. (2013) observed a very low total vegetation cover on non-sown sites. Native species were inhibited to establish themselves due to the lack of diaspores in the substrate and extreme abiotic site conditions. Competition was not included due to low above- and below-ground phytomass. This leads to the assumption that absent active grassland-reastablishment results in a very slow development of vegetation.
If the aim is to leave natural grassland re-establishment, recultivative measures have to be avoided in protected areas. Instead, natural processes should be used for primary succession. In the case of the valley Schwarzenseebach, the aim was to introduce productive meadows and pastures for cattle feeding and tourism. Hence, immediate revegetation was of upmost importance.

7. Conclusions

Based on the present results the following conclusions can be drawn:

(1) The lack of fine earth fraction and humus reduced the establishment of sown species. Low nitrogen contents in the soil are the reason why grasses did not grow vigourosly. Legumes used their nitrogen fixation ability to establish successfully. Thus, the portion of legumes was relatively high compared to the portion of grasses.

(2) Straw cover prohibited plant growth on several sites. Moreover, it further reduced nitrogen supply to plants according to nitrogen immobilization. Therefore, straw application on bare grounds has to be avoided. However, straw application increased species richness due to the introduction of arable crops and weeds.

(3) Since nitrogen is the limiting factor, application of lime was not effective for vegetation development. Humus build-up with farmyard manure or compost is of utmost importance. This measure is prohibited due to the Natura 2000 program in the Nature Park Sölktäler.

(4) *Poa pratensis* was the only species from the seed mixture which did not establish successfully. For future vegetation re-establishment it may be advisable to exclude *P. pratensis* from the seed mixture. Another strategy may be the dissemination of a hayflower seed mixture from the local meadows and pastures.

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9. Appendices

9.1. Reference list

ANGERER, H. (1994): Almwirtschaft und Erosion. In: Hellebart, S. (2006): Alp Austria: Programm zur Sicherung und Entwicklung der alpinen Kulturlandschaft - Almwirtschaft und Schutzfunktion. Umweltbüro Klagenfurt. 80 pp.

BARRETT, J.E. & BURKE, I.C. (2000): Potential nitrogen immobilization in grassland soils across a soil organic matter gradient. *Soil Biology & Biochemistry 32*:1707-1716.

BAUMANN, N., GEPP, J. UND ZIMMERMANN, A. (1984): Wasserschaupfade Sölktäler. Hrsg.: Verein Naturpark Sölktäler, Graz, 68 pp.

BECKER, L.P. (1981): Die Gliederung des Obersteirischen Altkristallins (Muriden) – Mit Bemerkungen zu den Erzvorkommen in den einzelnen Kristallinkomplexen. *Verh.Geol.B.-A.* 2: 3-17.

BECKER, L.P. (1989) Die Geologie der Sölktäler. 500 Millionen Jahre Erdgeschichte. In: HÖLLRIEGL, R. (ed.): Naturparkführer Sölktäler. Streifzüge durch Lebensbereiche von Natur und Mensch. Verein Naturpark Sölktäler, Graz: 13-19.

BENISTON, M., STEPHENSON, D.B., CHRISTENSEN, O.B., FERRO, C.A.T., FREI, C., GOYETTE, S., HALSNAES, K., HOLT, T., JYLHÄ, K., KOFFI, B., PALUTIKOF, J., SCHÖLL, R., SEMMLER, T. & WOTH, K. (2006): Future extreme events in European climate: an exploration of regional climate model projections. *Climatic Change*. Springer Verlag.

BILOVITZ, P. (2001): Epiphytische Flechten im Naturpark Sölktäler. Diplomarbeit, Instidut für Botanik, Universität Graz.

BIERINGER, B. (1984): Der Wald im Naturpark. In: Führer durch den heimischen Wald – Die Bedeutung des Waldes im Naturpark Sölktäler. Verein Naturpark Sölktäler, Stein an der Enns, 74 pp.

BMLFUW (2000): Natura 2000. 2. Auflage. http://www.salzburg.gv.at/natura2000-2.pdf (13.12.2014)

BMLFUW (2011): Ergebnisdokumentation 2010 - Bericht über die Wildbachereignisse im Sommer 2010 in Österreich, Wien, 187 pp.

BMLFUW (2014): Grüner Bericht 2014 – Bericht über die Situation der österreichischen Land- und Forstwirtschaft, Auflage 55, Wien, 43-45.

BOHNER, A., GRIMS, F. & SOBOTIK, M. (2007): Die Rotschwingel-Straußgraswiesen im Mittleren Steirischen Ennstal (Österreich) – Ökologie, Soziologie und Naturschutz. *Mitt. naturwiss. Ver. Steiermark* 136: 113-134.

BOHNER, A., FRÖHNER, S.E., LEINWEBER, P. & SCHIK, M. (2014): Rotschwingel-Straußgraswiesen im Naturpark Sölktäler (Steiermark, Österreich). *Acta 200 Bot. Austrian 150/151*: 157-174.

BOHNER, A., WINTER, S. KRAML, B. & HOLZNER, W. (2013): Destructive and constructive effects of mudflows – primary succession and success of pasture regeneration in the nature park Sölktäler (Styria, Austria) In: Bauch, K. (Ed.), Conference Volume 5th Symposium for Research in Protected Areas, Salzburger Nationalparkfonds, 10.-12. Juni 2013, Mittersil.

BORSVVDORF, A., & BENDER, O. (2007): Kulturlandschaftsverlust durch Verbuschung und Verwaldung im subalpinen und hochmontanen Höhenstockwerk: Die Folgen des klimatischen und sozioökonomischen Wandels. Sonderheft Hugo Penz, *Innsbrucker Geographische Gesellschaft*: 104-125.

BRAUN-BLANQUET, J. (1964): Pflanzensoziologie: Grundzüge der Vegetationskunde. Springer Verlag, Wien, 865 pp.

