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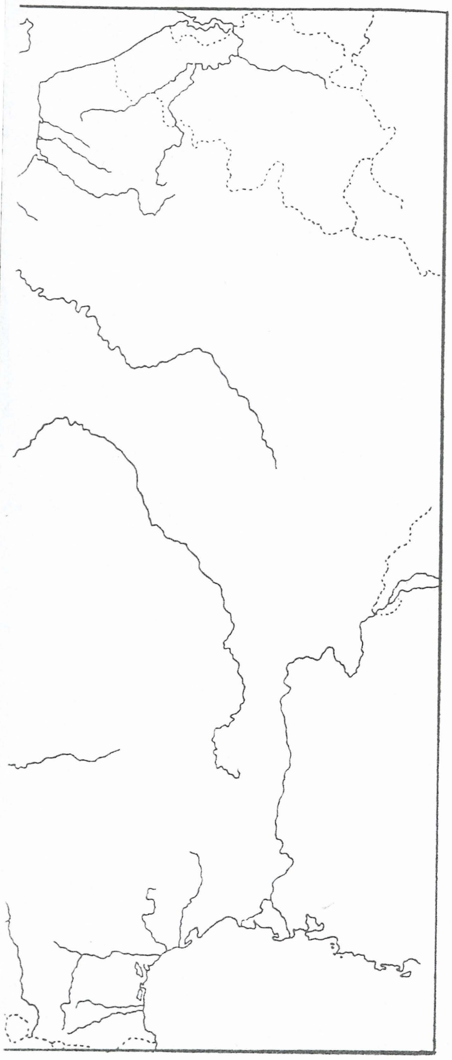

SPECIES COMPOSITION OF SMALL FENS IN RELATION TO THE NUTRIENT STATUS OF THE PEAT SOIL AND THE GROUND WATER

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ABSTRACT

Small mesotrophic fens with a floating mat of species-rich vegetation occur scattered in a landscape intensively used for cattle breeding in the Vechtplassen area, The Netherlands.

Species composition, biomass production and nutrient accumulation in the above-ground vegetation were studied in relation to the total amounts of N, P and K in the peat soil and to the nutrient concentrations in the ground water seeping continually into the fens.

Three types of fen vegetation were distinguished, one strongly dominated by large, highly productive species (e.g. *Carex acutiformis*), one characterized by species-rich stands with small *Carex* species and one with a strongly developed *Sphagnum* layer. Biomass production proved to be strongly correlated to the amounts of N, P and K accumulated in the above-ground plant parts.

A remarkable result was that the biomass production and nutrient accumulation were positively correlated with the total P and K content and not with the total N content of the peat soil. Apparently, the main P and K source to the vegetation is the mineralization of organic matter, whereas N is also provided by external inputs (rain, ground water).

An extensive study of the ground water quality revealed that species-rich fens only occur on spots with seepage of ground water rich in Ca, Fe and HCO_3. There are indications that the P availability to the vegetation is reduced as a result of enhanced absorption and precipitation of phosphate due to the inflow of ground water. The locally high NH_4 concentrations in the seepage water have no eutrophicating effect on the vegetation, as the NH_4 is absorbed in deeper peat layers before it can be reached by the plant roots.

It can be concluded that the seepage of ground water is essential for the conservation of the typically mesotrophic character of the fens.

RESUME - Composition floristique des petits marais tourbeux par rapport aux conditions nutritives du sol tourbeux et de l'eau souterraine

De petits marais tourbeux mésotrophes avec un tapis flottant de végétation riche en espèces se trouvent disséminés dans un paysage intensivement occupé par l'élevage des bestiaux dans la région "Vechtplassen", aux Pays-Bas.

La composition floristique, la production de biomasse et l'accumulation des éléments nutritifs dans la végétation aérienne ont été étudiées par rapport aux taux de N, P et K dans le sol tourbeux et aux concentrations des éléments nutritifs dans l'eau de source alimentant continuellement les marais.

