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Extensification of dairy farming and floristic richness of peat grassland

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Abstract

A comparative study of floristic richness of peat grasslands was performed in order to explore the perspectives for nature conservation of extensification of dairy farming. Three different parameters of floristic richness were used: the number of species, the number of those species that contribute to the conservational value and a 'nature-value' index that combines species richness with the rarity of species.

The amounts of fertilizer and animal manure proved to be the major factors for the floristic richness of peat grasslands. Additional factors were peat mud treatment and soil type. Way of utilization, ground water table, pH, P and K contents of the top soil and type of animal manure had no significant effects on floristic richness.

The relations between floristic richness and nitrogen supply revealed that the conservational profits of a moderate reduction of nitrogen supply are limited. Only a more extreme reduction, to levels not exceeding 200 kg N ha^{-1} yr^{-1}, will raise the floristic richness substantially. Hence, the chance to restore the floristic richness of peat grasslands at current agricultural practice is low.

Introduction

Dairy farming on peat grasslands in the western part of the Netherlands was intensified considerably in recent decades. This process included a rise of the nitrogen fertilization. From 1945 until 1980 the amount of fertilizer increased from an average of about 70 kg pure N ha^{-1} yr^{-1} to about 250-300 kg N ha^{-1} yr^{-1} (van Burg et al., 1980; de Boer, 1982). Also the increased stocking rate attributed to a higher nitrogen gift, causing the total average amount of nitrogen to exceed 400 kg N ha^{-1} yr^{-1}.

The development of dairy farming brought about many other changes in the grassland management. On most farms, liquid slurry replaced solid animal manure. The variation in the use of the fields decreased; many fields nowadays are used as alternate pastures that are often mown early for silage and grazed afterwards. In many areas the ground water table was lowered by establishing lower ditch water tables in order to provide for a bearing power that enables intensive grazing and the use of modern, heavy machinery throughout the year (de Boer, 1982).

The intensification caused a dominance of the productive grasses *Lolium perenne* and *Poa trivialis* in almost all farm grasslands. Nature conservationists point out a reverse side of this development: the decrease of the species diversity and the levelling down of differences in the botanical composition between grasslands. Species such as *Cynosurus cristatus*, *Lychnis flos-cuculi* and *Carex* spp. declined (de Boer, 1982).

At the actual high production levels of the fields, usually exceeding 10 ton dry matter ha^{-1} yr^{-1}, the fast-growing species suppress most other species in their competition for light (see Grime, 1979). To restore the species diversity the production level therefore must be lowered. Because the level of nitrogen supply is the major factor controlling production and botanical composition of the grassland vegetation (Heddle, 1967; van Burg et al., 1980), a decrease of the nitrogen gift is required.

The question arises which reduction of N-supply is needed to enhance the botanical richness considerably. Usually, extreme reductions are recommended, to levels not exceeding 50-100 kg N ha^{-1} yr^{-1} (apart from nitrogen from precipitation), to bring about a high species diversity. Yet, the conservational profits obtained by a lesser reduction of the N-gift, to levels still exceeding 100 kg N ha^{-1} yr^{-1}, are rather poorly known. That is because most studies on extensification concentrate on situations at a low level of N-supply; so the relations between species composition and richness and N-supply are still not exactly known throughout the entire N-range. Furthermore, in many studies about grassland vegetation the conservational profits are mainly expressed in terms of species diversity, without quantitatively taking into account the conservational value of species.

In addition, the relations between conservational values and nitrogen supply might depend on other factors. Though the nitrogen supply is the major factor for the composition of the grassland vegetation, several other factors may influence species composition and richness, e.g. way of utilization, ground water table, soil type, soil acidity and type of animal manure (Ennik, 1965; Kruijne et al., 1967; Klapp, 1971).

To explore the prospects of flora conservation on peat grasslands at extensification we will deal with the following questions:

- Which relation exists between conservational value ('floristic richness') of grasslands and nitrogen supply, over the entire N-range?
- To what extent does this conservational value depend on other factors?

This study is limited to the vegetation on the top of the fields; the vegetation of ditch sides will be discussed in a forthcoming paper.

