Einfluss von Ganzjahresbeweidung auf die Vegetationsentwicklung eines Sandmagerrasens nach Oberbodenabtrag

Impact of year-round grazing on vegetation development of a sand grassland after topsoil removal

Masterarbeit

Vera Vogt

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Westfälische Wilhelms-Universität Münster
Institut für Landschaftsökologie

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vorgelegt von

Vera Vogt

Erstgutachter: Prof. Dr. Norbert Hölzel
(Westfälische Wilhelms-Universität Münster, Institut für Landschaftsökologie, AG Ökosystemforschung)

Zweitgutachter: Dipl. Lök Kristin Fleischer
(Westfälische Wilhelms-Universität Münster, Institut für Landschaftsökologie, AG Ökosystemforschung)

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Year-round grazing with cattle on sand grassland: possible or not? Evaluation of the effects of topsoil removal and subsequently grazing on vegetation

Abstract

Land use change led to a decline of low-intensive used areas. Year-round grazing as an example for low-intensive grazing systems is able to preserve such open countries. As sand grasslands in particular have become rare since the decrease of sheep farming, also their special adapted plant and animal species are endangered today. Former sand grassland sites have been used as arable land or became fallow or afforested. Topsoil removal is one effective restoration measure in order to restore nutrient-poor sites. In this study, the influence of both, restoration of sand grassland on arable land by topsoil removal and year-round grazing, on development of sand grassland vegetation were investigated in the landform "Senne".

For this purpose, vegetation was recorded at 40 plots on the main area and 10 plots on the reference area as well as above ground biomass and soil were sampled. The investigations of the main area encompassed besides sand grassland vegetation the one of oligotrophic bodies of water.

The contents of phosphorus in the soil were considerably reduced by topsoil removal. Sand grassland vegetation developed with a high number of endangered species. Many target species emerged presumably from the soil seed bank. Especially *Betula pendula* established on nearly at the whole area and was not influenced by any soil or biomass parameters or the amount of bare soil. The occurrence of other woody plants was significantly positively influenced by ADL and pH.

Key words: Nutrient-poor, restoration, scrub encroachment, self-greening, soil seed bank, succession

1. Introduction

In our environment characterised by intensive agriculture low-intensive used areas have become increasingly rare (Sala et al. 2000). But especially these areas harbour many endangered species, plants as well as animals (Riecken et al. 1997). In context of nature conservation ways and means in order to preserve such areas are searched. Year-round grazing has proved to be successful as an economic and low work-intensive option to other maintenance measures (Bunzel-Drüke et al. 2008, Riecken et al. 1997). Basic information to define year-round grazing are among others a perennial grazing system with a minimum area of 10 ha and a maximum stocking rate of about 0.6 livestock units (LU) per ha. Additional feeding should be restricted to real times of distress in winter (Bunzel-Drüke et al. 2008). In most cases robust breeds of cattle and horses are used for year-round grazing systems, as they have a higher weather tolerance and are more able to utilize fibre rich fodder (Bunzel-Drüke et al. 2008, von Oheimb et al. 2006).

Hence, year-round grazing is as well as other extensive grazing systems able to preserve ecosystems depending on extensive use and disturbances like browsing and trampling of livestock. Such disturbances frequently initiate pioneer

stages many poorly competitive plant species depend on (Kratochwil & Schwabe 2001).
Furthermore, winter browsing is another important aspect for repressing succession of woody plants. Grazing animals graze plants belonging not to the preferred diet in winter. Buds at the shoot apex are an important food source in that case. Thus, it has also a repressing effect on the succession of woody pants (Briemle et al. 2002, von Oheimb et al. 2006).
In many cases a mosaic of open areas with various grazing intensities, alternating flowering plants, small-area special sites originated by livestock trampling, weltering or rank patches and smaller areas of shrubs and woods evolves (Schley & Leytem 2004).

Sand grassland ecosystems are bound to quartz loose sands. As a result of the mobility of this substrate a special biocoenosis can be found. Many plants and animals occurring in sand grasslands and sandy open countries are restricted to such sand sites in Central Europe (Quinger 2000). The decline of open and semi-open inland sand ecosystems started in the late 18th century. Especially the decrease of sheep farming in the second half of the 19th century often entailed forestations of no longer used common pasture areas (Quinger 2000). Since these sand sites have become rare, also the corresponding flora and fauna have become endangered (Ludwig & Schnittler 1996, Schwabe et al. 2004, Ssymank et al. 1998). Nevertheless, low-intensive ways of utilization are already sufficient to deforest and keep open the aeolian sand sites as well as to induce local sand movements repeatedly (Quinger 2000). Hence, a low-intensive year-round grazing should also be able to keep open at least most part of the area (Bunzel-Drüke et al. 2008).

Experiences of capabilities and effects of low-intensive year-round grazing are mostly known from more nutritious sites like wetlands (Bunzel-Drüke et al. 2008, Reisinger & Schmidtmann 2001). The Trial and Development Project “semi-open pasture landscape Höltigbaum” is about low-intensive year-round grazing of a 242 ha sand ecosystem near Hamburg. This project started in the year 2000 and delivered already results concerning year-round grazing on nutrient-poor sites (von Oheimb et al. 2006).

This study investigated the effects of year-round grazing with cattle on sand grassland vegetation after topsoil removal. In addition, the results of the topsoil removal were validated. The main area of this investigation was a year-round pasture after topsoil removal, the reference area a low-intensive seasonal permanent pasture with horses. The two areas were comparable regarding the sites, but not with regards to their historical usage and resulting characteristics. The objective was to work out possible differences between the sites concerning vegetation and its development, nutrient contents of soil and biomass and the scrub encroachment. In this context I addressed the following questions:

- How distinct are the effects of topsoil removal on soil, biomass and vegetation parameters?
- Is it particularly possible to reduce the level of plant available phosphorus by topsoil removal after decades of agricultural use?
- Are measures like hay transfer, transplantation of sods or seeding really necessary to establish target species or is the soil seed bank also a source of propagules?
- As scrub encroachment is a serious problem for management of open country in general and at the Güsenhofsee in particular, do the

amount of bare soil, biomass or soil parameters significantly influence the occurrence of young woody plants?

2. Methods

2.1 Study area

The study areas are located in the east of the German federal state North Rhine-Westphalia (NRW) in the landform Senne. The Senne belongs to the so called Ostmünsterland, a part of the Westphalian Basin, and is a wide sandy area with many dunes. An altitude of about 120 m a.s.l. is reached (Meisel 1959). It has been shaped by low-intensive utilization as pasture with the consequential afteruses, for example sod cutting, over hundreds of years (Seraphim 1978). The southeast subarea of the sandy area contains a military training ground (Harteisen 2000). The landform Senne is divided into three subareas, the Friedrichsdorfer Drumlinfeld in the North, the Obere Senne (dry Senne) in the South-East and the Untere Senne (wet Senne) in the west (Harteisen 2000, Seraphim 1978, Siekmann 2004). The study sites are located in the Untere Senne, the main one, Güsenhofsee, north of Paderborn-Sennelager, the second one, reference area Moosheide, in the south of Stukenbrock-Senne. Both are situated near the military training area and the motorway A33 (Fig. 1).

In the Senne suboceanic climate dominates with characteristics of the change from the oceanic climate of Northwest Europe to the continental climate of Central Europe. The annual change in temperature is characterised by relatively mild winters and moderately warm summers. Because of the location of the Senne in the windward of the range Teutoburger Forest the annual precipitation sum is high with an increase from the Westphalian Basin to the Central Senne to the foothills of the Teutoburger Forest (762 mm to 914 mm) (Harteisen 2000).