Trois communautés végétales ont été distinguées, la première fortement dominée par de grandes espèces sociales (p.e. *Carex acutiformis*), la seconde caractérisée par des groupements riches en espèces avec de petits représentants du genre *Carex* et la troisième avec une couche à *Sphagnum* très développée. La production de biomasse s'avère être correlée avec les quantités de N, P et K accumulées dans la biomasse aérienne.

Un résultat remarquable était le fait que la production de biomasse et l'accumulation des éléments nutritifs étaient correlées positivement avec les taux de P et K, mais pas avec le taux de N du sol tourbeux. La source principale de P et K pour la végétation est évidemment la minéralisation de matière organique dans le sol, tandis que N est aussi d'origine externe (précipitation, eau souterraine).

Une étude détaillée de la qualité de l'eau souterraine a montré que des marais tourbeux riches en espèces ne se trouvent qu'à des endroits où coule une source d'eau souterraine riche en Ca, Fe et HCO_3. Il y a des indices montrant que la disponibilité de P pour la végétation est réduite à cause de l'absorption élevée et des précipitations de phosphate en conséquence de l'arrivée d'eau souterraine. Le fait que le taux de NH_4 dans l'eau souterraine est localement élevé n'a pas d'effet eutrophisant sur la végétation, parce que NH_4 est adsorbé dans les couches de tourbe plus profondes avant que les racines des plantes ne peuvent l'ingérer.

On peut conclure que l'arrivée de l'eau de source souterraine est essentielle pour la conservation du caractère typiquement mésotrophe des marais tourbeux.

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INTRODUCTION

In areas with intensive agricultural activities, natural and semi-natural plant communities are being steadily enriched with nutrients. The effects of eutrophication on aquatic ecosystems are well-known (e.g. VOLLENWEIDER, 1971) , the information becoming available on the effects on terrestrial systems shows that drastic changes in the species composition and vegetation structure can be the result (WILLIS, 1963 ; VAN DEN BERGH, 1979; GUNTENSPERGEN and STEARNS, 1983).

In the "Vechtplassen" area, The Netherlands, small mesotrophic fens occur scattered in a "polder" landscape used for cattle breeding. An attempt was made to elucidate the effects of nutrient transports from the agricultural areas towards the fens. The species composition of the fen vegetation was studied in relation to biomass production and nutrient uptake. Further, a study was made of the stocks of nutrients stored in the peat soil and of the flow and chemical composition of the ground water. The aim of the study was to determine under what conditions these mesotrophic "islands" can be maintained amidst of strongly fertilized agricultural grounds.

METHODS

The study was carried out in the "Vechtplassen" area, The Netherlands. The whole landscape is man-made : it consists of polders reclaimed in the 12th century which have a shallow peat soil over sand. Where the peat has been dug up for fuel (18-19 th century), shallow broads occur that have developed to Alder woodlands or, under the influence of annual mowing for haymaking, to floating fens with a species-rich vegetation.

Twenty fens in the Westbroek, Tienhoven, Molenpolder and Het Hol polders (see fig. 1) have been selected for a comparative study of species composition, biomass production and nutrient uptake by the vegetation in relation to the nutrient status of the peat soil and of the ground water.

In each fen shoot biomass and soil were sampled randomly in series of 9 or 10 points within a homogeneous plot at the time of the biomass maximum (July, VERHOEVEN et al., 1983). At these points, sods (20 x 20 cm) were cut out from the vegetation, clipped onto the soil surface and sorted according to species. The samples were dried (48 h, 70C), weighed and ground. Total N, P and K of the plant material were determined with methods described by VERMEER and VERHOEVEN (1985).

The fen plots sampled were classified on the basis of their species composition with an ordination computer program (DECORANA ; Hill, 1979) in combination with a shuffle by hand.

Samples were taken from the upper 40 cm of peat for the determination of the total N, P and K content.

At 100 locations distributed all over the study area. the ground water table was determined every two weeks. Ground water samples for determination of the NH_4, NO_3, PO_4, Ca, HCO_3, K, Na, Cl, Fe, Mg, Al and SO_4 concentrations and the pH and conductivity were collected each month.