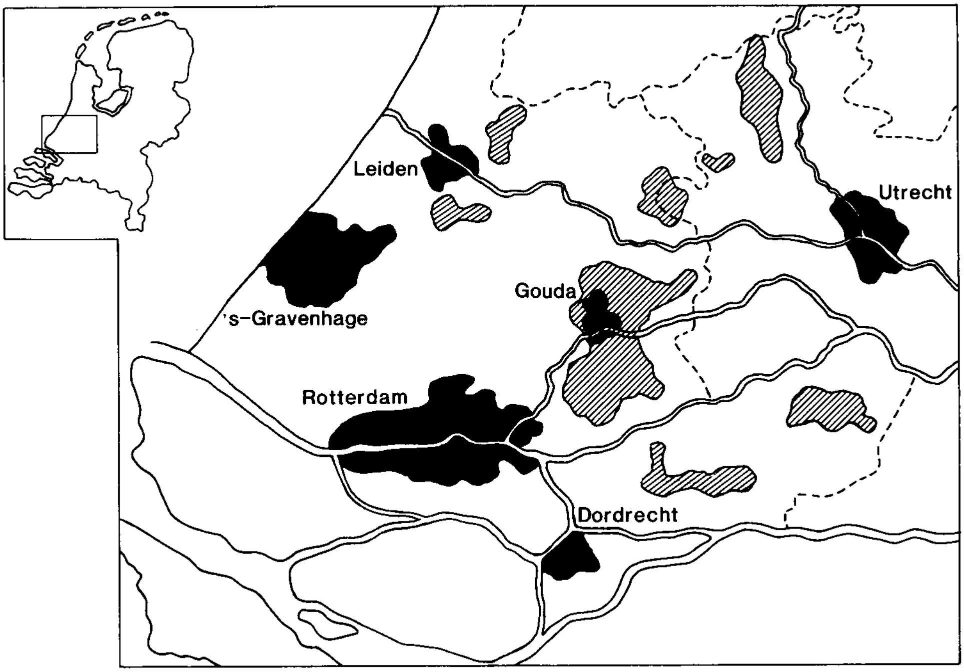

Fig. 1. Location of the study sites.

Study area

The study sites were located in the typical Dutch polder-landscape below the sea level in the provinces of Zuid-Holland and Utrecht (Fig. 1). This landscape originated about 6000 years B.C. with the formation of a wadden area by the flooding of the lower parts of the Netherlands after the last glacial period and subsequently by the formation of peat bogs after this area was shut of from the sea by coastal barrier deposits (Bijlsma, 1982). As a result, the surface soil of these areas nowadays consists of peat, while the intersecting rivers are bordered by zones of clay of some miles broad and clay-on-peat at greater distances.

The reclamation of the peat area, from about 1000 years ago onwards, formed the actual polderland. Systems of parallel drainage ditches were dug, usually perpendicular to the rivers, resulting in a landscape with long, narrow fields and farm-homesteads usually nearby the rivers (see van der Linden, 1982). In former days the most distant fields were used very extensively, whereas the fields immediately behind the farming-houses near the rivers were relative intensively exploited. These differences in exploitation, strengthened by the differences in soil type and moistness, were reflected by the vegetation. Nowadays this zonation has almost disappeared, most fields being exploited intensively (de Boer, 1982).

Material and methods

Study design

We selected 125 permanent grasslands on about 100 agricultural holdings for a comparative study of floristic richness in 1983-1984. This selection was based on questioning farmers about their management and comprised the entire range of nitrogen supply from 0-600 kg N ha^{-1} yr^{-1}. The inquiries of the farmers were checked on internal consistency and verified by direct observations about grassland exploitation during the visits at the study fields. The only fields used were those of which we had reliable and accurate information on management. All fields selected were used for dairy farming and had a management that was known to be more or less constant for 5-10 years.

To unravel the effects of the agricultural factors we tried to achieve an independent variation of all factors of interest, while striving for zero or random variation in factors that were not of interest in this study (e.g. the time of the year in which the vegetation is sampled). Because seepage influences the floristic richness (Grootjans, 1985), areas with significant seepage were avoided; areas with saltish grasslands were also omitted.

Agricultural and other factors

Nitrogen supply. Doses of fertilizer (mostly calcium ammonium nitrate), farmyard manure, slurry and nitrogen excreted by grazing cattle were derived from information of the farmers. The effective nitrogen doses were calculated by taking the nitrogen contents and losses given by Pelser (1984) into account. These nitrogen sources were summed in order to get the total amount of nitrogen applied on each study field. Nitrogen from precipitation was ignored.

Way of utilization. The fields were assigned to one of the following ways of utilization, more or less arranged according to increasing grazing pressure:
- 'meadow' (cut more than once a year, with first cut or grazing period before June),
- 'hay pasture' (cut in June and grazed only subsequently),
- 'alternate pasture' (grazing; cut no more than once a year; cut or first grazing period before June),
- 'rotational grazing' (without cutting),
- 'continuous grazing'.

Peat mud dressing. The ditches lining the fields usually were dredged with intervals of 5-10 years. The peat mud from these ditches, usually rich in nutrients, is spread over the fields. We distinguished fields that were dressed with sludge 1-5 years ago from fields that were dressed more than 5 years ago.

Water table. Both ditch water table as well as ground water table were measured 5 times in 1984: in January, March, April, May or June and in August.

Most ditches involved had in general constant water levels throughout the year; in a few ditches the level was about 20 cm lower in winter than in summer. The ditch water levels of the fields involved were known to have not substantially changed for at least 5 years; most of them had not been changed during at least 10 years.

Measurements of the ground water table were carried out in 3 PVC tubes (2.2 cm diameter; 1 m long). These tubes were placed in a transect, crossing the field transversely; one tube was situated in the middle of the field, another one at a distance of 3 m from one of the ditches, and the third one just between these two (Fig. 2).

The ground water levels, especially those in the centre of the fields, varied throughout the year, being highest in winter. The variations in other years may be more pronounced, because the summer of 1984 was rather wet. In addition, the levels in the middle of the fields differed from the levels near the ditches. During the winter months the central levels were highest; during the summer the opposite held. As a consequence, the soil in the centre of the fields with high ditch water levels was waterlogged in winter.

The course of the water levels throughout the year as well as the differences across the field were roughly the same for all fields. The fields differed, however, with regard to the height of the water tables, especially in spring and summer, and also with regard to the maximal difference between summer and winter levels due to differences in width of the field or permeability of the soil.

Soil type. Information about the soil type at the study sites was derived from soil maps (1:50000) (Anon., 1982) and verified by soil profile observations. The soil types involved are:
- mesotrophic peat,
- eutrophic peat,
- mesotrophic peat covered with clay, and
- eutrophic peat covered with clay.