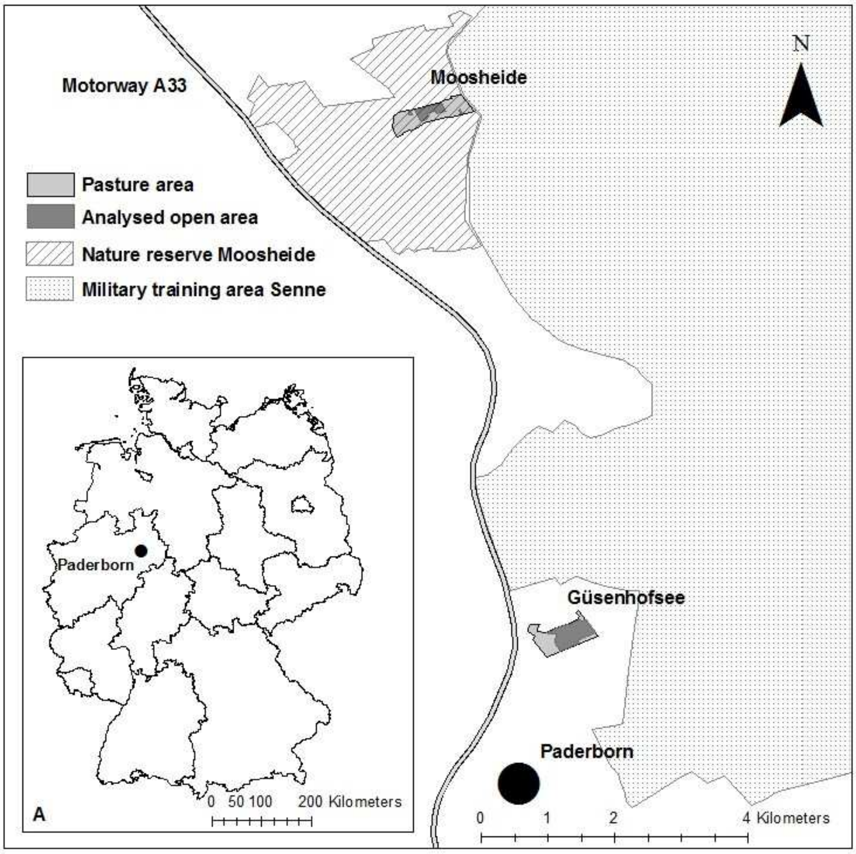

Fig. 1: Location of the study areas in (A) Germany; location of the study areas near Paderborn.

The investigation area Güsenhofsee was formerly used as arable land located on a lake. The area was bought by the City of Paderborn in the year 2000 in order to conduct compensating measures. In winter 2004/05 a topsoil removal of about 15-20 cm was executed to effect a nutrient removal. During the following years an artificial chain of dunes and several wet depressions on it and on the lakefront were constructed. As a result of the following self-greening, many individuals of mainly *Betula pendula* established rapidly (Venne pers. comment).

Since winter 2006/07 the area of 18 ha is year-round grazed by cattle. The stocking rate should not exceed 0.5 LU per ha. It varied in the past years from four to six cattle, over several years also two Konic horses belonged to the grazing animals (Biologische Station Kreis Paderborn-Senne 2010). In the study year six cattle (Angus and Hereford cattle cross-breeds) grazed on the area. Once a year in autumn a mowing of woody plants is conducted since 2008 (Biologische Station Kreis Paderborn-Senne 2010, Venne pers. comment).

Meanwhile, nutrient-poor sand ecosystems, oligotrophic bodies of water in the wet depressions and woody communities can be found at the Güsenhofsee. The latter consist mainly of *Betula pendula* and in moister areas of *Alnus glutinosa*. Species composition can be assigned to *Airo caryophylleae-Festucetum ovinae* in many parts of the area (Pott 1995).

In order to evaluate the effect of the topsoil removal, an arable reference area was chosen. It was about a slip of former arable land adjacently in the south of the investigation area. Two years after the restoration measures this slip became fallow. Until then it was used as arable land (Moritz pers. comment, Venne pers. comment).

The reference area Moosheide is located in the identically-named nature reserve. It is about former pasture and arable land. Since the year 2000 a grazing project with Senner horses, an old half-wild Westphalian breed (Marx 2002), runs on meanwhile 20 ha grazing area (Lühr 2007, Rüther & Venne 2002). Before starting the project, no restoration measures were made, the former arable land greened itself. In this part the stocking rate is very low, too, and varies between three and six horses. In the study year six Senner horses grazed on the investigation area. It is used as a low-intensive seasonal permanent pasture from May to October. The investigation area is a rough pasture on sand with the predominant *Festuca rubra-Agrostis capillaris*-association. Furthermore, it contains several small groves of mostly *Pinus sylvestris* which were arranged as forests in the past (Lühr 2007). The establishment of woods is more immaterial on this area as there are only a few young trees (Venne pers. comment).

2.2 Fieldwork

Sampling took place on the main area Güsenhofsee and the reference area Moosheide. In order to arrange the plots nearly equal over the investigation area, a 50 x 50 m² grid was laid over it.

In every possible grid of the area Güsenhofsee one vegetation relevée of sandy grassland was made. In addition to that some relevées were taken at the edge and dry ground, respectively, of the wet depressions. Hence there were 40 vegetation relevées on the main area Güsenhofsee, 32 on sand grassland and eight of the wet depressions. As reference, I made ten vegetation relevées in the Moosheide, similarly only open country was regarded.

In every grid, the plot-selection took place randomly-directed by stick throw backwards. The vegetation was collected on

4 x 4 m² plots from mid of June to mid of July of 2012. At each plot cover and mean abundance of all vascular plant species as well as mosses were estimated using the Braun-Blanquet scale, modified by Wilmanns (1998). The following vegetation parameters were collected: coverage of herb layer (%), mean height of herb layer (cm), percentage of bare soil (%).

Nomenclature of vascular plant species is based on Wisskirchen & Häupler (1998), the one of mosses on LANUV NRW (2011).

To examine the occurrence of young shrubs, all shrubs < 0.5 m were counted on 1 x 1 m² plots and their coverage estimated at the place where the most young shrubs grew in or near by the vegetation relevée.

Additionally, biomass and soil samples were taken at every vegetation relevée for further analysis. In both cases it was about composite samples consisting of five incremental ones (biomass: harvested on 0.5 m² per plot with a biomass frame, soil cores: upper 10 cm with N_{min}-soil corer). Moreover, five soil samples were taken at the arable reference area.

The samples were taken on three days in July after making the vegetation relevées, so that all samples were acquired at nearly the same time.

2.3 Biomass and soil analyses

After drying the biomass samples at 80 °C for 72 hours they were weighted and milled to 0.5 mm grain size. Afterwards their nutrient contents were analysed by near infrared spectroscopy (NIRS) (Spectra Star 2400, Unity Scientific, Columbia, MD, USA) (Kleinebecker et al. 2009). The percentages of carbon (C), calcium (Ca), magnesium (Mg), nitrogen (N), phosphorus (P), potassium (K) and of the fibre fractions neutral detergent fibre (NDF; sum of the structural substances), acid detergent fibre (ADF; NDF without hemicelluloses) and acid detergent lignin (ADL; ADF without cellulose) were determined.

Air dried soil samples were sieved (2 mm mesh size) and analysed for calcium-acetate-lactate (CAL) soluble P (spectral photometer Perking Elmer Lambda, 578 nm) and K (flame photometer Jenway PFP 7) (Schüller 1969). The pH-value was determined in $CaCl_2$ solution as a detergent. After milling the soil samples they were analysed for percentage of total N and total C using an elemental auto-analyzer (NA 1500, Carlo Erba, Milan, Italy). The organic C content corresponds to the total C content of the soils, since they were very acidic and contain no $CaCO_3$ (Geissen et al. 2013).

2.4 Statistical analysis

In order to prepare the vegetation data for the statistical analysis, the cover-abundance values were randomised into percentage quotation. Since the habitats were only gappy vegetated the lower third of the classes was chosen.