RESULTS

Table 1 lists the species composition of the fen plots studied ; extremely occasional species have been omitted from this table. The frequency of the species and their mean percentual contribution to the total biomass of the stand in the vegetation types distinguished are indicated in this synoptic table.

The species of species group a are frequent in all vegetation types distinguished. They are common fen species, such as *Juncus subnodulosus, Potentilla palustris*, *Stellaria palustris* and *Galium palustre.* Table 1 shows that

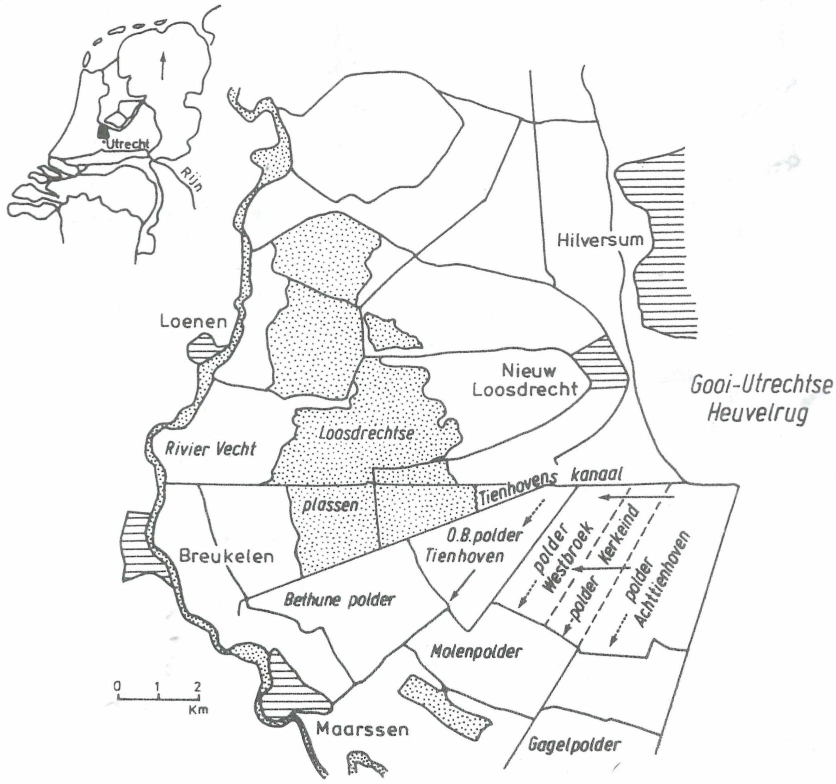
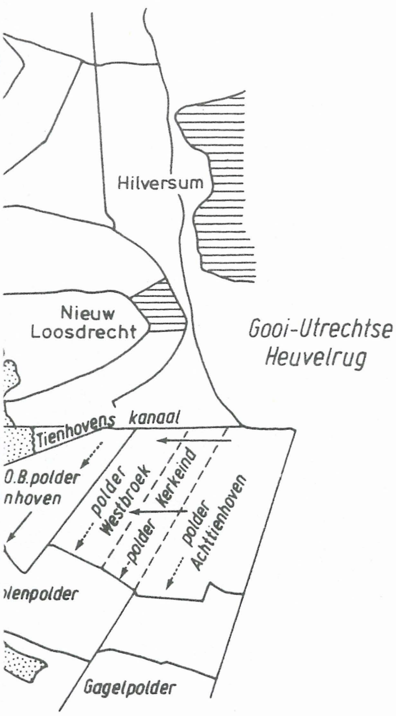


Figure 1 - Map of the study area. The quaking fens are located as small patches scattered in the landscape.
——→, direction of ground water flow ; - - - - ›, direction of surface water flow.



