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CHANGES OF GROUND WATER REGIME IN WET MEADOWS

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SUMMARY

Statistical analysis of ground water table measurements showed that significant differences could be assessed in ground water regimes of the following plant communities: *Caricetum gracilis typicum*, *Caricetum curto-echinatae typicum*, *Cirsio-Molinietum peucedanetosum* and *Senecioni-Brometum racemosi caricetosum nigrae*.
Drainage induced changes in a *Cirsio-Molinietum* vegetation, were studied during 12 years. The results were compared with changes in the ground water regime. Measurements of the ground water table during a five year period, preceding an interference in hydrology, were compared with measurements of a succeeding seven year period.

Significant differences were obtained in median and mean ground water levels, not in extreme values. However, the vegetation responded to extreme ground water levels quite clearly. Therefore it is concluded that semi-natural vegetation can be sensitive to changes in ground water levels that can hardly be proved. It is suggested not to concentrate on mere conditional relationships in field studies, but to consider positional relationships as well.

1. INTRODUCTION

In vegetation science much attention has been paid to the water relations of wet meadows belonging to the *Molinio-Arrhenatheretea*. There is little doubt that the economic significance of these meadows raised the interest of many scientists. Since the productivity of these meadows can be increased considerably by draining and subsequent manuring, various methods have been developed to evaluate suitability for agricultural amelioration (KRAUSE & BALÁTOVÁ-TULÁČKOVÁ 1977). Two main approaches can be recognized:

- The mapping of vegetation according to wetness characteristics (BUNDESANSTALT FÜR VEGETATIONSKARTIERUNG 1961);
- The application of indicator species; for moisture, pH, nitrogen status etc. by giving each species present in the vegetation a numerical value for each evaluated factor (ELLENBERG 1974, LONDO 1975, KRUIJNE et al.).

In agricultural amelioration projects both approaches can be applied rather successfully (MEISEL 1968, TÜXEN 1954). However, in these methods wetness characteristics are only roughly specified. For detailed analysis of the relation between vegetation and hydrological factors regular measurements of the ground water table are necessary (TÜXEN 1954, NIEMANN 1963, 1973, BALÁTOVÁ-TULÁČKOVÁ 1968, ZARZYKI 1958 e.a.). Relatively few authors concentrated on

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this problem (cf. TÜXEN 1961, TÜXEN & GROOTJANS 1978). NIEMANN (1973) (using over 600 waterlevel gauges), correlated patterns of ground water fluctuations from several years with plant communities (see also TÜXEN 1954). He was able to characterize the ground water regime of many plant communities and after statistical analysis of variance specified which hydrological parameters were best correlated with plant species composition (see also AARNINK 1969, KLÖTZLI 1969, PFROGNER 1973, KEMMERS 1979).

Nowadays wet meadows have become rare in most parts of Western Europe. They have been changed into highly productive pastures, poor in species. Remnants of old types of meadows are under protection as nature reserves. Here the aim is the preservation of species diversity instead of increasing productivity. However, as a result of land improvements in the surrounding area many reserves are influenced by changes in water management (GROOTJANS 1975, VAN DEN MUNCKHOF 1974). Still more interferences in hydrology are to be expected for instance in connection with drinking water supply.

Plant ecologists have been asked to evaluate the sensitivity of vegetation with respect to changes in ground water regimes (SCHUURMANS & SCHUURMANS 1974, VAN DAM et al. 1976, BOTH & VAN WIRDUM 1979). In order to establish this sensitivity it was necessary to trace the relationship between plant communities and ground water regime, as accurate as possible. Methods used in agricultural improvement schemes are not suitable for application in semi-natural vegetations which have a conservation destination. In most studies on ground water relations of semi-natural vegetation in The Netherlands only very rough relationships have been established. The results do not justify the predicitions concerning the sensitivity with respect to changes in ground water regime in nature reserves (VAN GIJSEN 1979, see also LONDO 1977).

The aim of this study is first to present a detailed picture of the correlations between some quantitative aspects of ground water regimes and the occurrence of some plant communities in wet meadows. Next the results will be compared with the observed response of a *Cirsio-Molinietum* vegetation to drainage.