Furthermore, mean Ellenberg indicator values for moisture, nitrogen, light and reaction (Ellenberg & Leuschner 2010) were calculated. Information about sand grassland species (Oberdorfer 2001) and the tendency of the species concerning establishing a soil seed bank (Bekker et al. 1998) was added. Information about the red data list status of North Rhine-Westphalia was gathered from LANUV NRW (2011) for vascular plants and mosses. All species belonging to one of the threat categories 1 (threatened with extinction), 2 (critically endangered), 3 (endangered) and to the early warning list were included. The digestibility of the vegetation for ruminants (y_1) and horses (y_2) was calculated with the biomass parameter ADF using the following formulas:

$y_1 = 87{,}6 - 0{,}81\ x$

$y_2 = 97{,}0 – 1{,}2\ x$

x = fibre content/ADF (Opitz von Boberfeld 1994).
Shannon-Wiener Diversity Index and Evenness were calculated.
Mean values of a number of parameters were made. Biomass, soil and vegetation parameters were tested for significant differences between the sites by Tamhane- and Tukey-post hoc tests (significance level $P < 0.05$) after testing for normal distribution using Kolmogorov-Smirnov test and for homogeneity of variance tested with the Levene test (IBM SPSS Statistics 20). Relations between vegetation relevées and environmental parameters were analysed by a Detrended Correspondence Analysis (DCA) (PC-Ord 5.10, McCune & Grace 2002). All species with an occurrence of less than three in the whole dataset were omitted, rare species were downweighted and abundances were square root transformed. The explanatory power was right good (gradient length first axis: 3.24 SD units, Eigenvalue first axis: 0.52, total inertia: 2.75) (Leyer & Wesche 2008).
Furthermore, the percentage of bare soil and some biomass and soil parameters (contents of N and P in the biomass, ADF, ADL, NDF and digestibility for cattle; pH, contents of P and K in the soil) were tested for significant influence on shrub occurrence (shrubs < 0.5 m on 1 x 1 m^2). The occurrence of woody plants total, woody plants except *Betula pendula* (consists of *Alnus glutinosa, Pinus sylvestris, Rubus fruticosus, Salix caprea, S. fragilis, F. repens*), *Betula pendula* and *Salix*-species was tested by general linear models (GLM) (R Core Team 2012, R 2.15.2). Only non-intercorrelated parameters (Pearson correlation $\rho > 0.7$) were used.

3. Results

3.1 Differences concerning soil parameters

For several soil parameters significant differences between the types could be figured out (Table 1).
Concerning the pH value the pasture area Moosheide differed significantly from the other three types. In the Moosheide it was about four, whereas at all types of the area Güsenhofsee about five.
Regarding plant available P in the soil the arable reference area and the wet depressions differed in each case significantly from the other three types (Fig. 2, Table 1). Most P was found in the soil of the arable reference area, the least contents in the wet depressions. For the sand grassland Güsenhofsee and pasture area Moosheide P contents were nearly equal.
Organic C and N contents, the latter one with very low values at the Güsenhofsee, were highest in the Moosheide and the arable reference area. The C:N ratios also revealed significant differences between the four sites. They were highest in the wet depressions and lowest in the arable reference area.
No differences could be detected for the content of plant available K in the soil. The values were very low at all sites.

3.2 Vegetation parameters

The Shannon-Wiener Diversity Index gave a high diversity of vascular plants for all three sites, whereas the diversity at the Güsenhofsee was particularly high (Table 1). According to the Evenness, there was a tendency that all plants had roughly the same abundance at all sites, but the values for the Moosheide were a little bit lower. They were highest for the wet depressions.
The tests for significant differences between the three sites yielded similar

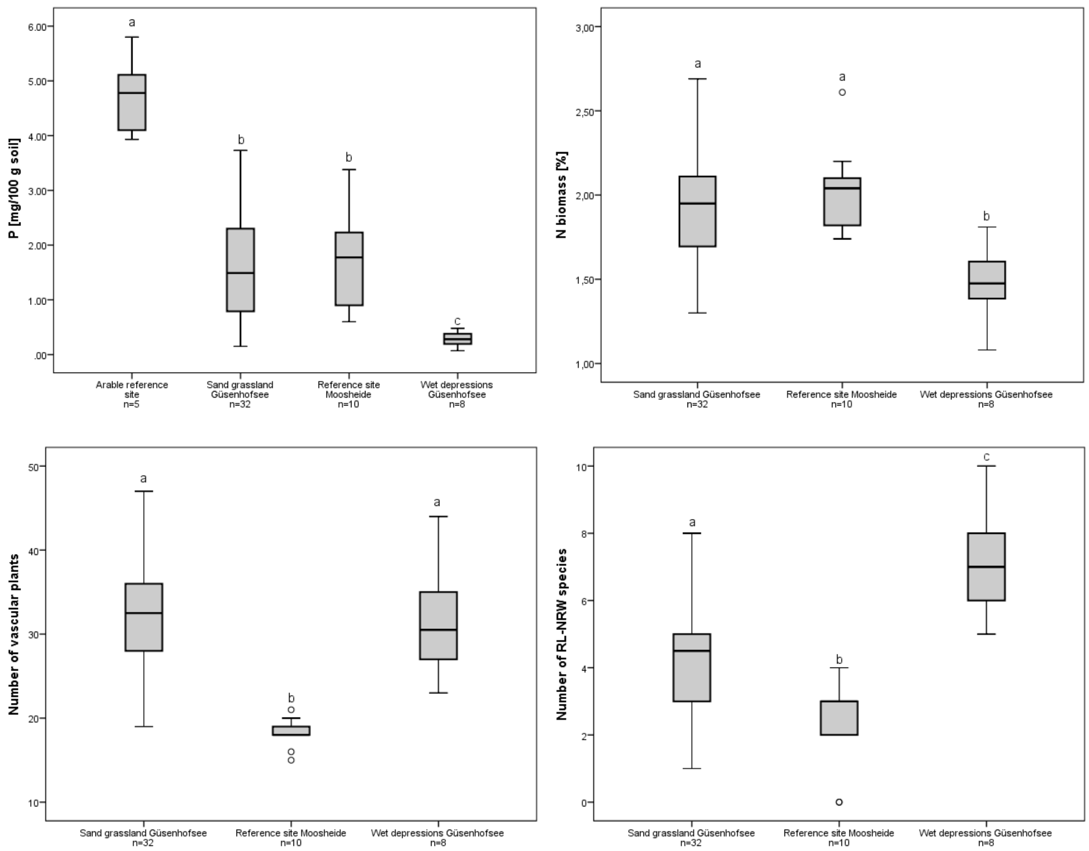

Fig. 2: Boxplots of selected parameters (P soil, N biomass, species number and number of endangered species). Site differences tested with ANOVA and post-hoc-tests. Different letters show significant differences ($P < 0.5$).

results. Diversity Index and also Evenness showed significant differences in the manner described above. In line with this, the number of species was substantially and significantly lower in the Moosheide than in both sites of the Güsenhofsee (Fig. 2).

Especially grasses were dominant in the Moosheide.

Differences between the types could be figured out for the following further parameters (Table 1). Concerning the number of red list NRW species, all three sites differed significantly from each other (Fig. 2). The wet depressions harboured with ten species the highest numbers of endangered plant species, for example *Isolepis setacea*, *Carex demissa*, *Drosera intermedia* and *Lycopodiella inundata*. The sand grassland Güsenhofsee hosted a number of eight endangered species like *Filago vulgaris*, *Aira caryophyllea* and *Jasione montana*. With a total number of four the fewest endangered species were found in the pasture area.

The coverage of the herb layer was highest at the reference area Moosheide on average. The maximum of bare soil mean values could be detected at the wet depressions followed by the sand grassland Güsenhofsee.

Mean Ellenberg light value was highest at the sand grassland Güsenhofsee, both moisture and nitrogen values reached their mean maximums at the wet depressions. The reaction value was uppermost for both sand grassland and wet depressions.

Mean seed-longevity also reached maximum values for both sites of the Güsenhofsee. The number of species tending to establish a long-term persistent seed bank was on average highest at the wet depressions, closely followed by the sand grassland. The peak of the number of sand grassland species as well as the one of the

number of therophytes was reached by the sand grassland Güsenhofsee.
No significant differences showed the mean height of the herb layer.