The top layer of clay, if present, was less than 40 cm thick.

Chemical soil factors. Samples of the upper 0-10 cm soil layer were collected in the autumn of 1983 and 1984 in order to determine the pH-KCl and the content of phosphorus and potassium. Phosphorus was measured after extraction in ammonium lactate acetic acid; potassium was measured after extraction in 0.1 mol l^{-1} HCl and 0.4 mol l^{-1} oxalic acid. The P-Al is expressed in mg P_2O_5 per 100 g dry soil. The K content was converted into the K-number, which is widely used in agricultural research (Pelser, 1984).

Use of herbicides. Two-third of the involved farmers used herbicides to control some agriculturally undesirable plant species, mostly *Cirsium arvense* and *Urtica dioica*. Since these herbicides were applied locally and selectively only, we considered their effects on the botanical composition as negligible and did not investigate these effects.

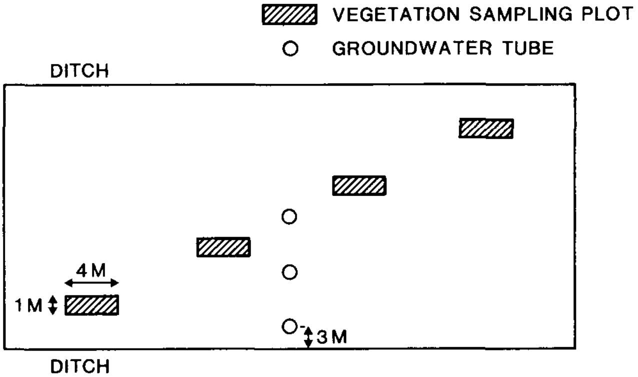

Fig. 2. Diagram (not to scale) showing the location of the vegetation sampling plots and the ground water tubes on a field.

Vegetation sampling

Vegetation was sampled in 1983 and 1984, between the end of June and the beginning of September. On each field, four relevés ($1 \times 4\ m^2$) were made, using the decimal cover scale of Londo (1976). The four sampling plots were situated along the diagonal of the field in order to sample the entire grassland (Fig. 2). Ditch banks, trenches etc. were not included. We always examined fields with a homogeneous management.

Several fields were examined in 1983 as well as in 1984 in order to check for systematic differences in the vegetation between the two years. Because we did not detect any such differences, we combined the data of these two years in the analyses.

Parameters of floristic richness

We used several parameters to express the conservational profits of a lower nitrogen supply.

Number of species. This measure is among the most widely used criteria to assess the conservational value (Margules & Usher, 1981). Though this parameter is elegant for its simplicity, its shortcoming is evident: common species and rare and endangered species are given equal value.

Number of quality-indicating species. In order to take the differences in conservational value between species into account, Drijver & Melman (see van Strien, in prep.; van Strien & Melman, 1987) proposed a variation on the number of species. They assigned all grassland species to three categories: very common species that are characteristic of very intensive exploitation and overexploitation (e.g. *Poa annua* and *Stellaria media*), species occurring only occasionally in grasslands, but frequently in other habitats (e.g. *Lamium purpureum*), and remaining species. Only species of the last group are considered to contribute to the conservational value of the vegetation and are called 'quality-indicating species'.

Nature-value index. A more sophisticated system distinguishing between rare species and more common species has been developed by Clausman & van Wijngaarden (see van Strien, in prep.; van Strien & Melman, 1987). On the basis of an extensive survey of the vegetation of Zuid-Holland they assessed the local rarity of the species. Also the national and mondial rarity of these species has been estimated as well as the rate of decline of species. In their valuation system, each plant species is weighted according to both its rarity in the different scales and to its rate of decline. This is called the nature-value index of the species. The nature-value index of a vegetation is calculated by combining the nature-values of all species involved, taking into account their abundances.

Statistics

Analysis of variance (ANOVA; Nie et al., 1975) was used to unravel effects of both non-metric and metric factors involved. Several series of ANOVA were run:
- using different dependent variables (number of species, number of quality-indicating species, nature-value index),
- using the metric factors either as covariates or as factors divided into several classes.

This approach was necessary because the ANOVA could not handle more than 5 non-metric factors in one run. The use of covariates made it possible to test more than 5 factors in the ANOVA simultaneously. With the factors arranged into classes, interactions could be tested between factors and corrected means of the dependent variables per factor class could be calculated. In all runs the effects of the factors were adjusted for the effects of all other factors involved. Effects of factors were assessed prior to interaction effects.

Results of ANOVA with number of species, number of quality-indicating species and nature-value index as dependent variables corresponded very well with each other. That is because these parameters correlated highly: Pearson's $r = 0.89$ between the number of species and the number of quality-indicating species; between the number of quality-indicating species and the nature-value index, $r = 0.82$. We concentrated on the number of quality-indicating species, because this parameter showed the greatest homogeneity of its error variance, which is a prerequisite of ANOVA (Sokal & Rohlf, 1981).

Results

Mutual independence of factors

To get reliable information about the relative importance of the independent factors, we only used factors in the ANOVA with mutual correlation coefficients below 0.5. Not all factors turned out to be completely independent of each other. Way of utilization and nitrogen supply correlated; the hay pastures involved were on the average less fertilized than the other fields. Ground water levels in several periods correlated with the total amount of nitrogen supply and with soil type; the P and K contents of the top soil correlated with nitrogen supply as well as with peat mud dressing; P moreover correlated with the pH of the top soil and with K. All these correlation coefficients, however, were below 0.5.