2. METHODS

Ground water table measurements during at least 12 months were gathered from the literature and from unpublished studies in the Netherlands (*table 1*). Plant communities to be discussed are the *Caricetum gracilis* (Graebn. et Hueck 1931) Tx. 1937 *typicum*, (= *Caricetum acuto-vesicariae* (W. Koch 1926, Westhoff 1949), the *Caricetum curto-echinatae* (Vl. 1937) *typicum*, the *Cirsio-Molinietum* (Siss. et de Vries 1942) *peucedanetosum* and the *Senecioni-Brometum racemosi* (Tx. et Prsg. 1951) *caricetosum nigrae*. The communities occur on peat – loam – sandy soils.

Ground water data of the *Cirsio-Molinietum* subassociation are from balanced nature reserves which have not been affected by drainage. Data of the following reserves have been used:

(i) "De Reitma" near Elp (Dr.) (1967-1970)
(ii) "Stelkampsveld" near Laren (Gld.) (1977, 1978)
(iii) Litter fens along some Frisian lakes (1979).

The data of the *Caricetum gracilis*, the *Caricetum curto-echinatae* and the *Senecioni-Brometum racemosi*, used in this study have been given in GROOTJANS (1980). Observations of the water level were done at least once a month, more often however, once a week. All ground water fluctuation data presented by the authors mentioned in *table 1*, have been transformed to cumulative frequency diagrams ("duration lines"). A duration line represents an approximation of the period, in days, that a certain ground water level is exceeded. In vegetation ecology this is thought to be a critical characterization of the ground water regime in wet places, as it appears to be correlated with the rate of important ecological processes, such as aeration of the soil, mineralisation of organic substances and supply of phosphorus to plant roots (NIEMANN 1973, KLÖTZLI 1969, KEMMERS & JANSEN 1979, ANDERSON 1970).

In order to characterize the ground water regime of vegetation types duration lines of closely related stands have been constructed by calculating the mean values of a bundle. NIEMANN (1973) points to the ratio of mathematical mean ($\bar{x}$) and median (M) of the ground water data distribution. If $\bar{x}/M > 1$, then higher ground water levels are more frequent than lower ones and the duration line has a convex shape. Convex shaped duration lines are associated with continuous supply of ground water by a regional base flow, especially during the winter and early spring. Concave shaped duration lines, with $\bar{x}/M < 1$ are associated with infiltration of water in the wet seasons, followed by rapid decreasing levels, until a regional base flow level has been reached. Neither convex- nor concave shaped duration lines, with $\bar{x}/M \pm 1$, often point to decreased supply of base flow water. A combination of convex- and concave-, so called sigmoid shaped duration lines can also be found. This points to the influence of superficial drainage (see also KEMMERS & JANSEN 1979). The index $\bar{x}/M$ has been calculated for each duration line, so all communities studied in this paper have been characterized by this ratio.

Table 1. References of ground water fluctuation diagrams that that have been used in the statistical analysis.

Community	Authors and country	no. of duration lines
Caricetum gracilis typicum	BALÁTOVÁ-TULÁČKOVÁ (1965, 1969), ČSSR; BLAŽKOVÁ (1973), ČSSR; GROOTJANS (1977), N.L.; WIEDENROTH (1971) B.R.D.; ZARZYCKI (1958), Polska.	12
Caricetum curto-echinatae typicum	GROOTJANS (unpubl.) N. L.; HOSPER (1980), N. L.; KOENE & VEERMAN (1978), N. L.; BOEDELTJE (1976) N. L.; ZARZYCKI (1958), Polska.	8
Cirsio-Molinietum peucedanetosum	GROOTJANS et al. 1979, N. L.; HOSPER (1980), N.L. and unpublished data from N.L.	12
Senecioni-Brometum racemosi caricetosum nigra	GROEN & RINGENALDUS (1980), N. L.; GROOTJANS (1977) N. L.; KNAUER (1972) B. R. D.	17

Statistical analysis of duration line bundles follows NIEMANN (1973). To test whether or not the two bundles are centred differently, the Wilcoxon-Mann-Whitney test has been used. The W test is a very sensitive test for small independant random samples (SACHS 1968). All available data were used, not merely the extreme duration lines.

Actually observed changes in a *Cirsio-Molinietum* stand, as mentioned in the introduction, have been studied in the Nature Reserve "De Reitma" in permanent plots (1.5 × 1.5 m) in the period between 1967–1979, using the Braun-Blanquet approach. The nomenclature of the Phanerogams follows HEUKELS & VAN OOSTSTROOM (1977).