3.3 Biomass contents

The contents of the nutrients and fibre fractions in the biomass were all rather low and the weight of the biomass ranged from 4.5 g/m² as the lowest value of the wet depressions to 67.8 g/m² as the highest value of the Moosheide (Table 1). Thus the Moosheide had by far the most biomass.
Several further biomass parameters showed significant differences between the sites.
The content of ADL was highest for the wet depressions and lowest in the Moosheide. The C concentration was maximally in the Moosheide. For Ca, K and Mg the means of the sand grassland Güsenhofsee were uppermost, followed by the wet depressions.
C:N ratio was higher in the wet depressions than in the other two sites. The statistical analysis revealed significant differences only between the reference area Moosheide and the two sites of the Güsenhofsee.
The N content of biomass was lowest in the wet depressions, whereas it was nearly the same in the biomass of the sand grassland Güsenhofsee and the pasture in the Moosheide with little higher values in the latter one (Table 1, Fig. 2).
The NDF values were similar to this. They were highest in the Moosheide, followed by the sand grassland Güsenhofsee.
No significant differences could be detected for the contents of P and ADF and the resulting digestibility for cattle and horses.

3.4 Relationship between vegetation and environmental parameters

The relationship between vegetation and environmental parameters is related by the Detrended Correspondence Analysis (DCA) (Fig. 3). The three vegetation types are clearly distinguished from each other along the first axis in the DCA. The first axis can be interpreted as a moisture gradient. To the right the relevées of the wet depressions and many water and moisture-loving species, respectively, were arranged. Furthermore, there was the highest number of red list plant species together with the number of species tending to establish a long-term persistent soil seed bank (seeds remaining germinable for > 4 years in the soil) (Bekker et al. 1998). At the top of the ordination scheme there were ruderal-initial species and arable weed species. Most of them are typical pioneer plants like *Fallopia convolvulus, Erodium cicutarium* and *Chenopodium album* (Oberdorfer 2001). The relevées of the pasture area Moosheide were arranged with lower values of the first axes and hence correlated to a high cover of herbs and a high NDF content in biomass. The relevées of the sand grassland Güsenhofsee were scattered around the origin of the vectors. Some were distinguished by an extremely high amount of bare soil.
Ellenberg indicator value F was inversely correlated with the number of sand grassland species. Hence, the dryer the soil, the more sand grassland species occurred.
The vectors of Ellenberg indicator values N and F were strongly correlated to each other, whereas N content of biomass and C and N contents of the soil pointed into the opposing direction. This seems to be contradictory.

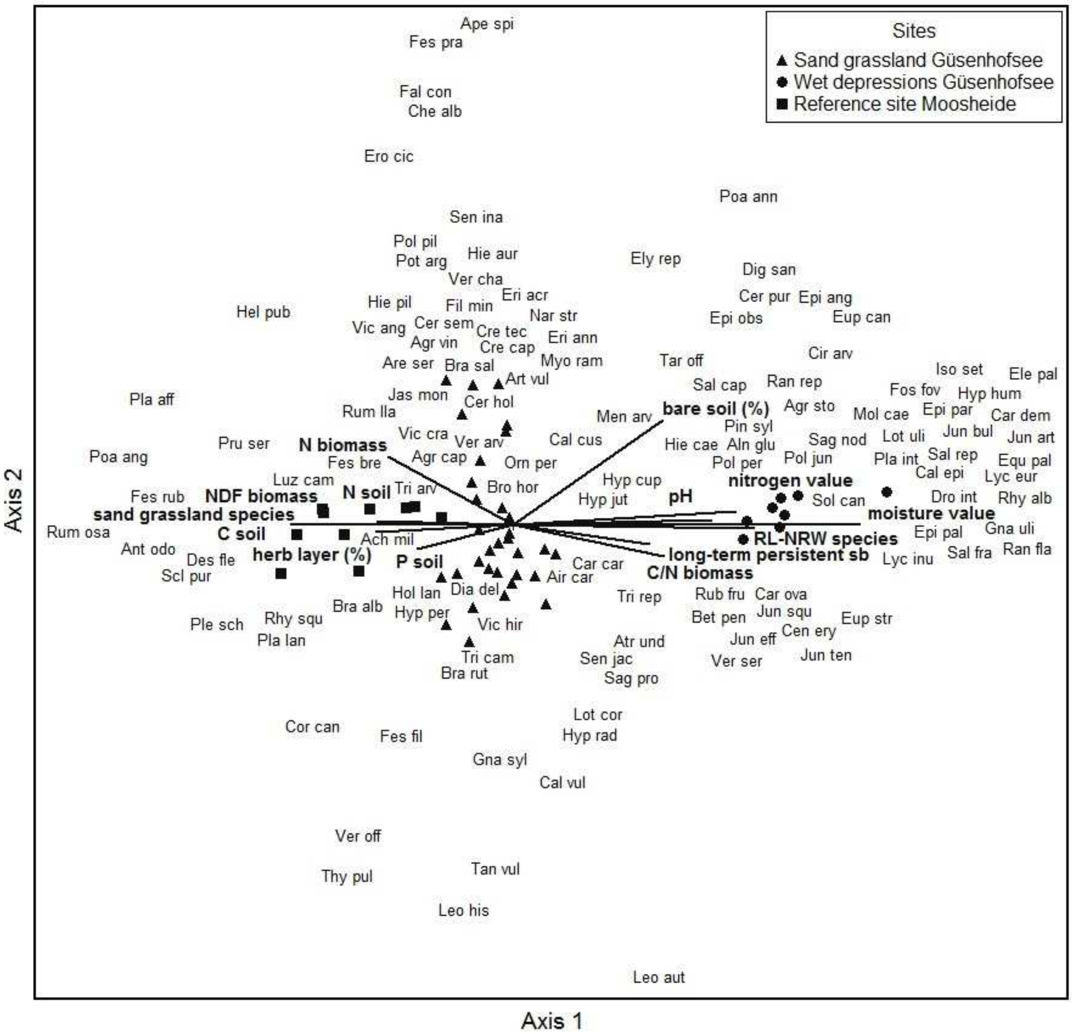

Fig. 3: Detrended Correspondence Analysis (DCA) of vegetation relevées and environmental parameters.

3.5 Occurrence of woody plants

The GLM detected no significant parameters influencing the occurrence of the total number of woody plants or of *Betula pendula* alone. However, the occurrence of woody plants except *Betula pendula* was significantly positively influenced by ADL (**) and pH (*) (Table 2). The existence of *Salix*-species was influenced by the same parameters and additionally negatively affected by contents of P in the soil (*) (Table 2).

Table 2: Statistics of GLM: Relationship between occurrence of young *Salix*-species and young woody plants except *Betula pendula* (response variables) and soil and biomass parameters (predictor variables). Non-significant predictors were excluded from the final models by stepwise backward-selection (P > 0.05).

	Parameters	Estimate	SE	*Z*	*P*
***Salix*-species**	ADL	0.6172	0.2051	3.009	**
	P soil	- 0.3800	0.1971	- 1.928	*
	pH	1.2570	0.5220	2.408	*
	PseudoR² (McFadden): 0.43				
Woody plants except *Betula pendula*	ADL	0.5172	0.1681	3.077	**
	pH	1.1627	0.4813	2.416	*
	PseudoR² (McFadden): 0.26				

3.6 Mosses

17 moss species were found at the main area Güsenhofsee and 15 at the reference area Moosheide, among 13 species occurring at both areas. There were typical sand grassland and heath species like *Polytrichum piliferum* and *Hypnum jutlandicum* as well as generalists like *Brachythecium rutabulum, B. albicans* and *Ceratodon purpureus* (Nebel et al. 2001). Apart from *Fossombronia* cf. *foveolata* none of the mosses was listed on the red list NRW (LANUV NRW 2011). Especially *B. rutabulum, B. albicans, Polytrichum juniperinum* and *P. perigoniale* were the mosses with the highest continuities and also the highest abundances.

4. Discussion

4.1 Differences concerning soil parameters

Soil nutrient contents were rather low at all sites. The pH value indicated acidic grasslands, whereas the Moosheide had a little bit lower values. An influence of topsoil removal on soil parameters, especially P, could be detected.