Vegetation differences within the fields

Due to the hydrological differences across the fields, differences in the botanical composition within the fields might be expected. To examine this, we compared the abundances of some species that are known to indicate moist or drought circumstances (according to the list of de Boer, 1965) in the two sampling plots at the outside of the fields with those in the two plots near the middle of the fields. There were indeed differences within the fields: the moisture-indicating species *Alopecurus geniculatus* and *Glyceria fluitans* had a significantly, but slightly, higher abundance in the middle of the fields, whereas the drought indicators *Dactylis glomerata* and *Poa pratensis* did not differ significantly (Table 1).

Only in winter and in spring the water table is higher in the middle of the field than at the margins, which points at some importance of winter and spring water levels for moisture-indicating species. In spite of some differences in the botanical composition, no differences could be discovered in the number of quality-indicating species (Table 1). Therefore, we considered the fields as being homogeneous with respect to floristic richness, and combined the data of the four sampling plots. The ground water tables of the sampling plots have been derived from the ground water level measurements in the tubes. The ground water levels of the sampling plots were averaged as well.

Table 1. Comparison of several vegetation parameters of the two plots near the margin of the fields with the two central plots.

Vegetation parameter	Plots near the middle	Plots near the margin	Sign test T value (n = 125)
Mean cover of *Alopecurus geniculatus and Glyceria fluitans* together (%)	9.9	8.1	20*
Mean cover of *Dactylis glomerata* and *Poa pratensis* together (%)	2.0	2.5	10
Mean number of quality-indicating species	7.4	7.7	5

* $P \leq 0.05$.

Vegetation differences between the fields

Three factors proved to be important for the number of quality-indicating species: nitrogen supply, peat mud dressing and soil type (Table 2). The multiple r is 0.8, which means that these factors explained about two-third of the variance in the number of quality-indicating species. As expected, the nitrogen supply was the most important factor determining the number of quality-indicating species (Table 2; Fig. 3). The number of quality-indicating species was higher on fields on which peat mud was applied more than 5 years ago than on the other fields, especially at a low nitrogen supply (Table 2; Fig. 3; ANOVA interaction between peat mud treatment and nitrogen gift F value = 4.65; $P < 0.05$). Corrected for the effects of other relevant factors, fields on mesotrophic peat on average contained about 2 quality-indicating species more than fields on the other soil types, which did not differ in floristic richness.

The way of utilization, the ground water level (in April), the pH and the P and K status of the top soil had no separate effects on the number of quality-indicating species. In addition, neither the ground water levels in other periods had significant effects on the number of quality-indicating species, nor the maximal difference between winter and summer ground water levels. This agrees with the findings about the vegetation differences within the fields.

Differences in the nitrogen supply had the greatest effects in the low application range (Fig. 4; $B_1 > B_2$). This holds for the number of species ($B_1 = 0.020$ and $B_2 = 0.012$) and the number of quality-indicating species ($B_1 = 0.040$; $B_2 = 0.017$), but especially for the nature-value index ($B_1 = 0.062$; $B_2 = 0.005$). At 400 kg N ha^{-1}

Table 2. Results of ANOVA using the number of quality-indicating species as dependent variable. Effects of each factor have been corrected for effects of all other factors. F values are given for each factor. Multiple $r = 0.80$.

Factors	Ranges or categories involved	F value
Nitrogen supply	0-600 kg N ha^{-1} yr^{-1}	131.34**
Way of utilization	from frequently cut to continuously grazed	1.01
Peat mud dressing	less or more than five years ago	4.01*
Ground water table in April	10-60 cm below surface	1.66
Soil type	mesotrophic (clay-on-) peat and eutrophic (clay-on-) peat	3.90*
pH-KCl	3.7-5.7	0.44
P-Al	6-260 mg P_2O_5 per 100 gr dry soil	0.67
K-number	7-110	0.32

* $P \leqslant 0.05$.
** $P \leqslant 0.01$.

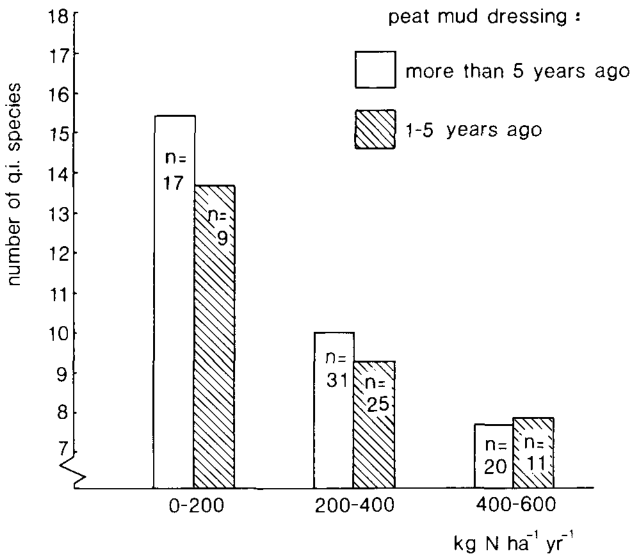

Fig. 3. Average number of quality-indicating species (see text) with different nitrogen supply at different periods after peat mud dressing. Corrected for soil type by means of ANOVA. *n* = number of fields.