DEUTSCH, A. (2007): Bestimmungsschlüssel für Grünlandpflanzen während der ganzen Vegetationszeit. Österreichischer Agrarverlag, 12. Auflage, Wien.

Die Saat (2014): Das Fachblatt für Grünland - Dauergrünland und Feldfutterbau. Volume 2014/15/16.

DIETL, W., & JORQUERA, M. (2007): Wiesen- und Alpenpflanzen – Erkennen an den Blättern Freuen an den Blüten. Österreichischer Agrarverlag, 3. Auflage, Wien.

DULLINGER, S., DIRNBÖCK, T. & GRABHERR, G. (2001): Die subalpine und alpine Vegetation der Schneealpe (Steiermark, Österreich). *Mitt. Naturwiss. Ver. Steiermark* 131: 83-127, Graz.

FAHRIG, L. (2003): Effects of Habitat Fragmentation on Biodiversity. *Annual Review of Ecology, Evolution, and Systematics 34 (1):* 487–515.

FISCHER, M.A., OSWALD, K. & ADLER, W. (2008): Exkusionsflora für Österreich, Liechtenstein und Südtirol, Biologiezentrum der Oberösterreichischen Landesmuseen Vol. 3, 1391 pp.

GIS-Steiermark (1999): Provisorische Geologische Karte der Republik Österreich: 128 – Gröbming. Ausgabe 2006/02, Bundesamt für Eich- und Vermessungswesen Wien.

GROISMAN, P.Y.A., KNIGHT, R.W., EASTERLING, D.R., KARL, T.R., HEGERL, G.C. & RAZUVAEV, V.N. (2004): Trends in Intense Precipitation in the Climate Record. *Journal of Climate* 18: 1326-1350.

HEJL, E. (2006): Bericht 2006 über geologische Aufnahmen im Wölzer Kristallinkomplex auf Blatt 128 Gröbming in Blatt Gröbming 128: 659-660.

HÖLLRIEGEL, R. & MAYRHOFER, H. (1989): Der Alpenraum – Lebensraum für Pflanze, Tier und Mensch. In: HÖLLRIEGL, R. (ed.): Naturparkführer Sölktäler. Streifzüge durch Lebensbereiche von Natur und Mensch. Verein Naturpark Sölktäler, Graz: 9-12

HUMER, J. (2014): So wird man Moose in Wiesen los. Referat Bodenbewirtschaftung und Pflanzenernährung, Landwirtschaftskammer Niederösterreich: 1-4.

HUSEN, Dirk van (1987): Die Ostalpen in den Eiszeiten. Geologische Bundesanstalt, Wien, 24 pp.

KAINDL, A. (2014): 15 Meter hohe Mure versperrt Tal, in Salzburger Nachrichten.

KIENINGER, P. & POSTL, S. (2013): Nach der Mure – Über den Umgang mit Naturgewalten im Kleinsölktal. Documentation, Naturpark Sölktäler, Stein an der Enns.

KIRMER, A. & TISCHEW, S. (2006): Handbuch naturnahe Begrünung von Rohböden. Springer-Verlag, 184 p.

KRAUTZER, B., GRAISS, W., KLUG, B. (2010): Standortgerechtes Saatgut für die Hochlagenbegrünung: Entwicklung und Stand der Technik. *European Journal of Turfgrass Science 4/2010*, 85-89.

KRAUTZER, B., WITTMANN, H. (2006): Restoration of alpine ecosystems. in: Andel, J., Aronson, J.: Restoration ecology. *The new frontier*, Blackwell Publishing, malden u.a., 208-220.

LLOYD, P.S. & PIGOTT, C.D. (1967): The influence of soil conditions on the course of succession on the chalk of southern England. *Journal of Ecology* 55: 137 – 146.

Land Steiermark – Amt der Steiermärkischen Landesregierung (2014): Natura 2000 – Niedere Tauern. http://www.verwaltung.steiermark.at/cms/beitrag/11680814/7483 5791/ (11.04.2014).

MAGNES, M. & DRESCHER, A. (2001): Bergahorn-Bergulmenwaldreste im Naturpark Sölktäler (Niedere Tauern, Steiermark) und die Ursprünglichkeit des Vorkommens von *Campanula latifolia* in den Ostalpen. *Linzer biol. Beitr*. 33/1: 607-623.

MIRZA, M.M.Q. (2003): Climate change and extreme weather events: can developing countries adapt?. *Climate Policy* 3: 233–248.

NERAT, C. (2010): Kleinsölktal: Bilanz einer Katastrophe. Kleine Zeitung. http://www.kleinezeitung.at/steiermark/2457313/bilanz-katastrophe.story (17.11.2013).

N.N. (2010): Kleinsölk: Nach Murenabgängen Personen ausgeflogen, in Kleine Zeitung. http://www.kleinezeitung.at/steiermark/liezen/multimedia.do?action=showEn try_detail&project=25719 (20.02.2014).

N.N. (2012): Der Almsommer in der Kleinsölk ist gesichert, in Kleine Zeitung. http://www.kleinezeitung.at/steiermark/liezen/kleinsoelk/2958569/almsommer-kleinso elk-gesichert.story (21.07.2014).

N.N. (s.a.): Düngen mit Kalk im Frühjahr. Landratsamt Rems-Murr-Kreis, http://www.rems-murr-kreis.de/Duengen_mit_Kalk_im_Fruehjahr.pdf (30.08.2014).

Österreichische Hagelversicherung (2013): Bisherige Wetterbilanz 2013: Jahr der Wetterextreme. http://www.hagel.at/site/index.cfm?objectid=AF7D5754-5056-A500-09055E776CA37873&refid=B17D1B2C-5056-A500-6A6AEF053B6D1F79 (21.11.2013).

PITZER, K. (2014): mündliche Mitteilung, Karl Pitzer Tiefbau GmbH.