The lower pH values at the reference area Moosheide may result from the age and historical use of the area. As the area Güsenhofsee was completely used as arable land it has probably been fertilized and perhaps also with liming. The pasture area Moosheide is older and only a small part has been used as arable field. The pH of the arable reference area does not significantly differ from the ones of the sand grassland and the wet depressions. Hence, it would be possible that the lower pH values at the Moosheide result from the age of the site. Several authors assessed decreasing pH values during succession from pioneer stages to later grassland stages (Jentsch & Beyschlag 2003).

Considering Fig. 2 (P) the effect of the topsoil removal can be seen. The arable reference area gave an idea of the P-level of the area Güsenhofsee before the restoration measures. The P-level of the sand grassland was even a little bit lower than the one of the reference pasture area Moosheide. The wet depressions were scooped a little bit deeper, so their even lower P contents can be explained by these measures. Hence, topsoil removal is an effective method to reduce the level of plant available P after decades of agricultural use. But also the P contents of the arable reference area are in conformity with the values given in literature for unfertilized sandy soils, which are below 100 mg/kg (Blume et al. 2010). This is probably because of the missing fertilisation over the last years and the missing humus content of the sandy soil. The P content in the soil increases from the sand to the clay fraction and with the humus content (Blume et al. 2010).

The higher soil contents of organic C of the Moosheide and the arable reference area can be accounted for by higher humus contents and therefore more soil organic matter of these sites (Schaefer 2003). This was already clearly recognizable during the sampling as the soil of these sites was much darker, almost black. Altogether, organic C contents were rather low at all sites compared with contents reported by Geissen et al. 2013 for restored and non-restored heathlands and heathland sites used as farmland.

The soil contents of N were very low at all sites and especially at the two of Güsenhofsee. Hence, there is also a little effect of the topsoil removal, but not as clearly as it could be seen from the contents of P. The arable reference area became fallow shortly after the restoration measures and no nitrogen was delivered subsequently in terms of nitrogen fertiliser. Atmospheric nitrogen inputs should be the same for the different sites due to spatial proximity. Additionally the vegetation, first of all a succession of *Betula pendula*, extracted

Table 1: Habitat parameters and vegetation characteristics. Declaration of the means with standard error. Site differences tested with ANOVA and post-hoc-tests. Different letters show significant differences (P < 0.05).

Site		Sand grassland Güsenhofsee	Reference area Moosheide	Arable reference area	Wet depressions Güsenhofsee
	ANOVA	N = 32	10	5	8
Soil conditions					
C [%]	***	0.4 ± 0.1[b]	0.9 ± 0.3[a]	0.9 ± 0.2[a]	0.2 ± 0.1[c]
C:N	*	39.0 ± 27.8[ab]	22.2 ± 10.8[a]	16.8 ± 1.0[a]	51.8 ± 25.5[b]
N [%]	***	0.0 ± 0.0[b]	0.1 ± 0.0[a]	0.1 ± 0.0[a]	0.0 ± 0.0[b]
pH	***	5.0 ± 0.2[a]	4.0 ± 0.2[b]	4.8 ± 0.2[a]	5.2 ± 0.3[a]
P (CAL) [mg/ 100 g]	***	1.6 ± 1.0[b]	1.7 ± 0.9[b]	4.7 ± 0.8[a]	0.3 ± 0.1[c]
K (CAL) [mg/ 100 g]	n.s.	1.2 ± 1.9	1.4 ± 1.0	2.1 ± 1.2	1.6 ± 1.0
Vegetation parameters					
Coverage herb layer [%]	***	30.0 ± 11.9[a]	75.0 ± 11.6[b]	.	26.3 ± 5.7[a]
Evenness	**	0.7 ± 0.1[a]	0.6 ± 0.1[b]	.	0.8 ± 0.1[c]
Height herb layer [cm]	n.s.	14.5 ± 5.9	14.6 ± 8.9	.	14.4 ± 5.6
Mean light value	***	7.5 ± 0.1[a]	7.1 ± 0.2[b]	.	7.3 ± 0.1[c]
Mean moisture value	***	4.0 ± 0.2[a]	4.1 ± 0.2a	.	6.6 ± 0.6[b]
Mean nitrogen value	***	3.7 ± 0.3[a]	3.1 ± 0.3[b]	.	4.3 ± 0.3[c]
Mean reaction value	***	4.5 ± 0.3[a]	3.9 ± 0.6[b]	.	4.5 ± 0.2[a]
Mean seed-longevity	***	0.5 ± 0.0[a]	0.5 ± 0.1[b]	.	0.5 ± 0.0[a]
Number of					
red list species (NRW)	***	4.4 ± 1.5[a]	2.4 ± 1.6[b]	.	7.1 ± 1.6[c]
sand grassland species	***	9.8 ± 1.7[a]	6.4 ± 1.8[b]	.	1.6 ± 0.5[c]
species (vascular plants)	***	32.3 ± 6.2[a]	18.1 ± 1.7[b]	.	31.5 ± 6.6[a]
species with persistent sb	***	13.2 ± 3.0[a]	5.7 ± 1.3[b]	.	14.1 ± 2.0[a]
therophytes	***	8.8 ± 3.1[a]	2.2 ± 1.2[b]	.	3.6 ± 2.0[b]
Percentage bare soil [%]	***	40.8 ± 21.5[a]	3.8 ± 1.3[b]	.	56.9 ± 16.3[a]
Shannon-Wiener-Index (H')	***	2.5 ± 0.4[a]	1.8 ± 0.3[b]	.	2.8 ± 0.3[a]
Biomass parameters					
ADF [%]	n.s.	27.6 ± 1.7	26.6 ± 1.8	.	28.0 ± 2.1
ADL [%]	***	7.7 ± 0.8[a]	6.5 ± 0.7[b]	.	8.7 ± 0.6[c]
Biomass [g/m²]	***	21.2 ± 9.2[a]	43.3 ± 24.5[b]	.	21.9 ± 17.4[b]
C [%]	***	45.7 ± 0.6[a]	46.5 ± 0.4[b]	.	46.9 ± 1.5[ab]
C:N	***	24.6 ± 4.9[a]	23.1 ± 2.5[b]	.	32.5 ± 5.6[a]
Ca [%]	***	1.0 ± 0.2[a]	0.6 ± 0.1[b]	.	0.9 ± 0.2[a]
Digestibility for cattle [%]	n.s.	65.2 ± 1.4	66.1 ± 1.4	.	64.9 ± 1.7
Digestibility for horses [%]	n.s.	62.2 ± 2.2	63.6 ± 2.2	.	61.7 ± 2.7
K [%]	**	1.4 ± 0.4[a]	0.8 ± 0.4[b]	.	1.2 ± 0.3[ab]
Mg [%]	**	0.4 ± 0.0[a]	0.3 ± 0.0[b]	.	0.4 ± 0.1[ab]
N [%]	**	1.9 ± 0.4[a]	2.0 ± 0.3[a]	.	1.5 ± 0.2[b]
NDF [%]	***	48.7 ± 4.2[a]	54.4 ± 4.0[b]	.	43.9 ± 6.0[c]
P [%]	n.s.	0.2 ± 0.0	0.2 ± 0.0	.	0.2 ± 0.0

nutrients from the soil over years. The similar contents in the Moosheide can be explained by the missing topsoil removal, so that the contents are a little bit higher than at the Güsenhofsee. But the vegetation could extract nutrients over years as well, even though it is about a nutrient cycle which recycles some (Ellenberg & Leuschner 2010). Furthermore, nitrogen exists only in small quantities in parent rock material and soil mineral matter. Moreover, the plant available nitrogen compound nitrate is known as easy soluble and therefore washable, especially in sandy soils nearly without clay (Blume et al. 2010). Another important and also plant available compound is ammonium. It is not easy washable but exists only in small percentages in aired soils of Central Europe (Blume et al. 2010). The findings of this investigation are consequently not surprising as fertilisation is missing at all sites for years. In addition the topsoil removal was conducted at the Güsenhofsee sites.