yr^{-1} several species, such as *Alopecurus pratensis*, were abundant that were absent or scarce at 600 kg N ha^{-1} yr^{-1} (Fig. 5). However, these are all common species (with low nature-value indexes) that hardly contribute to the nature-value of the vegetation. From 400 to 200 kg N ha^{-1} yr^{-1} several very common species, such as *Chenopodium album* and *Capsella bursa-pastoris*, decreased, whereas a number of more valuable species, such as *Cardamine pratensis* and *Rumex acetosa*, increased. Still, most of these last-mentioned species are far from endangered and therefore hardly raise the nature-value index of the fields. Mainly at levels below 100-200 kg N ha^{-1} yr^{-1} a considerable number of species became abundant that really have some conservational value, such as *Lychnis flos-cuculi* and *Carex nigra*. Hence, above that level a lower nitrogen gift hardly provided for a higher nature-value index (Fig. 4).

The relations between the parameters of floristic richness and the nitrogen supply (Fig. 4) were not corrected for other factors. However that will hardly affect these relations, since other factors are either not relevant to floristic richness or are independent of the nitrogen gift.

Because correlations between fertilizer, excreta deposited during grazing, manure and slurry were below 0.5, we could assess their specific effects. Corrected for peat mud dressing, soil type and for the other types of nitrogen supply, especially the amount of fertilizer was found to be important for the number of quality-indicating species (ANOVA F value = 16.90; $P < 0.01$). The dose of both manure and slurry also affected the number of quality-indicating species (ANOVA F value = 4.34; $P < 0.01$), but their effects did not differ from each other (ANOVA F value =

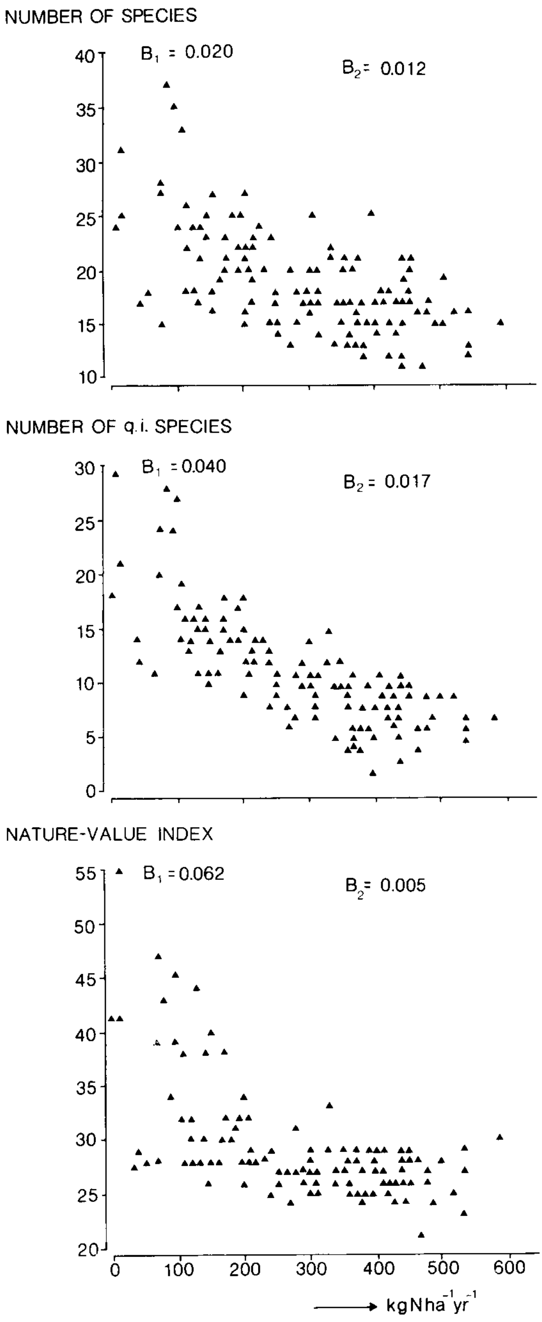

Fig. 4. Relations between three parameters of floristic richness (number of species and of quality-indicating species and nature-value index) and nitrogen supply. B_1: slope of the relation between 0 to 200 kg N ha^{-1} yr^{-1}. B_2: slope of the relation between 200 to 600 kg N ha^{-1} yr^{-1}.