PÖLZL, M. (2007): Wiesen im Naturpark Sölktäler. Diplomarbeit, Institut für Umwelt und Naturschutz, Universität für Bodenkultur Wien.

PÖLZL, M. (2007): Wiesen im Naturpark Sölktäler. Diplomarbeit, Institut für Umwelt und Naturschutz, Universität für Bodenkultur Wien. Datengrundlage: Digitale Bodenkarte von Österreich, 1km-Raster Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (BFW).

PRENNER, F. (2014): mündliche Mitteilung, Nature Park Sölktäler.

PRÖBSTL, U. & PRUTSCH, A. (2010): Natura 2000 - outdoor recreation and tourism: a guideline for the application of the habitats directive and the birds directive. Bundesamt für Naturschutz, Bonn.

Raumberg-Gumpenstein (2011): Aktionstag im Sölktal - Ennstaler helfen im Sölktal: http://www.raumberggumpenstein.at/c/index.php?option=com_content&view=article&id=1923:aktionstag-im-soelktal-1452011&catid=227:3institut-3-news&Itemid= 355&lang=de (11.02.2013)

RESCH, R. (1989): Der Naturpark Sölktäler. In: HÖLLRIEGL R. (ed.): Naturparkführer Sölktäler. Streifzüge durch Lebensbereiche von Natur und Mensch. Verein Naturpark Sölktäler, Graz, 5-80.

RESSEL, M. (2003): Die Rolle des Naturparks zur Erhaltung der Landwirtschaft im Berggebiet. Bundesanstalt für alpenländische Landwirtschaft Gumpenstein, 45-47.

SCHAAF, W., O. BENS, A. FISCHER, H.H. GERKE, W. GERWIN, U. GRÜNEWALD, H.M. HOLLÄNDER, I. KÖGEL-KNABNER, M. MUTZ, M. SCHLOTER, R. SCHULIN, M. VESTE, S. WINTER & R.F. HÜTTL (2011): Patterns and processes of initial terrestrial-ecosystem development. *J. Plant Nutr. Soil Sci.* 174: 229-239.

SCHARLER, A. (2014): Mündliche Mitteilung, Ottacheralm – Nationalpark Hohe Tauern.

SCOTTON, M., KIRMER, A. & KRAUTZER, B. (2012): Practical handbook for seed harvest and ecological restoration of species-rich grasslands. Padova, Italy: Cooperativa Libraria Editrice Università di Padova, 116.

SIDLE, R.C. & OCHIAI, H. (2006): Landslides: processes, prediction, and land use. *Water Resources Monograph* 18, American Geophysical Union, Washington, DC. 317 pp.

WAKONIGG, H. (1978): Witterung und Klima in der Steiermark. Verlag für die technische Universität Wien. 473 pp.

WANEK, W., MOOSHAMMER, M., BLÖCHL, A, HANREICH, A. & RICHER, A. (2010): Determination of gross rates of amino acid production and immobilization in decomposing leaf litter by a novel15 N isotope pool dilution technique. *Soil Biology & Biochemistry 42*: 1293-1302.

WINTER, S. (2005): Einfluss der Bewirtschaftung auf die Pflanzenvielfalt im Schwarzenseebachtal (Niedere Tauern) – Geschichtlich und Gegenwart. Diplomarbeit, Universität für Bodenkultur.

ZAMG (2002): Klimadaten von Österreich 1971 2000. http://www.zamg.ac.at/fix/klima/oe71-00/klima2000/klimadaten_oesterreich _1971_ frame1.htm (17.02.14).

9.2. List of figures

9.3. List of tables

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9.4. Material

SPECIES NAME	consistency	201222010001	201222010002	201222010003	201222010004	201222010005	201222010006	201222010007	201222010008	201222010009	201222010010	201222010011	201222010012	201222010013	201222010014	201222010015	201222010016	201222010017	201222010018	201222010019	201222010020	201222010021	201222010022	201222010023	201222010024	201222010025	201222010026	201222010027	201222010028	201222010029	201222010030	201222010031	201222010032	201222010033	201222010034	201222010035	201222010036	201222010037	201222010038	201222010039	201222010040	201222010041	201222010045	201222010046	201222010047	201222010048	201222010049	201222010050	201222010051	201222010052	201222010053	201222010054	201222010055
altitude in m		970	971	1008	995	996	1000	1011	1011	1051	1060	1062	1057	1064	1064	1066	1071	1070	1082	1083	1080	1098	1106	1100	1112	1110	1124	1120	1120	1131	1136	1071	1090	1116	1136	1118	1036	1015	1046	1051	966	1014	1060	1055	1053	1032	1076	1076	1067	1043	997	1067	1075
slope angle in °		4	10	12	14	12	4	10	10	12	10	4	18	10	8	8	8	8	9	5	8	9	6	6	4	4	4	4	5	8	20	7	10	14	9	7	2	10	11	10	2	3	4	4	2	28	2	7	9	14	14	5	5
exposition		N W	N N W	N N W	W	N W	W N W	W	W N W	W S W	W N W	N	W N W	W N W	N W	W	W N W	W N W	W N W	W	W N W	W	N W	N	N W	W N W	N W	N W N	N W N	N W N	N W N	N W N	N W N	N	N W N	N W	N W	S O	S O	S O	O	N N O	O	O S O	O	O	N O	O	O S O	O	S S W	W	N W
vegetation cover in %		80	70	25	30	70	40	70	75	35	80	70	80	65	90	40	5	70	30	10	45	85	70	55	30	25	65	20	80	70	20	75	80	25	40	60	30	30	25	25	20	35	20	30	40	50	65	60	75	25	75	30	40
bryophyte cover in %		15	15	2	3	4	2	3	3	1	2	20	8	4	20	2	3	1	1	1	1	2	10	10	1	1	1	1	2	2	1	3	3	1	5	5	1	1	1	1	1	1	1	1	2	5	10	10	5	1	1	10	10
straw cover in %		10	0	0	0	0	0	0	0	50	0	0	0	25	0	0	0	0	60	80	50	0	0	0	0	0	20	0	0	15	65	0	0	50	0	0	40	60	65	75	60	50	50	50	0	0	0	0	0	45	20	0	0
grass cover in %		50	75	80	80	75	80	59	59	54	47	50	44	54	50	55	90	95	44	49	59	44	55	50	75	60	20	59	70	60	90	45	45	59	80	65	40	35	23	20	59	65	64	29	54	60	45	40	50	45	35	54	45
herb cover in %		1	1	1	2	1	1	1	1	1	3	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
legume cover in %		49	24	19	18	24	19	40	40	45	50	48	55	45	48	44	9	4	55	50	40	55	44	49	24	39	79	40	29	39	9	54	52	40	19	33	59	64	76	79	40	34	35	70	45	39	54	59	48	53	64	45	54