The low nitrogen contents are reflected in the C:N ratio, too. The two sites at the Güsenhofsee had a wide C:N ratio, especially the wet depressions. Thus, the decomposition by microorganisms was inhibited (Schaefer 2003). Both the Moosheide and the arable reference area showed a narrower C:N ratio around 20:1. In the case of a C:N ratio roughly below 20:1 organic nitrogen gets degraded to anorganic plant available compounds (Schaefer 2003). Hence, at these two sites the decomposition by microorganisms was not inhibited in most cases.

The contents of plant available K were not effected by the topsoil removal, as there were no significant differences between all sites. In general the K contents of clay-poor sandy soils are very low and increase with the clay content (Blume et al. 2010). Furthermore, K is very mobile and easily washed out (Klapp 1971). Therefore the missing significant differences between the sites are convincing.

Generally sand grasslands are characterised by a low to very low nutrient supply (Quinger 2000), the investigated soil nutrient contents are consistent with this statement.

Although topsoil removal is sometimes called into question concerning its effects on soil quality like C-storage, filtering and buffering (Geissen et al. 2013), it is without doubt an appropriate method to change intensively used arable land into nutrient-poor ecosystems.

4.2 Vegetation parameters

The influence of topsoil removal on at least some vegetation parameters was nearly as evident as the one on soil parameters, even though it might be oblique in some cases.

Ellenberg indicator values L, M, N and R gave a rough summary of the site conditions. According to the light value, the sand grassland Güsenhofsee harboured most light plants. As the vegetation was less dense here the site conditions were optimal for them. Nevertheless, competition for nutrients affects species composition of sand grasslands rather than light (Jentsch & Beyschlag 2003). Moisture value was highest for the wet depressions, so typical plants of humid habitats could be found here. Nitrogen value was also highest for the wet depressions. This was rather unexpected since the nitrogen contents of the soil were very low (cf. 3.1 Results soil parameters, Table 1). A possible explanation is that many moisture-loving species simultaneously are referred to be nitrogen indicators. But this may only apply to vital plants. In the sand grassland and especially in the wet depressions some nitrogen indicators like *Lycopus europaeus* grew only miserable, so that they cannot really be viewed as nitrogen indicators in this case (Hölzel pers. comment). Additionally, it has to be taken into account that indicator values are not valid absolute but bound to a certain utilisation (Briemle et al. 2002). Furthermore, several authors challenged the interpretation of Ellenberg N as a “nitrogen value”. This was underlined by Klaus et al. (2012). They investigated correlations between Ellenberg indicator values and nutrient concentrations, especially P, in the biomass and concluded that the term Ellenberg “nitrogen” value should be replaced by nutrient or productivity value (Klaus et al. 2012). P concentrations in biomass were low (cf. 3.3 Results biomass parameters, 4.3 Discussion biomass parameters, Table 1), but yet they may be an explanation for the high Ellenberg N values.

While pH values were higher at the two Güsenhofsee sites than at the Moosheide (cf. 3.1 Results soil parameters, Table 1), the noticed reaction values of the wet depression and sand grassland species are consistent with this.

Mean height of the herb layer was nearly the same at all three sites. This lets assume that the site conditions are comparable, even though there were much more high plants, primarily grasses, at the Moosheide. The results of the soil nutrient contents confirm the assumption that P and N contents were roughly comparable.

The substantially lower numbers of species in the Moosheide can be explained by the lower pH value. As the soil of the pasture area of the Moosheide is more acidic, fewer species are able to tolerate such soil conditions (Schuster & Diekmann 2003). Additionally, nitrifying bacteria as well as plant nutrient uptake are limited by low soil pH values and low water contents (Jentsch & Beyschlag 2003). Another linkage between soil parameters and species number are P contents in the soil. Janssens et al. (1998) detected highest species numbers at P contents < 5 mg/100 g soil. The P contents were below 5 mg/100 g soil at all sites. Because of the pH values the ones of the Güsenhofsee had the highest numbers of species.

Furthermore, stages dominated by *Agrostis capillaris* and *Deschampsia flexuosa* often develop on acidic sand sites (Schwabe & Kratochwil 2009). The latter one was rarely found in the vegetation relevées, but especially in the sparse woody areas. The dominance of grasses in this area may result from its historical use. About three-quarters of the area were used as pasture before, so when the project started a large percentage had a closed sward and was dominated by grasses. Consequently, the differences detected for the coverage of the herb layer also result from the historical utilisation. The sites at the Güsenhofsee are at an initial stage with higher percentages of bare soil caused by the topsoil removal contrary to the non-restored site of the Moosheide. On the one hand colonisation by plants being able to survive on such soils takes place slowly. On the other hand many sand grassland species do not produce much biomass. They are mostly small, not uncommonly tiny and have quite often small leaves (Rüther & Venne 2002). Low nutrient availability along with low soil water contents in the summer months are in addition limiting factors for plant growth on sandy soils (Jentsch & Beyschlag 2003).

Shannon-Wiener Index and Evenness reflect the species numbers and also the dominance of grasses at the Moosheide contrary to the Güsenhofsee sites. The highest diversity was found at the Güsenhofsee sites with inferior abundances of grasses. Nonetheless the Shannon-Wiener Index determined for the Moosheide also indicates a relative high diversity. The high diversity of the investigated sites was underlined by the tendency that all plants had nearly the same abundance at all sites given by the Evenness (Back & Türkay 2001).

Most red list NRW species were found at the wet depressions. Such oligotrophic bodies of water have become rare and therefore also their typical vegetation (Ssymank et al. 1998, Ludwig & Schnittler 1996). Hence, the wet depressions have to be validated as ecologically very valuable. However, also the sand grassland sites are very valuable with many endangered species. Most of them are low competitive and well adapted to survive on nutrient-poor sites contrary to competitive species (Jentsch & Beyschlag 2003).

The number of sand grassland species may be seen in the same way as species numbers, since the result was similar. On the one hand sand grassland species are low competitive and require much light in many cases, but on the other hand they have special adaptations to survive at such nutrient-poor as well as nearly inhospitable sites (Jentsch & Beyschlag 2003). A high amount of solar radiation, drought, flight of sand grains and sand covering, for instance, are factors which make it more difficult for plants to survive at these sites. Thus, the majority of sand grassland species is characterised by a silver grey tomentose hairiness or glaucesence. These adaptations function highly reflective. *Hieracium pilosella* is one of such plants with a silver grey tomentose hairiness, for instance. Hyaline hairs of sand mosses like *Polytrichum piliferum* have got the same effect (Jentsch & Beyschlag 2003, Quinger 2000).

However, sand grasslands are known for harbouring comparatively high numbers of therophytes with an early development. They outlive midsummer droughts already at the seed stage (Jentsch & Beyschlag 2003). Hence, it is possible that the sites hosted more therophytes which had already completed their growing season. Nonetheless, most therophytes were found at the site of the Güsenhofsee. This shows that the vegetation at this site can most likely be described as sand grassland vegetation.