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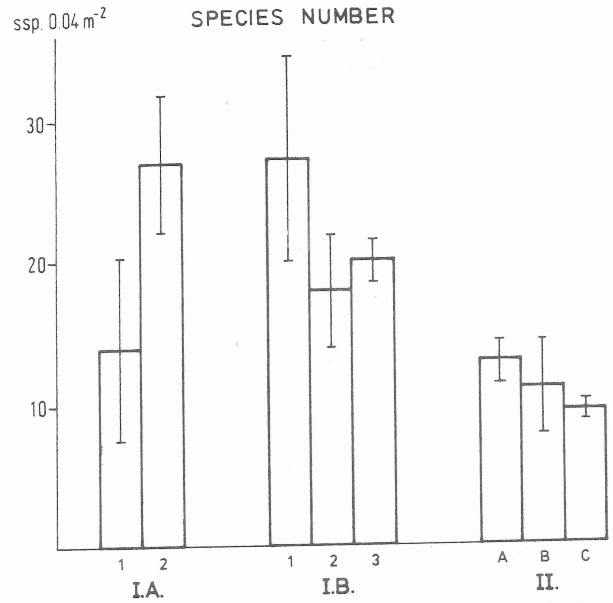

Figure 2 - Species density of the plant communities distinguished

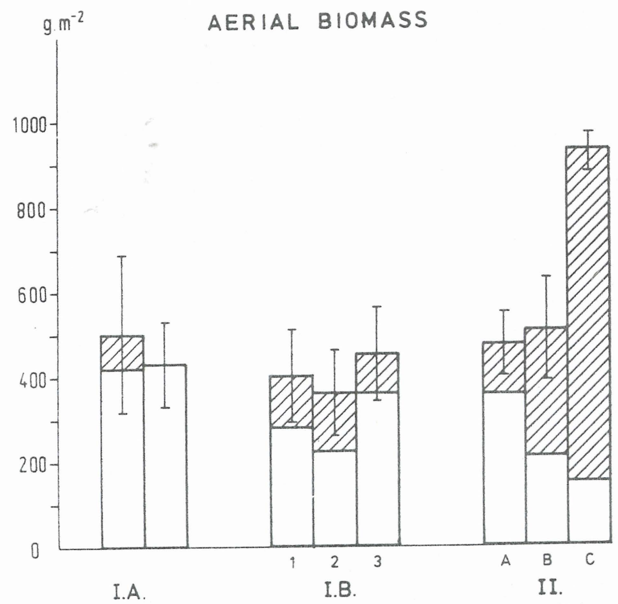

Figure 3 - Maximum standing crop of the plant communities distinguished (white, phanerogams ; hatched, bryophytes)

the "releve's" are subdivided into two main sections. Section II is characterized by the strong dominance of *Sphagnum* spp. and *Phragmites australis* and by the absence of species group b that characterizes the complete section I. Species groups c, d and e, characteristic for the various subsections of section I, are absent in section II as well.

In general there is a shift from species characteristic for marsh and fen communities in section I towards species characteristic for wet grassland and heathland communities in section II. Fig. 2 shows that the phanerogam species richness of the various vegetation types is quite different : the species richness of the types of section I is generally greater than that of section II. The only section I - type with a small species density is IA1, where the vegetation is strongly dominated by highly productive species such as *Carex acutiformis*. There are also differences in above-ground biomass between thestands of the various types (fig. 3), particularly with respect to the contribution of the phanerogams and the bryophytes.

Table 2 gives the results of a correlation analysis between various plant and soil parameters. There is a significantly positive correlation between shoot biomass (exclusive mosses) and the total amounts of N, P and K contained in the plant biomass ($p < 0.05$). The concentrations and total amounts of N, P and K are also positively correlated to one another. Species richness is not correlated to shoot biomass nor to nutrient concentrations in the plant material. The diversity index (Shannon) is, however, negatively correlated with biomass and with the amount of N contained therein.