Species in the seed mixture

Poa pratensis	15				+					+	+			+	+																							+					+	+			+				r	+	r	+	+	+	
Festuca pratensis	49	1	+	+	+	1	+	2a	1	1	2a	1	1	1b	1	1a	+		1	1a	1a	1a	+	1a			1a	+	+	1a	+	1	1	1a	+	+	1	1	1	1a	1a	+	1a	1a		+	1	1a	1a	+	1b	1a	+
Phleum pratense	54	1	1a	1	1	+	+	+	+	+	1	1	+	1a	1a	+	+	+	+	1	1a	1a	1a	+	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1	1a	1b	1	+	1a	+	1a	1a	+	1	1	1
Festuca rubra agg.	55	1	1	2	2	2	2	2a	2a	2	2	1	2b	2b	2	2	2a	1	2	1b	2	2	2b	2b	1	1	2	2	2b	2	2	2	1b	2b	2b	2	2b	2	2	2	2b	2b	2	2a	1	2b	2	2	2	2	2	2	2
Trifolium repens	53	2	2a	1a	1	1	1a	2b	2b	2	2b	2	3	2	3a	2	+	+	2	1b	2a	3a	3a	3a	2	2	3a	2	2b	2b	1	3a	3a	2	2	2	3a	3a	3a	3	2b	2	2a	3a	3a	1b	3a	3a	3a	2	3	2	3a
Dactylis glomerata	52	1a	+	1a	1a	+	+	1a	+	1	1a	1a	1	1a	1a	1	+	+	+	+	1	1	+	1a	1a	1a	1a	1	r	1a	1a	+	+	1	+	+	+	1	1	1	1a	1a	+	1	+	1a	1a	1a	1a	1a	1b	1	1
Lolium perenne	50	1b	1	1	1	2	1b	2	2	+	2a	2	2	2a	2	2a			1	1a	1a	1b	1a	1a	1	1a	1	1	1	2a	1a	1	2	1	1b	+	1	1	1a	1	1a	1a	1a	1	+	+	1	1	1	1	2	1	1a
Agrostis capillaris	55	2b	2b	2a	2	2	2	2b	2b	1a	2	2	1a	1	1a	2a	1	3	1a	1a	1a	1	1	1	2b	2b	1	1	2	2a	1a	1b	1	1	1	3a	1	1a	1a	1a	1a	1a	+	+	2	2	1	1	2b	1b	1a	1	1
Trifolium hybridum	51	2a	1	1	1	1b	1a	1	1	1	2	2	1	2	1	2a	+	+	2	1	1	2	1a	1	+	+	2		1a	1a	+	1	1	1a	1a	1a	1	2a	2	1b	2	1	1b	2b	1	1	1	1	1	1	2b	1	1a
Lotus corniculatus	53	1b	1b	+	1	2a	1b	2	2	1	2	2	1b	1b	1	2a	1a	1a	1a	1a	1a	1a	2a	2a	1	1	2a	1b	2	1b	1	2a	+	1	1b	1a	1b	1b	2	1	1b	2	1	2a	1	2	1	1a	1	2	2	2a	2

Typical grassland species

Achillea millefolium agg.	33	+		+	+			r	r		+	1a	r	+	1a	r	r				r	+			1a	1a	+	1a	+	+	r	+	+	+	+	+		+					r				+	+	1a	+		r	
Arabidopsis halleri	1							r																																													
Arrhenatherum elatius	5									1a											+																			+		+									1a		
Campanula patula	1																																									r											
Carum carvi	2																								+	+																											
Cerastium holosteoides	36	+	r		+			r			+	+	+	r	1a				+			+		+	1a	1a		+	+			r	+		r	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	
Galium album	1																																									+											
Holcus lanatus	3				+																					r																			r								

Leontodon hispidus	4							r					r									+											+																				
Leucanthemum ircutianum	3																																r	+														+					
Lolium x boucheanum	5																			+	+				+																							+	+				
Medicago lupulina	1																											+																									
Plantago lanceolata	8												r									+			+	+		1				r								r		1a											
Poa trivialis	15	+			+						1a	1a			+						r	+	r		r									+				+			r	+	r										+
Prunella vulgaris	23	r			+			r			+	1a	+		1	r	r		+			+				r	r			+		+	+		+	+		+		+			r					r		+			
Ranunculus acris ssp.acris	16				+			r			r	+	+		+					r										r			+			+		+		r	r		r						r	r			
Silene dioica	6														+																				+		r						r				r					r	
Taraxacum officinale agg.	10										+		r		+				+	+																		r	r				+							r		r	
Trifolium dubium	1																									r																											
Trifolium pratense	20		r							r	1	+	+		1a										1	1a	r	1b	+			+	1a	r	+	1a											+	+		+	+		
Veronica chamaedrys ssp.chamaedrys	14	r									+				r					+							r			r		r	+	r		+		+	r			r								+			
Veronica serpyllifolia ssp.serpyllifolia	7										+	1a	+		+																		+		r			r															