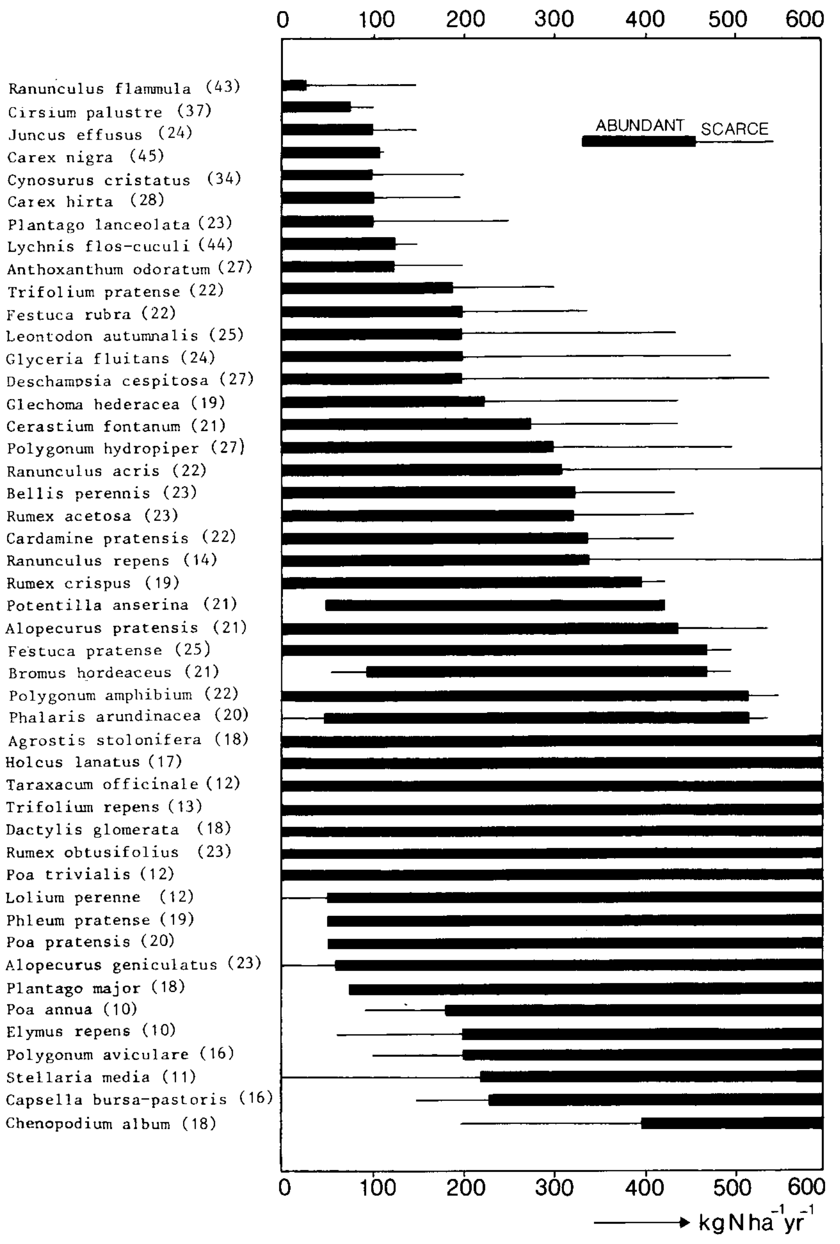

Fig. 5. Occurrence of grassland species on 125 fields with different nitrogen supply. The species are arranged according to response to nitrogen gift. In brackets: the nature-value index of each species according to Clausman & van Wijngaarden (see van Strien, in prep.). The mean cover of species indicated as 'scarce' is less than 10 % of the cover indicated as 'abundant'. Species that were found less than 5 times as well as species that often were chemically combatted have been left out of consideration.

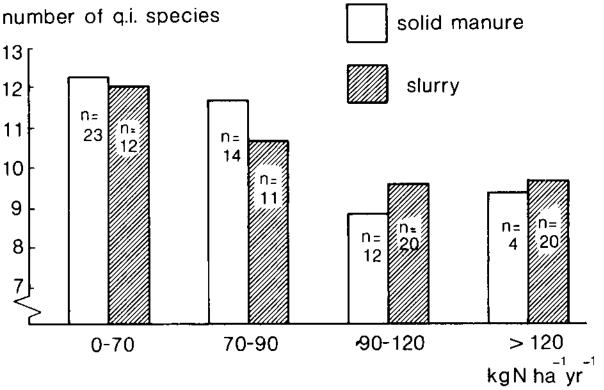

Fig. 6. Average number of quality-indicating species on fields treated with different doses of manure or slurry. Corrected for effects of fertilizer treatment, excreta deposited during grazing, peat mud dressing and soil type by means of ANOVA. The doses of both types of animal manure have been converted into amounts of effective nitrogen supply.

0.73; $P > 0.05$) (Fig. 6). However, the amount of fertilizer explained most variance of the number of quality-indicating species because of its extensive range; per kg N its effect did not differ from the effect of manure or slurry. The amount of nitrogen excreted by grazing animals had no significant effect on the number of quality-indicating species (ANOVA F value = 0.78; $P > 0.05$).

Discussion

Fertilizer, manure, slurry and to a smaller extent peat mud dressing and soil type proved to be the only factors that determined the floristic richness of peat grasslands. The same mechanism, viz. the availability of nutrients, probably underlies their effects. Though the application of manure is sometimes said to be more profitable for species diversity than slurry, we could not detect such a difference.

The absences of separate effects of P and K contents of the soil is less striking, because of the limited number of fields that contained insufficient P and K in the top soil as compared with the agricultural requirements stated by Pelser (1984). Especially because the fields with low P and K values also had low amounts of nitrogen application, we suppose that P and K are no limiting factors for the vegetation growth on most fields. The lack of an effect on floristic richness of the nitrogen excreted by grazing cattle is affirmed by the study of Lantinga et al. (1987) on grassland production.

Several studies report the importance of pH, way of utilization or ground water table for the species diversity of grasslands (e.g. Kruijne, 1964; Silvertown, 1980; Oomes & Mooi, 1981; Grootjans, 1985). Our findings seem to disagree with these studies. We don't think that the measurements were too inaccurate or that the ranges involved in our study were too small; similar or even smaller ranges revealed

Table 3. Mean cover of the group of species that preferred grazing (in the studies of Ennik (1965) and Elberse et al. (1983)) at different ways of utilization. This group consists of *Agrostis stolonifera*, *Lolium perenne*, *Poa annua* and *Ranunculus repens*. Corrected for nitrogen supply, peat mud dressing, ground water table, soil type and pH by means of ANOVA; way of utilization F value = 2.80; $P \leq 0.05$.