The highest numbers of species tending to establish a long-term persistent seed bank were found at the wet depressions and the sand grassland Güsenhofsee. The results for the mean seed-longevity of the species were similar with maximum values for both sites of the Güsenhofsee. A number of these species are also indicated as target species as they are typical for sand grasslands but also endangered (LANUV NRW 2011, Oberdorfer 2001). For instance, *Isolepis setacea* and *Juncus squarrosus* are typical species of oligotrophic waters tending to establish a long-term persistent seed bank and in addition listed on the red list (Bekker et al. 1998, LANUV NRW 2011). The amount of species establishing a long-term persistent seed bank rises with an increasing soil moisture as well as an increasing frequency of disturbances of the habitat (Thompson et al. 1998). This lets assume that there were already moister areas at the site before it was used as arable land. The site supervisors of the Biological Station even supposed areas of former fens. Historical maps show that the whole region was characterised by fen sites 100 years ago (Venne pers. comment). Nonetheless, it should be kept in mind that the data of seed persistence are not representative as data for rare species and some other groups are quite often seldom or absent (Thompson et al. 1998). Furthermore, some species tend to be either persistent or transient in soil seed bank as Thompson & Grime (1979) figured out. Presumably, different factors like soil and climate conditions are able to influence seed longevity, which is primarily a species trait (Fenner & Thompson 2005). However, not only target species of oligotrophic waters and nutrient-poor sand grasslands were found at the Güsenhofsee, but also species of fallow arable land like *Trifolium arvense, Arenaria serpyllifolia, Veronica serpyllifolia, V. arvensis* and *V. hederifolia* (Oberdorfer 2001). Especially species with shorter life histories, therophytes for instance, are tending to have persistent seeds in the soil compared with perennials (Thompson et al. 1998). Frequently disturbed sites like arable land harbour many species which often have permanent seed banks. But the intensity of weed control is an important aspect in this context. On fields with an intensive weed control most propagules can not stay dormant in the soil (Poschlod 1991). The high numbers of species tending to establish a long-term persistent seed bank explain the emergence of many target species without hay transfer or similar methods (Bekker et al. 1998, LANUV NRW 2011, Oberdorfer 2001). As there are no comparable sites being a possible source of propagules in the proximity it can be assumed that most of the target species arose from the persistent soil seed bank. Particularly small species and specialists of sand sites are only able to overcome short distances by anemochory (Hölzel 2009, Jentsch & Beyschlag 2003). The closest open areas of the military training ground located at a distance of about two kilometres could be a source of propagules, but apart from the distance also barriers like woods need to be overcome. Hence, the soil seed bank is in this case the most effective source of propagules. Measures like hay transfer, transplantation of sods or seeding were not absolutely necessary to establish management indicator species. But they could had helped to reduce the amount of bare soil faster so that woody plants and also undesired neophytes like *Senecio inaequidens* would have not established so easy. In this case *Senecio inaequidens* immigrated most probably from the nearby motorway “A33”.

4.3 Biomass contents

The results show that the amount of biomass was rather low at all sites, although the ones of the Moosheide were nearly twice as high as the ones of the Güsenhofsee sites. However, low nutrient contents in the soil should lead to an inferior amount of biomass. The higher values of the Moosheide result from the history of the area with missing topsoil removal in contrast to the sites of the Güsenhofsee. As the pasture area of the Moosheide is much older and had a closed sward at the beginning of the project, the higher biomass values are hardly surprising. Concerning nutrient contents in biomass the effect of topsoil removal is not so distinct.

Biomass contents of C were highest at the pasture area Moosheide, but also the ones of the sand grassland Güsenhofsee were partly even higher than values of fertilised meadows detected by Klaus et al. (2011). This suggests that the contents were quite good.

Güsenhofsee biomass contents of Ca correspond approximately to values of unfertilized pastures of the UNESCO Biosphere Reserve Schwäbische Alb (Klaus et al. 2011). According to Frey & Lösch (2010) the Ca content of plants varies between 0.1 and > 5 % of plant dry matter depending on the site. Hence, the values are located at the lower end of this range.

The contents of K were very low, the ones of the Güsenhofsee sites also equate most likely to values of unfertilized pastures of the Schwäbische Alb (Klaus et al. 2011), but were mostly even lower. According to Frey & Lösch (2010), the amount of K is ideally about 2-5 % of plant dry matter. Thus, the contents of all sites were below this optimum of K.

Biomass contents of Mg were highest on the two sites of the Güsenhofsee. These values were higher than the ones determined by Klaus et al. 2011 for unfertilized pastures at different sites. In general, the ingestion of Mg is often affected by effects of ionic competition. This means that higher contents of for example K^+, NH^{4+} or Ca^{2+} in the soil solution may lead to a plantal lack of Mg, even though there might be enough available in the soil (Frey & Lösch 2010).

Concerning N the biomass of the sand grassland Güsenhofsee and the pasture Moosheide had nearly the same contents. So the biomass of the restored area is quite as nutritious as the one of the older area. The lower values for the wet depressions result from the higher abundances of

Juncaceous, they contain fewer nutrients (Fleischer pers. comment). Overall, the N contents of the sand grassland biomass can be assessed as quite good, since Klaus et al. (2011) did not detect much higher contents for fertilised meadows.

The decomposability of the biomass given by the C:N ratio is rather good for the sand grassland Güsenhofsee and the reference area Moosheide (Schaefer 2003). This again shows that the biomass of the restored sand grassland is comparable with the one of the older reference area. The higher C:N ratio of the wet depressions should again be explained by higher abundances of *Juncaceous* as they contain fewer nutrients and therefore fewer N (see above).

Güsenhofsee biomass contents of P correspond to values of unfertilized pastures of the National Park Hainich (Klaus et al. 2011). Even if they were low, they stay within the limits of demands on low-intensity pastures. Concerning plant species richness, such low P concentrations have to be validated as good. Klaus et al. (2011) confirm a negative relationship between species richness and P concentrations in biomass.

NDF concentrations were highest for the pasture area Moosheide, followed by the sand grassland Güsenhofsee. The site at the Moosheide harboured by far the most grasses, which contain at a comparable content of cellulose essentially more hemicelluloses and therefore more NDF (Gruber 2009). Due to the low abundances of grasses at the wet depressions the contents of NDF were lowest at these sites.

Contents of ADF showed no significant differences between the three sites. Especially the contents of cellulose in biomass were nearly the same at all sites in contrast to the contents of hemicelluloses and lignin.

The highest ADL concentrations could be detected for the wet depressions, followed by the sand grassland. This is in line with the occurrence of woody plants, which have a high percentage of lignin. Most woody plants established at the wet depressions and at some sites of the sand grassland. The pasture area Moosheide hosted by far the fewest woody plants. However, the ADL concentrations are relatively low as older woody plants were excluded from biomass sampling. Furthermore, not only woody plants but also all other vascular plants contain lignin. The low values indicate a good digestibility of the biomass (Frey & Lösch 2010, Schopfer & Brennicke 2010).

The resulting digestibility for cattle and horses from ADF is estimation (Opitz von Boberfeld 1994). Values of about 60 % reveal a quite good digestibility for cattle, as a high fibre content is important for the digestion of cattle (Klapp 1971). Hence, also the values for the digestibility show that the biomass of all sites is suitable as fodder for cattle and also horses. However, it is more suitable for robust breeds at the most only producing meat in a slowly way than for high-performance livestock (Bunzel-Drüke et al. 2008).

4.4 Relationship between vegetation and environmental parameters

The ordination (DCA) related well the vegetation surveys with environmental variables and summarised and confirmed, respectively, partly previous results. As the first axis is a moisture gradient, moisture seems to be the most important parameter in order to differentiate the three sites. The wet depressions harboured the most moisture-loving species. Among them also the most red list species were found. This is in line with the fact that oligotrophic bodies of water are also scarce and threatened (Ssymank et al. 1998). As opposed to this, dryer sites hosted most sand grassland species. The vector “Number of species tending to establish a long-term persistent soil seed bank” pointed into the same direction, so most species which are noted for a long-term persistent seed bank were found at the wet depressions. Typical species tending to establish a long-term persistent seed bank are *Betula pendula, Isolepis setacea, Veronica serpyllifolia* and several *Juncus*-species (Bekker et al. 1998). Particularly the latter and *Isolepis setacea* are species occurring mainly at the wet depressions.

The arrangement of ruderal-initial species and arable weed species isolated from the others shows that there are early successional stages with a high amount of bare soil and, mostly, without woods as well as further developed sand ecosystems.

Concerning the reference area Moosheide the higher coverage of herbs can be explained by the older age of the area and its historical usage. On the one hand the development is more advanced so that in particular grasses could establish and reach a high coverage. On the other hand a closed sward was present at three quarters of the area when the grazing project started. Thus, the starting conditions were not the same.

Higher NDF-contents of the Moosheide can be explained by higher occurrence of grasses (cf. 4.3 Discussion biomass parameters).

The distribution of the sand grassland Güsenhofsee relevées shows that different successional stages could be found. Certain were characterised by a high amount of bare soil, so they can be denoted as initial stages. Others had less bare soil, succession has further proceeded. Reasons for this could not be detected. The soil nutrient contents for instance were not in line with it.