Trees and shrubs

Abies alba	2																											r																		r							
Acer pseudoplatanus	40	1	1a	+	+	+	+	+	r	r	+	+	r		r			+	r	r		+			+	r	1a	1a	+		+		+	+	+	r				+	+	r	r		r	1a					r	r	+
Alnus alnobetula	41		r	+	+	+	+	+	+	+	r			+			+	r	r	r	+	+	+	+	+	+	+	+	+	+	+	+	r	+	+	+	+	+			r	+	r		+	+				+		+	+
Alnus incana	5																																								+	+	+	r	+								
Betula pendula	1				r																																																
Betula pubescens	1																					+																															
Larix decidua	1				r																																																	
Picea abies	34		r				r	r		+				+		r	+	r	r		+	+	r	+	+	+	r	+			+			r	r		r	+	r		r	+	+	+	+	+						+	r
Salix myrsinifolia	28		+	+	+	+	+				1a	+		+			+	r	+	r	r	+					r		+	+	+	+	r		+		1a				+	1a	+		+	+		r					
Vaccinium myrtillus	2																																+	+																			

Forest and edge species

Anemone nemorosa	17	r		+	+		r									+				r	r								r		r		r	+	r			+	+							+				r	r		
Athyrium filix-femina	2																																								+					+							
Cardamine flexuosa	4																			r														r														+				+	
Cardamine impatiens	3										+						r																																	+			
Carduus personata	1					r																																															
Digitalis grandiflora	1																														+																						
Epilobium montanum	22		r	+	+	r	r				r						+	+		r		+				r			r		r	r	r			r							+		r	+			r			+	r
Fragaria vesca	5										r									+												r	r																	+			
Galeopsis speciosa	5					r											r								r					r																r							
Hieracium	3																					r												r															r				

murorum																																																					
Homogyne alpina	2																																	+		+																	
Lamium sp.	2																	r																							r												
Luzula luzuloides	36	+	+	+	+		+	+	r		+			+	+	+	1a	+	r		+	+	+	+			+		+		1a	r	r	+	1a	+	+				+	+	+		+	1a	+		+			+	+
Luzula pilosa	1					r																																															
Luzula sylvatica ssp.sylvatica	4														r																			+	+	r																	
Lysimachia nemorum	5																				r									+	+		+														+						
Maianthemum bifolium	1																																+																				
Moehringia trinervia	2										+																															+											
Petasites albus	11						r				+		r																		+							r			r				r	+				r			
Rubus idaeus	6																			r																		r	r									r	+	r			
Mycelis muralis	1																																							r													
Scrophularia nodosa	1																																															r					
Senecio ovatus	2																														r							r															
Thelypteris limbosperma	2																																	+					r														
Verbascum densiflorum	1																																														r						
Viola riviniana	3			r																		r																												+			

Cropland species

Anthemis arvensis	1																								+																												
Cyanus segetum	1																											r																									
Equisetum arvense	4															+											r					r	+																				
Hordeum vulgare	6																									+		1a										+		+		+	+										
Secale cereale	2																								+		r																										
Stellaria media	1																																					r															
Tripleurospermum maritimum subsp. Inodorum	3			r																						+		+																									
Triticale rimpaui	1									+																																											

Pasture plants and species indicating comacted soils

Bellis perennis	4							r				+	r		+																																						
Cynosurus cristatus	33	1								1a	+	1			1				1	1a	1a	1a	+	+	+	+	2a		1	1	+	1	1	1	+	1	1		+	1						+	1	2	1b	1a	1	+	1a
Leontodon autumnalis	12			r							r	+	+		+												r		r	r		r			r	+		+															
Plantago major ssp.major	11										1a	1a	+		1b								r										+			+		1a									r	r	r				
Poa annua	1																																																			+	
Poa supina	12			+								r			+							+			+	+							r			r											r	+	+	+			
Ranunculus repens	18							+			+	+	+		1			r												r	r	+	+			+		r		r							+	1	+	+			
Sagina procumbens	24				+						1a	1a		+	1b				+			+	1a	+		1a						1a	1a	1a	+	+		+	+		+	+	+		1a					+		1a	1a

Low-nutrient indicator species

Anthoxanthum odoratum	16		+	+	+			+			+	+			+							+			+								+	+	+	+					+					+			+	+			
Avenella flexuosa	1																																																	+			
Carex leporina	12										+	+			1a														1a	+		+			+	1a									+		+	+	+				
Carex pilulifera	12		+	+	1															+		+											+	+		1a					+		+						1a	r			
Carex pallescens	25	+	+		+	+				r	+	+			1a					+					r	+	+		1a	1a	+	+	1a	+	1a	1	+	1a				+			+					+			
Danthonia decumbens ssp.decumbens	1																																			+																	
Euphrasia officinalis ssp.picta	6				+			+	+													r						r									+																
Euphrasia officinalis ssp.rostkoviana	24	+	+	1a	r		+	+	+	r	+	+	r	1a		1a	+		+										+	+		+	+	+	1a	1a	+														+		
Galium pumilum	1				+																																																
Gnaphalium sylvaticum	14			+									r									r								r	+	r	+		r	r		+				r								+			
Hieracium lactucella	1																																		r																		
Hieracium pilosella	6				+								r									+																									r		r	r			
Hypericum maculatum	2																																+			+																	
Hypochoeris radicata	1																																																	r			
Luzula campestris	22	+	+	+			+			+	+				+						+								+					+	+	+		+	r	+			+	r	+	+			+	+	+		
Luzula multiflora	1				+																																																
Nardus stricta	1																																			+																	
Potentilla erecta	31	r	+	r	+		r				r	+	+	r	+			r		+	+	r				r			+	+	+	+	+	1	+	1a		+	+		+		+		+		r		1	+			
Ranunculus nemorosus	5																												r	+			+	r								r											
Sanguisorba minor	3																								+	+		+																									
Silene vulgaris ssp.vulgaris	1																																																r				
Stellaria graminea	10				+						+	r			r																	+	r					+		+								+		r			
Thymus pulegioides	6				+												+					+											+			+														+			
Veronica officinalis	26			+	1a						+				+					+	r	+							r	r	+	+	+	+	+	+	+	+		+	r	+	+				+	+	1a	1a		+	