One should realize for the interpretation of the data on the amounts of nutrients in the soil, that the total amounts were determined, not the quantities available to plants. The amounts of N determined in the plant biomass are not correlated to the total amounts in the soil. The amounts of P and K are, however, positively correlated with the total amounts of P and K, respectively, in the soil. This leads to the assumption that larger amounts of P and K will be available to plant growth when larger total amounts of these elements are present in the soil. The ground water study in the "Vechtplassen" area showed that there is a groundwater flow in SW direction from an area of sandy hills (Utrechtse Heuvelrug) towards the polders bordering the Vecht river (see fig. 1 ; BELTMAN, 1984). There is an upward seepage of this ground water into all fens classified in section I. This is clearly reflected in the chemical composition of the water in these fens (high concentrations of Ca and HCO_3, low concentrations of SO_4 and Cl, see the "Stiff" diagram A in fig. 4). The ground water seeping into these fens contained locally high NH_4 concentrations (3-5 ppm). In the fens of section II there is more influence of rain water (lower pH, higher SO_4- concentrations, see fig. 4, diagram b) because of the absence or small importance of ground water seepage.

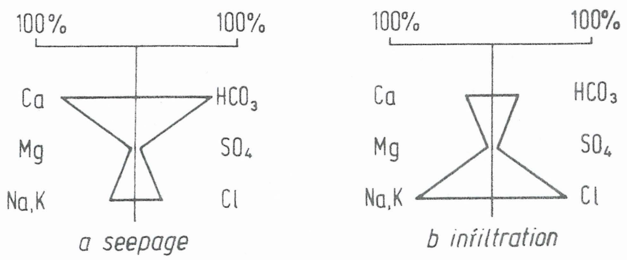

Figure 4 - Stiff diagrams of yearly averages expressed as percentage of the total amounts of cations and anions, respectively: a = seepage areas ; b = infiltration areas.

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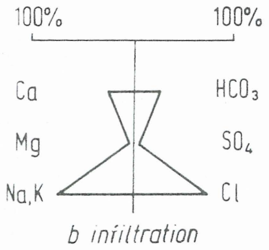

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DISCUSSION

The locations sampled are all structurally similar quaking fens occurring under conditions of small variations in the water level. The plant communities found consist mainly of species dependent on water-logged, meso- to eutrophic conditions. Most conspicuous is a large group of species-rich fens (subsection IB in table 1) characterized by low-productive small sedges and a well-developed bryophyte layer (*Caricion curto-nigrae*, WESTHOFF & DEN HELD, 1969. WHEELER, 1980). A second group (IA) consists of fens poorer in species and strongly dominated by tall species, such as *Carex acutiformis (Magnocaricion)*. The third group of fens (section II) is poor in phanerogam species and is characterized by a thick *Sphagnum* layer. The plant communities in this group contain species characteristic for wet grasslands and moist heathlands (*Cirsio-Molinietum*, WESTHOFF & DEN HELD, 1969 ; *Molinia-Myrica* community, WHEELER, 1980).

The positive correlation between biomass production and nutrient accumulation in the above-ground plant material indicates that the availability of nutrients determines the level of biomass production. The negative correlation between biomass and diversity shows the importance of low plant productivity in maintaining the typical characteristics of the fen communities. In previous studies it has been shown that N and P are important as factors limiting plant growth in the fens (VERHOEVEN et al., 1983 ; VERMEER, 1985). It is very interesting that the amount of N taken up by the plants is not correlated to the total amount of N in the soil, whereas such correlations do exist for P and K. N is, much more than P and K, an element that is continually being supplied to the fens by rain by the upwelling ground water. The importance of these external sources of N is due to intense fertilization of the grasslands surrounding the fens with cattle dung and artificial fertilizer. The main source of P is apparently the mineralization of the large amounts of P stored in organic matter, a proces that is a part of the internal P cycle in the fen.

The importance of seepage of "old" ground water into the fens should be stressed here. This water is locally eutrophicated with NH_4. There are indications, however, that the NH_4 is absorbed in deeper fen layers before the plant roots can reach it (VERHOEVEN et al., 1983).

Studies of the mineralization rate of the organic matter in the fen soils have revealed that the P availability is much smaller in fens with ground water seepage (section I) than in fens with stronger rain water influence (section II) (VERHOEVEN, 1985). The smaller P availability in the fens of section I compared to these of section II is probably due to the adsorption of phosphate to amorphously precipitated Fe $(OH)_2$. This difference is caused by the continuous inflow of Fe II into the fens of section I via the seepage of ground water.