The questionability of Ellenberg indicator value N was already discussed above (cf. 4.2 Discussion vegetation parameters). The ordination graph supports the suspicion that this indicator value has to be seen critical.

4.5 Occurrence of woody plants

The question asked in the introduction, if the occurrence of young woody plants is significantly influenced by the amount of bare soil, biomass or soil parameters, has to be considered differentiated. Especially *Betula pendula* was not influenced by any soil or biomass parameters. This pioneer species established or had the ability to establish on almost three-fourths of the area, respectively. As *Betula pendula* was that frequent, it also controlled the results for the total number of woody plants. This is confirmed by the fact that for woody plants except *Betula pendula* two parameters with a significant influence on their occurrence could be detected (Table 2). As the occurrence of *Betula pendula* is obviously neither influenced by any soil or biomass parameters nor by the percentage of bare soil, it seems to be attributed to the initial stage of the area after topsoil removal. Sites with a very low content of P in the soil where assumedly characterised by a high percentage of bare soil, since herbaceous plants did not establish so fast. Thus, woody plants and especially *Betula pendula* as a pioneer species with low demands for soil conditions and preferring sand (Oberdorfer 2001, Ellenberg & Leuschner 2010) could establish more simply. Sites with a higher content of P were probably faster colonised by herbaceous plants so that fewer shrubs could establish. Missing herbaceous competition on sites with a higher amount of bare soil is an issue for the generative establishment of woody plants (Berger 1996). This can also be seen at the reference area Moosheide, because of the closed sward on three-quarters of the area from the beginning, the establishment of woody plants is more immaterial for this site.

The results for woody plants except *Betula pendula* with a positive effect of ADL let assume that the lower the fodder value was, the lesser cattle grazed on these sites. Thus, also fewer young woody plants were grazed. This results in an inferior occurrence of woody plants < 0.5 m on sites with a better fodder value and an accordingly lower ADL value. Our assumption is confirmed by the results for *Salix*-species, as beside a positive effect of ADL also a negative one of P soil could be detected. The more P was in the soil the fewer *Salix*-species established. This seems to be contradictory because at least *Salix fragilis* and *S. caprea* prefer nutrient-rich soils (Oberdorfer 2001). Nevertheless a higher content of P in the soil may lead to a better fodder value which may lead to more intensively browsing of cattle. The content of P in the soil may be an issue for *Salix*-species because they are particularly harboured near the wet depressions, which were characterised by a lower content of P in the soil.

The positive effect of pH for both woody plants except *Betula pendula* and *Salix*-species could be explained by the fact that most plants prefer pH values of intermediate levels between 5 and 6 (Isermann 2005). Ellenberg & Leuschner 2010 denote pH values from 4.5 to 5.5 as a hospitable range for germination of *Betula pendula*. At the Güsenhofsee pH ranges from 4.5 to 5.9 with means of 5.0 (sand grassland) and 5.2 (wet depressions), respectively, so in this regard germination conditions are well for *Betula pendula*. Moreover, *Betula pendula* is called the most important species establishing natural woods on very nutrient-poor sand sites of Northwest Germany with Atlantic climate (Quinger 2000).

4.6 Mosses

The number of moss species is relatively high for sandy grasslands. It is also typical of these ecosystems that there are no more than a few endangered species (Schmidt pers. comment, von Brackel 2002). The moss *Atrichum undulatum* for example is distinctive of bare soil. Several species are described as pioneer species, like *Polytrichum perigoniale, Ceratodon purpureus*, *Brachythecium albicans* and *B. rutabulum.* The latter one is additionally described as highly competitive (Nebel et al. 2001). This is an explanation for their high continuities and abundances, excluding *C. purpureus*. This synanthropic species is commonly occurring at the Güsenhofsee, but only with low abundances. The acidification indicator *Pleurozium schreberi* (Nebel et al. 2001) was found several times at the Moosheide, this was the site with the lowest pH values.

5. Conclusions and outlook

Soil conditions confirm that a nutrient poor site was re-established at the Güsenhofsee. These sites are more valuable from a nature conservation perspective as they harboured more endangered species and had a higher diversity. But it must be noted indeed that with ten relevées only a small extend of the pasture area Moosheide was investigated. Previous studies detected higher species numbers at this site (Lühr 2006). Furthermore, Lühr (2006), (2007) and Rüther & Venne (2005) determined an increase in species numbers since the beginning of the grazing project with Senner horses in the Moosheide. Sand grassland species were facilitated by grazing as well as numbers of red list species and Shannon diversity. Even former lists of species of the sand grassland Güsenhofsee included some more species, as it was in each case a vegetation mapping over the whole site (Biologische Station Kreis Paderborn-Senne 2010).

Horse grazing has a particular influence on vegetation development as they have got an intense footstep effect with their high body weight and their distinctive urge to move (Nitsche & Nitsche 1994, Rüther & Venne

2002). Concerning the grazing behaviour horses graze the sward down to the soil as opposed to cattle. Their browsing is described as more gentle and they leave no steady depth of browsing. The rest of the sward remains able to assimilate in most cases. Additionally, horses graze woody plants more intensively and also peel the bark so that some woods and scrubs die back (Klapp 1971, Sieling 2002). Due to the very low-intensive stocking rate no negative impacts on especially endangered plants by browsing or footsteps were detected. Only the high encroachment of woody plants and especially *Betula pendula* has to be assessed as negative, since the valuable areas of open landscape are threatened of overgrowth. Especially *Betula pendula* is avoided by cattle and sheep in summer months as Oheimb et al. (2006) figured out. Hence, an effective influence on this expansive pioneer species can only be expected at times of hibernal food shortage. But in this case, there are too much individuals of *B. pendula* so that the influence of cattle in a low stocking rate is rather low.

Composition of vegetation shows influences of grazing. Some poisonous plants occurred, for example *Arenaria serpyllifolia*, as well as so called inferior plants like *Juncus spec*., *Mentha spec*. and *Veronica officinalis*. Furthermore, there were both indicator plants for selective overgrazing, *Agrostis stolonifera* and *Leontodon hispidus* for instance, and for selective undergrazing *Festuca ovina* or at low coverages *Nardus stricta*. This is characteristic of pastures as livestock selects while browsing (Nitsche & Nitsche 1994).

The encountered biomass was suitable for cattle and also horses. But it is a fact that horses ingest more nutrients per unit of weight and day than cattle. Especially concerning higher fibre contents horses have a better nutrient utilisation (Sieling 2002).

Horses as well as cattle have got positive and negative grazing properties and different adaptations concerning the digestive system (Bunzel-Drüke 2004, Sieling 2002). The reintroducing of mixed grazing with a small number of horses and some cattle would be the best practice for the sand grassland Güsenhofsee. Another consideration could be a higher stocking rate in summer months. A temporary grazing with goats limited to the scrubby sites would also be a possibility, as goats graze woody plants even better (Schwabe & Kratochwil 2009). Otherwise, the mowing of woody plants over years is also an effective measure (Nitsche & Nitsche 1994). Meanwhile first stirrings of its efficacy can be seen at the sand grassland Güsenhofsee.

Until now, many target species established at the Güsenhofsee and a nutrient-poor site with a high degree of structural diversity developed. It is expected that the high diversity will be preserved under the influence of a low-intensive grazing by cattle.

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Personal comments

Fleischer, Dipl. Lök Kristin (University of Münster, Institute of Landscape Ecology): personal comment of December 2012.

Hölzel, Prof. Dr. Norbert (University of Münster, Institute of Landscape Ecology): personal comment of December 2012.

Moritz, Gerhard (Stadt Paderborn): personal comment of February 2012.

Schmidt, Dr. Carsten (Moss expert, Münster): personal comment of September 2012.

Venne, Christian (Biologische Station Kreis Paderborn-Senne): personal comments of January and February 2012 and April 2013.

Eidesstattliche Erklärung

Hiermit versichere ich, dass ich diese Masterarbeit einschließlich der beigefügten Abbildungen, Tabellen, Karten und Fotos, soweit nicht anders gekennzeichnet, selbst angefertigt und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.
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