Species of higher altitudes

Ajuga pyramidalis	24							r	r		+	1a	r		1a	r	r				r	+			r		+		+	+	r	+	+		+	+		+												r		r	
Arnica montana	1				r																																																
Campanula barbata	1																																																	r			
Campanula scheuchzeri	1																																																	r			
Crocus albiflorus	2				+																													r																			
Peucedanum ostruthium	2																														r															r							
Poa alpina	1																																			r																	
Potentilla aurea	10				+																								r			r	+	+		1a								r				r	r	r			
Ranunculus	2				+																	r																															

montanus																																																					
Rumex alpestris	10							r							+										r					+	+		r		r	+				+											+		
Viola biflora	13			+	+																									+	+	+	+	+	+	1a					r					+			+	+			
Veratrum album ssp.album	3																														r			+		+																	
Veronica fruticans	1																																		r																		

Moisture indicator species

Cardamine pratensis	2											+																																						r			
Carex remota	1															+																																					
Cirsium palustre	29				r		r	+		r	r	r	1a	r	+	+			r	r	r								+	+	r	+	+		r	+	r									r	+	r	+	+		r	
Deschampsia cespitosa	6				+							+			+	+														+						+																	
Epilobium alsinifolium	1																																									r											
Galium uliginosum	9											+			+													+								+		r	+								r	+		+			
Glyceria notata	1														r																																						
Juncus alpinoarticulatus	2																															+				+																	
Juncus articulatus	3										+	1			+																																						
Juncus bufonius	1											+																																									
Juncus effusus	4										+	1a				+														+																							
Myosotis nemorosa	2										+				+																																						
Pinguicula alpina	3																													+			r				r																
Rorippa palustris	2										r				+																																						
Saxifraga stellaris ssp.robusta	2				+																															r																	
Veronica beccabunga	1										+																																										

Nutrient indicator species

Geranium robertianum	1																			+																																	
Rumex obtusifolius	3											+			1																																		r				
Urtica dioica	1										+																																										

Pioneer species and species indicating bare ground

Bromus hordeaceus	1								+																																												
Cardamine hirsuta	1																																														+						
Daucus carota ssp.carota	1																											1a																									
Sideritis montana	1																																									r											
Silene rupestris	8			+													+					+							r		+					r									+					+			
Rhinanthus minor	6					r					r	+						r							+	r																											
Rumex acetosella ssp.acetosella	1														r																																						

Species occurence without straw

Anthemis arvensis	1																								+																												
Arabidopsis halleri	1							r																																													
Arnica montana	1				r																																																
Bellis perennis	4							r				+	r		+																																						
Bromus hordeaceus	1								+																																												
Cardamine hirsuta	1																																													+						
Carduus personata	1					r																																															
Carex remota	1															+																																					
Carex sp.	4																+	+																												+							
Carum carvi	2																								+	+																											
Danthonia decumbens ssp.decumbens	1																																			+																	
Daucus carota ssp.carota	1																											1a																									
Euphrasia picta	3							+														r						r																									
Galeopsis speciosa	3					r											r																													r							
Galium pumilum	1				+																																																
Glyceria notata	1														r																																						
Hieracium lactucella	1																																		r																		
Holcus lanatus	3				+																					r																			r								
Hypericum maculatum	2																																+			+																	
Juncus alpinoarticulatus	2																															+				+																	
Juncus articulatus	3										+	1			+																																						
Juncus bufonius	1											+																																									
Leontodon hispidus	4							r					r									+											+																				
Luzula multiflora	1				+																																																
Luzula pilosa	1					r																																															
Maianthemum bifolium	1																																+																				
Medicago lupulina	1																											+																									
Myosotis nemorosa	2										+				+																																						
Nardus stricta	1																																			+																	
Poa alpina	1																																			r																	
Poa annua	1																																																			+	
Ranunculus montanus	2				+																	r																															
Rhinanthus minor	6					r					r	+						r							+	r																											
Rorippa palustris	2										r				+																																						
Rumex acetosella ssp.acetosella	1														r																																						
Rumex obtusifolius	3											+			1																																		r				
Sanguisorba minor	3																								+	+		+																									

Saxifraga stellaris ssp.robusta	2				+																															r																	
Scrophularia nodosa	1																																														r					
Silene vulgaris ssp.vulgaris	1																																															r			
Trifolium dubium	1																									r																											
Tripleurospermum maritimum subsp. Inodorum	3			r																						+		+																									
Urtica dioica	1										+																																										
Verbascum densiflorum	1																																													r						
Veronica beccabunga	1										+																																										
Veronica fruticans	1																																		r																		

Species occurence with straw

Avenella flexuosa	1																																																+			
Campanula barbata	1																																																r			
Campanula patula	1																																								r											
Campanula scheuchzeri	1																																																r			
Digitalis grandiflora	1																													+																							
Epilobium alsinifolium	1																																								r											
Galium album	1																																								+											
Geranium robertianum	1																			+																																	
Hypochoeris radicata	1																																																r			
Mycelis muralis	1																																						r													
Senecio ovatus	2																													r							r															
Sideritis montana	1																																								r											
Stellaria media	1																																				r															
Thelypteris limbosperma	2																																+					r														