Way of utilization	Cover of grazing-preferring species together (%)
1. Meadow (n = 5)	27.8
2. Hay pasture (n = 32)	42.9
3. Alternate pasture (n = 62)	50.9
4. Rotational grazing (n = 13)	48.0
5. Continuous grazing (n = 6)	48.5

effects in other studies. To be sure, however, we investigated the relations between plant species that are known to prefer certain circumstances and way of utilization and ground water table. With respect to the way of utilization, we chose several species that showed a preference for grazing above cutting on fertilized fields in the studies of Ennik (1965) and Elberse et al. (1983): *Agrostis stolonifera*, *Lolium perenne*, *Poa annua* and *Ranunculus repens*. ANOVA revealed that this group of species was indeed less abundant on the fields that were less grazed (Table 3).

With respect to the moisture status, the moisture-indicating species *Alopecurus geniculatus* and *Glyceria fluitans* and the drought indicators *Dactylis glomerata* and *Poa pratensis* were examined. Moisture and drought indicators significantly correlated with – in decreasing order – ground water levels of April, March, May/June, August and January. This corroborates the importance of the water table in spring for these moisture and drought indicators. The moisture species group was indeed favoured by a higher water level, whereas the drought indicators did significantly better at lower levels (Fig. 7).

These results show that the ranges of the factors involved apparently were not too small and the measurements were sufficiently accurate to detect any effects on the vegetation, at least for the way of utilization and the ground water table. Far more probably, the lack of effects of these factors on floristic richness is due to the dominance of the nitrogen supply at agriculturally exploited fields. The other factors may play a role with regard to the floristic richness at a low nitrogen gift and a low production level only (Grime, 1979; van Strien & Melman, 1987). Indeed, the studies mentioning the effects of way of utilization or ground water table on species diversity concerned such low-productive circumstances. The increasing importance of other factors with lower nitrogen supply is also indicated by the somewhat greater variation in the floristic richness at lower nitrogen levels (Fig. 4). To test the interest of other factors at lower nitrogen gifts, we repeated the ANOVA and tested for interactions between effects of level of nitrogen supply and all other factors. Except for peat mud dressing, no significant interactions could be established, but this lack of interaction effects might well be due to the limited number of cases with low nitrogen supply.

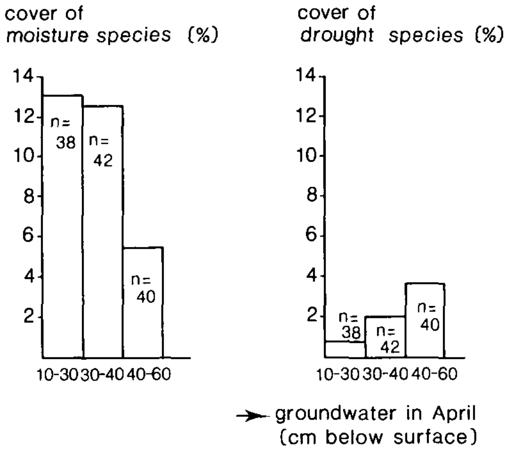

Fig. 7. Mean cover of moisture-indicating species (cover of *Alopecurus geniculatus* and *Glyceria fluitans* added) and drought-indicating species (cover of *Dactylis glomerata* and *Poa pratensis* added) with different ground water levels in April. Corrected for nitrogen supply, way of utilization, peat mud dressing, soil type and pH by means of ANOVA; ground water table F value = 3.59; P = 0.03 with respect to moisture species, and ground water table F value = 3.93; P = 0.02 with respect to drought species.

Significance for nature conservation

The only measures that will raise the floristic richness of agriculturally used grasslands are reduction of the nitrogen supply and – mainly at low levels of nitrogen supply – prevention of peat mud dressing. At a lower nitrogen supply the number of species and the number of quality-indicating species were always higher. Roughly stated: with every decrease of 100 kg N ha^{-1} yr^{-1} on average about 2-3 species were gained, 2 of which are quality-indicating species. Reducing the nitrogen gift thus appears to offer some conservational advantages, even when reductions are small. The nature-value index, on the contrary, only was higher when the nitrogen gift dropped below 200 kg ha^{-1} yr^{-1}. In fact, the profits of a lower nitrogen supply are rather limited if the N-supply stays above 200 kg N ha^{-1} yr^{-1}, because most species occurring more at that dose are common species that are not endangered at all.

To increase the conservational value, an even greater reduction of the nitrogen application might be necessary. The management on most fields intensified in recent decades. We selected fields with a management that had been managed in a more or less constant way for 5-10 years, and expected that this time is long enough for the vegetation to adapt (see for instance the rapid adaptations of the vegetation in the study of Ennik (1965)). However, it may take more than 5-10 years for the vegetation to adjust (van den Bergh, 1979; van Duuren et al., 1981). As a consequence, the species richness of these fields with intensified exploitation might decrease further in the future; the nitrogen gift allowed in order to obtain grassland vegetations with conservational value may turn out to be lower than 200 kg N ha^{-1}

yr^{-1}. This is not very far from the common opinion that a level less than 50-100 kg N ha^{-1} yr^{-1} is needed.