The seepage of ground water, even if enriched with NH_4, seems, therefore, essential for the maintainance of the mesotrophic character of these fens, situated as they are in an intensely fertilized landscape.

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Table 1: Synoptic table of types of mesotrophic fen vegetations in the 'Vechtplassen' area. The first number is the frequency in which a species occurs in each type; the second number is the mean biomass contribution (%) of each species.

	I.A.1	I.A.2	I.B.1	I.B.2	I.B.3	II.A	II.B	II.C
Juncus subnodulosus Schrank	3 2.8	4 9.5	5 17.1	5 8.5	5 3.1		5 0.4	5 5.5
Potentilla palustris (L.)Scop.	3 0.5	5 0.5	5 2.3	3 7.0	5 2.5	3 0.3	3 0.3	3 0.3
Stellaria palustris Retz.	3 0.3	4 0.5	5 1.6	4 1.1	5 0.5	5 1.2		
Galium palustre L.	5 0.7	4 1.1	5 1.4	5 0.8	5 1.5	5 5.0		
Cardamine pratensis L.	5 0.5	5 0.6	5 0.7	5 0.9	5 0.7	3 0.5		
Calamagrostis canescens (Web.)Roth	1 0.1	4 17.0	5 3.1	3 0.8	3 1.5			5 3.0
Betula pubescens Ehrh.	2 0.2	4 0.5	3 0.3	2 0.1	2 0.2			5 1.0
Lythrum salicaria L.		2 0.1	3 0.4	2 0.1	2 0.2	2 0.3	2 0.2	
Lycopus europaeus L.	2 0.2	3 0.3	4 0.3	3 0.3	2 0.3	3 0.5		
Holcus lanatus L.	1 0.1	4 0.4	4 2.6		4 0.5	3 2.0		5 0.5
Lysimachia vulgaris L.	1 0.1		4 0.5	2 0.3	5 4.0	2 0.3		3 0.3
Menyanthes trifoliata L.	5 1.7	4 3.0	5 7.8	4 0.5	5 4.3			
Equisetum fluviatile L.	5 0.8	4 9.6	5 13.1	5 13.5	4 0.5			
Peucedanum palustre (L.)Moench	2 0.2	3 0.3	5 0.7		2 2.0	2 0.3		
Iris pseudacorus L.	1 0.2	4 0.5	4 0.7	5 1.4	1 0.1	2 0.2		
Carex acutiformis Ehrh.	5 81.8	5 11.6	3 0.9	3 5.5	5 2.3			
Equisetum palustre L.	5 2.0	5 5.0	3 3.4		1 0.1			
Lemna minor L.	3 0.3	3 0.5	1 0.1		3 0.3			
Poa trivialis L.	2 0.2	5 4.2	4 0.7	3 0.4	1 0.1			
Ranunculus flammula L.	1 0.1	4 0.5	3 0.4	2 0.1	2 0.2			
Glyceria maxima (Hartm.)Holb.		5 4.5	1 0.4	2 0.3	1 0.1			
Carex disticha Huds.		4 1.0	2 0.4					
Carex pseudocyperus L.		4 13.3	2 0.5					
Filipendula ulmaria (L.)Maxim.		3 3.0						
Lathyrus palustris L.		4 0.9						
Hierochloe odorata (L.)P.B.		3 4.0	1 0.1					
Galium aparine L.		3 0.5						
Carex curta Good.		2 2.7	3 0.8	3 0.3	1 0.1		2 0.2	
Caltha palustris L.	1 0.1		4 1.2	3 1.5			2 0.2	
Mentha aquatica L.	2 0.2		5 0.7	2 0.1	1 0.1			
Eleocharis acicularis (L.)R.et Sch.			1 0.1	3 7.5	3 0.3	2 0.2		
Lysimachia thyrsiflora L.		4 2.8	3 1.0	3 0.6	2 0.5			
Carex diandra Schrank	1 0.1		5 10.0	3 3.0	1 0.1	2 0.2		
Pedicularis palustris L.	1 0.1		5 4.3	5 5.8	4 12.5			
Carex rostrata Stokes		2 0.7	3 0.6	5 12.5	3 0.3			
Ranunculus lingua L.		2 0.3	3 0.3	4 0.5	2 0.1			
Valeriana officinalis L.	1 0.1		3 0.5					
Myosotis palustris (L.)L.			2 0.3	2 0.1	1 0.1			
Alisma plantago-aquatica L.			1 0.1					
Cicuta virosa L.			1 0.2					
Phragmites australis (Cav.)Trin.ex Steud.	5 1.7	4 1.3	1 0.1		4 8.0	5 14.	5 0.5	5 0.4
Sphagnum			1 0.1		2 0.3	5 18.	3 12.0	5 84.
Agrostis stolonifera L.	3 0.2	2 2.8	2 0.2	2 0.3	5 2.0	5 36.		
Thelypteris palustris Schott	1 0.1				2 1.0	5 3.0		
Typha latifolia L.					2 0.3	3 5.3		
Sparganium erectum L.						3 6.3		
Rumex hydrolapathum Huds.		2 0.2	2 0.2		2 0.6	3 0.3		
Carex lasiocarpa Ehrh.	1 0.1		2 1.0		3 1.5		3 15.	
Juncus articulatus L.			1 0.1				5 2.0	
Carex demissa Hornem.	1 0.1						5 2.2	
Molinia caerulea (L.)Moench							5 9.0	
Myrica gale L.							5 4.2	
Drosera rotundifolia L.							5 2.8	
Hydrocotyle vulgaris L.	1 0.1						3 0.3	
Carex riparia Curt.							2 2.0	
Erica tetralix L.			1 0.1				2 1.3	
Anthoxanthum odoratum L.								5 0.5
Carex paniculata L.								5 0.5
Sample number	6	4	12	4	7	3	3	2