Plots with lime application

SPECIES NAME	consistency	201222010022	201222010023	201222010049	201222010050	201222010055
altitude in m		1106	1100	1076	1076	1075
slope angle in °		6	6	2	7	5
exposition		NW	N	NO	O	NW
vegetation cover in %		70	55	65	60	40
bryophyte cover in %		10	10	10	10	10
straw cover in %		0	0	0	0	0
grass cover in %		55	50	45	40	45
herb cover in %		1	1	1	1	1
legume cover in %		44	49	54	59	54
Species in the seed mixture						
Poa pratensis	2			r	+	
Festuca pratensis	5	+	1a	1	1a	+
Phleum pratense	5	1a	+	+	1a	1
Festuca rubra agg.	5	2b	2b	2	2	2
Trifolium repens	5	3a	3a	3a	3a	3a
Dactylis glomerata	5	+	1a	1a	1a	1
Lolium perenne	5	1a	1a	1	1	1a
Agrostis capillaris	5	1	1	1	1	1
Trifolium hybridum	5	1a	1	1	1	1a
Lotus corniculatus	5	2a	2a	1	1a	2
Typical grassland species						
Achillea millefolium agg.	2			+	+	
Arrhenatherum elatius						
Bromus hordeaceus						
Campanula patula						
Cerastium holosteoides	3		+	+	+	
Danthonia decumbens ssp.decumbens						
Holcus lanatus						
Leontodon hispidus						
Leucanthemum ircutianum	1				+	
Lolium x boucheanum	1				+	
Medicago lupulina						
Plantago lanceolata						
Poa annua						
Poa trivialis	2	r				+
Prunella vulgaris	1				r	
Ranunculus acris ssp.acris						
Taraxacum officinale agg.						
Trifolium dubium						
Trifolium pratense	2			+	+	
Veronica chamaedrys ssp.chamaedrys						
Veronica serpyllifolia ssp.serpyllifolia						
Trees and shrubs						
Abies alba						
Acer pseudoplatanus	1					+
Alnus alnobetula	3	+	+			+
Alnus incana						
Betula pendula						
Betula pubescens						
Larix decidua						

Picea abies	3	r	+			r
Rubus idaeus	1				r	
Salix myrsinifolia	1				r	
Vaccinium myrtillus						

Forest and edge species

Anemone nemorosa						
Athyrium filix-femina						
Cardamine flexuosa	1				+	
Cardamine hirsuta	1			+		
Cardamine impatiens						
Carduus personata						
Daucus carota ssp.carota						
Digitalis grandiflora						
Fragaria vesca						
Galeopsis speciosa						
Galium pumilum						
Hieracium murorum						
Homogyne alpina						
Hypochoeris radicata						
Lamium sp.						
Luzula luzuloides	4	+	+	+		+
Luzula pilosa						
Luzula sylvatica ssp.sylvatica						
Lysimachia nemorum	1			+		
Maianthemum bifolium						
Moehringia trinervia						
Mycelis muralis						
Scrophularia nodosa	1				r	
Senecio ovatus						
Verbascum densiflorum	1			r		
Viola riviniana						

Cropland species

Anthemis arvensis						
Cyanus segetum						
Equisetum arvense						
Hordeum vulgare						
Secale cereale						
Stellaria media						
Tripleurospermum maritimum subsp. Inodorum						
Triticale rimpaui						

Pasture and step indicator species

Leontodon autumnalis						
Cynosurus cristatus	5	+	+	1	2	1a
Plantago major ssp.major	3	r		r	r	
Poa supina	2			r	+	
Ranunculus repens	2			+	1	
Sagina procumbens	3	1a	+			1a

Low-nutrient indicator species

Anthoxanthum odoratum						
Arabidopsis halleri						
Avenella flexuosa						
Carex leporina	2			+	+	
Carex pilulifera						
Carex pallescens						
Euphrasia officinalis ssp.picta						
Euphrasia officinalis ssp.rostkoviana						

Euphrasia picta						
Gnaphalium sylvaticum						
Hieracium lactucella						
Hieracium pilosella	1			r		
Hypericum maculatum						
Luzula campestris						
Luzula multiflora						
Potentilla erecta	1			r		
Ranunculus nemorosus						
Rhinanthus minor						
Rumex acetosella ssp.acetosella						
Sanguisorba minor						
Silene rupestris						
Silene vulgaris ssp.vulgaris						
Stellaria graminea	1				+	
Thymus pulegioides						
Veronica officinalis	2			+	+	

Alpine species

Ajuga pyramidalis						
Arnica montana						
Campanula barbata						
Campanula scheuchzeri						
Crocus albiflorus						
Epilobium alsinifolium						
Epilobium montanum	1					r
Juncus alpinoarticulatus						
Nardus stricta						
Peucedanum ostruthium						
Pinguicula alpina						
Poa alpina						
Potentilla aurea	1				r	
Ranunculus montanus						
Rumex alpestris						
Saxifraga stellaris ssp.robusta						
Sideritis montana						
Thelypteris limbosperma						
Viola biflora						
Veratrum album ssp.album						
Veronica fruticans						

Moisture indicator species

Cardamine pratensis						
Carex remota						
Cirsium palustre	2			+	r	
Deschampsia cespitosa						
Galium uliginosum	2			r	+	
Glyceria notata						
Juncus articulatus						
Juncus bufonius						
Juncus effusus						
Myosotis nemorosa						
Petasites albus						
Rorippa palustris						
Silene dioica	1			r		
Veronica beccabunga						

Nutrient indicator species

Bellis perennis						
Carum carvi						

Galium album						
Geranium robertianum						
Rumex obtusifolius						
Urtica dioica						