This implies that the conservational profits of moderate extensification are limited. A more extreme extensification by reducing the N-supply to levels at least below 200 and possibly even below 100 kg N ha^{-1} yr^{-1}, on the other hand, seems to be not feasible in current agricultural practice. Therefore, the chance to restore floristically rich grasslands in an agricultural context is low. Other perspectives, however, may exist for endangered grassland species in the peat districts. From preliminary surveys it appeared that many plant species that disappeared from the fields are still present along the ditch sides. We expect much higher conservational benefits of a proper management of ditch banks than of moderate extensification of the grassland exploitation, while the agricultural disadvantages are much lower.

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References

Anonymous, 1982. Soil map of The Netherlands. Scale 1:50000. Soil Survey Institute, Wageningen.

Bergh, J. P. van den, 1979. Changes in the composition of mixed populations of grassland species. In: M. J. A. Werger (Ed.), The study of vegetation, p. 59-80. Junk, The Hague.

Boer, Th. A. de, 1965. Grouping of regions on the basis of grassland vegetation. *Netherlands Journal of Agricultural Science* 13: 207-211.

Boer, Th. A. de, 1982. The use of peat soils for grassland. In: H. de Bakker & M. W. van den Berg (Eds). Proceedings Symposium on peat lands below sea level, p. 214-221. ILRI, Wageningen.

Burg, P. F. J. van, M. L. 't Hart & H. Thomas, 1980. Nitrogen and grassland. Past and present situation in the Netherlands. In: W. H. Prins & G. H. Arnolds (Eds), The role of nitrogen in intensive grassland production, p. 15-33. Pudoc, Wageningen.

Bijlsma, S., 1982. Geology of the Holocene in the western part of The Netherlands. In: H. de Bakker & M. W. van den Berg (Eds). Proceedings Symposium on peat lands below sea level, p. 11-30. ILRI, Wageningen.

Duuren, L. van, J. P. Bakker & L. F. M. Fresco, 1981. From intensively agriculture practices to haymaking without fertilization. *Vegetatio* 47: 241-258.

Elberse, W. Th., J. P. van den Berg & J. G. P. Dirven, 1983. Effects of use and mineral supply on the botanical composition on heavy-clay soil. *Netherlands Journal of Agricultural Science* 31: 63-88.

Ennik, G. C., 1965. The influence of management and nitrogen application on the botanical composition of grassland. *Netherlands Journal of Agricultural Science* 13: 222-237.

Grime, J. P., 1979. Plant strategies and vegetation processes. Wiley, London, 222 pp.

Grootjans, A. P., 1985. Changes of groundwater regime in wet meadows. Doctoral Thesis, Department of Plant Ecology, University of Groningen, 146 pp.

Heddle, R. G., 1967. Long-term effects of fertilizers on herbage production. I. Yields and botanical composition. *Journal of Agricultural Science* (Cambridge) 69: 425-431.

Klapp, E., 1971. Wiesen und Weiden. Eine Grunlandlehre. Paul Parey, Berlin/Hamburg, 628 pp.

Kruijne, A. A., 1964. The number of species in grassland. Jaarboek IBS, Meded. 253, p. 167-175. Centre for Agrobiological Research, Wageningen.

Kruijne, A. A., D. M. de Vries & H. Mooi, 1967. Bijdrage tot de oecologie van de Nederlandse grasplanten. *Agricultural Research Reports* 696: 1-65. Pudoc, Wageningen.

Lantinga, E. A., J. A. Keuning, J. Groenwold & P. J. A. G. Deenen, 1987. Distribution of excreted nitrogen by grazing cattle and its effects on sward quality, herbage production and utilization. In: H. G. van der Meer et al. (Eds). Animal manure on grassland and fodder crops. Fertilizer or waste?, p. 103-117, Martinus Nijhoff, Dordrecht.

Linden, H. van der, 1982. History of the reclamation of the western fenlands and of the organizations to keep them drained. In: H. de Bakker & M. W. van den Berg (Eds). Proceedings Symposium on peat lands below sea level, p. 42-73. ILRI, Wageningen.

Londo, G., 1976. The decimal cover scale for relevés of permanent quadrats. *Vegetatio* 33: 61-64.

Margules, C. & M. B. Usher, 1981. Criteria used in assessing wildlife conservation potential: a review. *Biological Conservation* 21: 79-109.

Nie, N. H., C. Hadlai Hull, J. G. Henskins, K. Steinbrenner & D. H. Brent, 1975. Statistical package for social sciences. McGraw-Hill, New York, 675 pp.

Oomes, M. J. M. & H. Mooi, 1981. The effect of cutting and fertilizing on the floristic composition and production of an *Arrhenatherion elatioris* grassland. *Vegetatio* 47: 233-239.

Pelser, L., 1984. Handbook for Dairy Farming. Research and Advisory Institute for Cattle, Sheep and Horse Husbandry, Lelystad, Netherlands (in Dutch).

Silvertown, J., 1980. The dynamics of a grassland ecosystem: botanical equilibrium in the Park Grass Experiment. *Journal of Applied Ecology* 17: 491-504.

Sokal, R. R. & F. J. Rohlf, 1981. Biometry. Freeman & Co., New York, 857 pp.

Strien, A. J. van & Th. C. P. Melman, 1987. Effects of drainage on the botanical richness of peat grassland. *Netherlands Journal of Agricultural Science* 35: 103-111.

Strien, A. J. van. Dairy farming and vegetation management. Doctoral Thesis, Department of Environmental Biology, University of Leiden (in prep.).