Table 2 : Correlationcoefficients (Pearson) - only the significant correlations between various soil and plant parameters are given. * - $p < 0.05$; ** - $p < 0.01$; t - $p < 0.10$.

	biomass,excl	biomass,incl	species nr	Diversity	N,excl	N, incl	P, excl	P, incl	K, excl	K, incl	g $N.g^{-1}$pl	g P. g
g $N.m^{-2}$ in plant(excl.mosses)	0.348^{+}			-0.594^{++}								
g $N.m^{-2}$ in plant (incl.mosses)		0.49^{+}		-0.513^{+}								
g $P.m^{-2}$ in plant (excl.)	0.628^{++}				0.661^{++}							
g $P.m^{-2}$ in plant (incl.)				-0.490^{+}		0.721^{++}						
g $K.m^{-2}$ in plant (excl.)	0.478^{++}				0.735^{++}		0.719^{++}					
g $K.m^{-2}$ in plant (incl.)						0.729^{++}		0.637^{++}				
mg N. g^{-1}plant					0.540^{+}	0.549^{++}	0.381	0.392	0.535^{++}	0.579^{++}		
mg P. g^{-1}plant			-0.448^{+}		+	0.459^{+}	0.456^{+}	0.831^{++}	0.627^{++}	0.689^{++}	0.534^{++}	
mg K. g^{-1}plant					0.638^{++}	0.526^{+}	0.565^{++}	0.555^{+}	0.907^{++}	0.778^{++}	0.652^{++}	0.65
thickness 'kragge'	0.669^{++}	0.629^{++}										
mg N. dm^{-2} soil (0-10 cm)												
mg P. dm^{-2} soil (0-10 cm)							0.579^{+}	0.672^{++}	0.501^{+}	0.519^{+}		0.77
mg K. dm^{-2} soil (0-10 cm)	0.728^{+}	0.825^{+}										
mg N. dm^{-2} soil (0-20 cm)												
mg P. dm^{-2} soil (0-20 cm)								0.534^{+}				0.69
mg K. dm^{-2} soil (0-20 cm)									0.695^{++}	0.686^{+}	0.602^{+}	