Species occurence without straw

Anthemis arvensis						
Arabidopsis halleri						
Arnica montana						
Bellis perennis						
Bromus hordeaceus						
Cardamine hirsuta	1			+		
Carduus personata						
Carex remota						
Carex sp.						
Carum carvi						
Danthonia decumbens ssp.decumbens						
Daucus carota ssp.carota						
Euphrasia picta						
Galeopsis speciosa						
Galium pumilum						
Glyceria notata						
Hieracium lactucella						
Holcus lanatus						
Hypericum maculatum						
Juncus alpinoarticulatus						
Juncus articulatus						
Juncus bufonius						
Leontodon hispidus						
Luzula multiflora						
Luzula pilosa						
Maianthemum bifolium						
Medicago lupulina						
Myosotis nemorosa						
Nardus stricta						
Poa alpina						
Poa annua						
Ranunculus montanus						
Rhinanthus minor						
Rorippa palustris						
Rumex acetosella ssp.acetosella						
Rumex obtusifolius						
Sanguisorba minor						
Saxifraga stellaris ssp.robusta						
Scrophularia nodosa	1				r	
Silene vulgaris ssp.vulgaris						
Trifolium dubium						
Tripleurospermum maritimum ssp. inodorum						
Urtica dioica						
Verbascum densiflorum	1			r		
Veronica beccabunga						
Veronica fruticans						

Species occurence with straw

Avenella flexuosa						
Campanula barbata						
Campanula patula						
Campanula scheuchzeri						
Digitalis grandiflora						
Epilobium alsinifolium						
Galium album						
Geranium robertianum						
Hypochoeris radicata						
Mycelis muralis						
Senecio ovatus						
Sideritis montana						
Stellaria media						
Thelypteris limbosperma						

Statistics

		vegetation cover in %	bryophyte cover in %	grass cover in %	herb cover in %	legume cover in %	species in the seed mixture in %	straw cover in %
without straw	**mean**	55,74	4,93	33,37	0,80	21,57	39,25	0,00
	median	70,00	3,00	35,00	0,70	18,00	32,90	0,00
	standard deviation	24,25	5,32	14,35	0,62	14,65	23,94	0,00
	minimum	5,00	1,00	4,50	0,05	0,45	0,78	0,00
	maximum	90,00	20,00	66,50	2,40	46,75	80,00	0,00
straw	**mean**	36,05	1,95	17,21	0,37	18,47	22,99	48,42
	median	30,00	1,00	13,00	0,30	17,70	18,13	50,00
	standard deviation	19,62	3,24	11,24	0,20	11,95	15,45	19,30
	Minimum	10,00	1,00	4,90	0,10	1,80	2,15	10,00
	maximum	80,00	15,00	42,00	0,80	51,35	52,80	80,00
lime	**mean**	58,00	10,00	27,45	0,58	29,97	38,41	0,00
	median	60,00	10,00	27,50	0,60	30,80	39,05	0,00
	standard deviation	11,51	0,00	7,53	0,12	5,82	6,86	0,00
	minimum	40,00	10,00	18,00	0,40	21,60	29,00	0,00
	maximum	70,00	10,00	38,50	0,70	35,40	47,95	0,00

T-test comparing plots with straw cover and plots without straw cover

		Levene-Test for homogeneity of variance		T-Test for averaging equality		
		F	**Sig.**	**t**	**df**	**Sig. (2-sited)**
vegetation cover in %	Variances are equal	4,18	0,047	2,93	44,00	0,005
	Variances are unequal			3,04	43,05	0,004
grass cover in %	Variances are equal	0,90	0,348	4,10	44,00	0,000
	Variances are unequal			4,28	43,42	0,000
herb cover in %	Variances are equal	8,12	0,007	2,87	44,00	0,006
	Variances are unequal			3,32	33,01	0,002
legume cover in %	Variances are equal	3,52	0,067	0,76	44,00	0,451
	Variances are unequal			0,79	42,96	0,435
species in the seed mixture in %	Variances are equal	9,75	0,003	2,60	44,00	0,013
	Variances are unequal			2,80	43,75	0,008

Mann-Whitney test

	N			average value	
	without straw	**straw**	**total**	**without straw**	**straw**
vegetation cover in %	27,00	19,00	46,00	30,93	17,71
bryophyte cover in %	27,00	19,00	46,00	30,63	14,55
grass cover in %	27,00	19,00	46,00	32,56	16,11
herb cover in %	27,00	19,00	46,00	31,31	17,50
legume cover in %	27,00	19,00	46,00	26,04	22,89
species in the seed mixture in %	27,00	19,00	46,00	29,65	19,18

	Mann-Whitney U	**Wilcoxon W**	**Z**	**Asymp. Sig. (2-sited)**
vegetation cover in %	56,00	336,50	-4,50	0,000
bryophyte cover in %	64,00	276,50	-4,51	0,000
grass cover in %	12,00	306,00	-5,46	0,000
herb cover in %	45,50	332,50	-4,73	0,000
legume cover in %	188,00	435,00	-1,53	0,126
species in the seed mixture in %	90,50	364,50	-3,70	0,000

T-test comparing plots without straw and plots with lime cover (N=5)

		N	means	Standard deviation
vegetation cover in %	without straw	5	64,00	8,94
	lime	5	58,00	11,51
grass cover in %	without straw	5	34,39	1,56
	lime	5	27,45	7,53
herb cover in %	without straw	5	0,68	0,04
	lime	5	0,58	0,12
legume cover in %	without straw	5	18,34	1,28
	lime	5	29,97	5,82
species in the seed mixture in %	without straw	5	36,61	6,41
	lime	5	38,41	6,86

		Levene-Test for homogeneity of variance		T-Test for averaging equality		
		F	Sig.	t	df	Sig. (2-sited)
vegetation cover in %	Variances are equal	0,12	0,737	0,92	8,00	0,384
	Variances are unequal			0,92	7,54	0,386
grass cover in %	Variances are equal	3,25	0,109	2,02	8,00	0,078
	Variances are unequal			2,02	4,34	0,108
herb cover in %	Variances are equal	2,63	0,144	1,81	8,00	0,108
	Variances are unequal			1,81	5,18	0,128
legume cover in %	Variances are equal	7,48	0,026	-4,36	8,00	0,002
	Variances are unequal			-4,36	4,38	0,010
species in the seed mixture in %	Variances are equal	0,04	0,852	-0,43	8,00	0,680
	Variances are unequal			-0,43	7,96	0,680