3. RESULTS

3.1. Characterization of ground water regimes

The duration line bundles of the 4 plant communities have been compared two by two. The results of the statistical analysis have been depicted in *fig. 1–6* and in *fig. 1A–6A*. The level of significance has been indicated at 4–6 intervals.

Caricetum gracilis typ. / Caricetum curto-echinatae typ.
(fig. 1/1A)

The *Carex acuta* dominated *Caricetum gracilis typicum* differs from the *Carex nigra* dominated *Caricetum curto-echinatae typicum* mainly in the maxium levels, not in the duration of flooding, which is c. 5 months in average in both communities (*fig. 7*). There appears to be no significant difference in the lowest levels, although the mean lowest level in the *Caricetum curto-echinatae* is almost 20 cm higher than in the *Caricetum gracilis* (*fig. 7*).

In both communities the characteristic duration lines are convex (*fig. 7*) the ratio $\bar{x}/M$ being over 1 (*table 2*). This points to the influence of a regional base flow. possibly supported by water supply by a discharging local subsurface flow.

Caricetum gracilis typ. / Cirsio - Molinietum peuc.
(fig. 2/2A)

Ground water levels of the *Carex panicea* dominated *Cirsio-Molinietum peucedanetosum* differ significantly from the *Caricetum gracilis typicum* in almost all highest and intermediate levels, not in lowest levels. The duration of flooding differs also, being an average of five and two months, respectively (*fig. 7*). The communities have duration lines that are shaped almost indentical. The index $\bar{x}/M$ of *Caricetum gracilis* is slightly higher (1.5 versus 1.3).

Caricetum gracilis typ. / Senecioni-Brometum rac. car. nigrae
(fig. 3/3A).

The differences in duration lines between these two vegetation types are considerable. Highest and intermediate levels differ significantly. The lowest levels, however, do not. In contrast to the *Caricetum gracilis* the characteristic duration ine of the *Senecioni-Brometum* is not clearly convex-shaped (*fig. 7*). The index $\bar{x}/M$ of the Senecioni-Brometum, 1.1, is only slightly more than 1 (*table*

Table 2. Median- (M) and mean ($\bar{x}$) ground water levels of four types of wet meadows.

	M	$\bar{x}$	$\bar{x}$/M
Caricetum gracilis typicum	− 3.5	− 5.4	1.5
Caricetum curto-echinatae typicum	− 2.6	− 6.8	2.6
Cirsio-Molinietum peucedanetosum	−13	−17.4	1.3
Senecioni-Brometum racemosi car. nigrae	−20.9	−19	1.1

2), while $\bar{x}$/M of the *Caricetum gracilis* is 1.5. This points to influence of superficial drainage. The relatively low maximum levels and the relatively high minimum levels indicate that especially highest levels are influenced by drainage. The high lowest levels point to the presence of a strong base flow. Furthermore, the duration of floodings in the *Caricetum gracilis* stands is much longer than in the *Senecioni-Brometum*. High levels in the latter are maintained only one month in average, while in the sedge community the floodings last for an average of 5 months.

Caricetum curto-echinatae typ. / Cirsio-Molinietum peuc.
(fig. 4/4A)
Significant differences in duration lines of these two communities can only be assessed in the period where the levels are below soil surface. Both types have convex shaped duration lines. There appear to be some differences in duration of high levels close to the surface, which are more persistent in the *Caricetum curto-echinatae* (*fig. 4A*).

Caricetum curto-echinatae typ. / Senecioni-Brometum racemosi car. nigrae
(fig. 5/5A)
Striking differences are found in the highest and intermediate levels. Differences are also clearly expressed in the median ground water levels (*fig. 7*). Lowest levels however, are slightly different. The duration of high levels close to the surface is much longer in the sedge community (*fig. 5A*).

Circio-Molinietum peuc./Senecio-Brometum rac. car. nigrae
(fig. 6/6A).
The differences in ground water levels between the two vegetation types are most pronounced in the levels close to the surface. The original ground water fluctuation pattern shows that in contrast to the *Senecioni-Brometum racemosi* the ground water levels in the *Cirsio-Molinietum* are much closer to the surface in spring and early summer. The duration of high levels is consequently longer in the *Cirsio-Molinietum* as is shown in *fig. 6A*. With respect to most other levels no significant differences could be assessed.

3.2. Changes in vegetation and ground water regime

In this paper changes in the groundwater regime and vegetation of the reserve

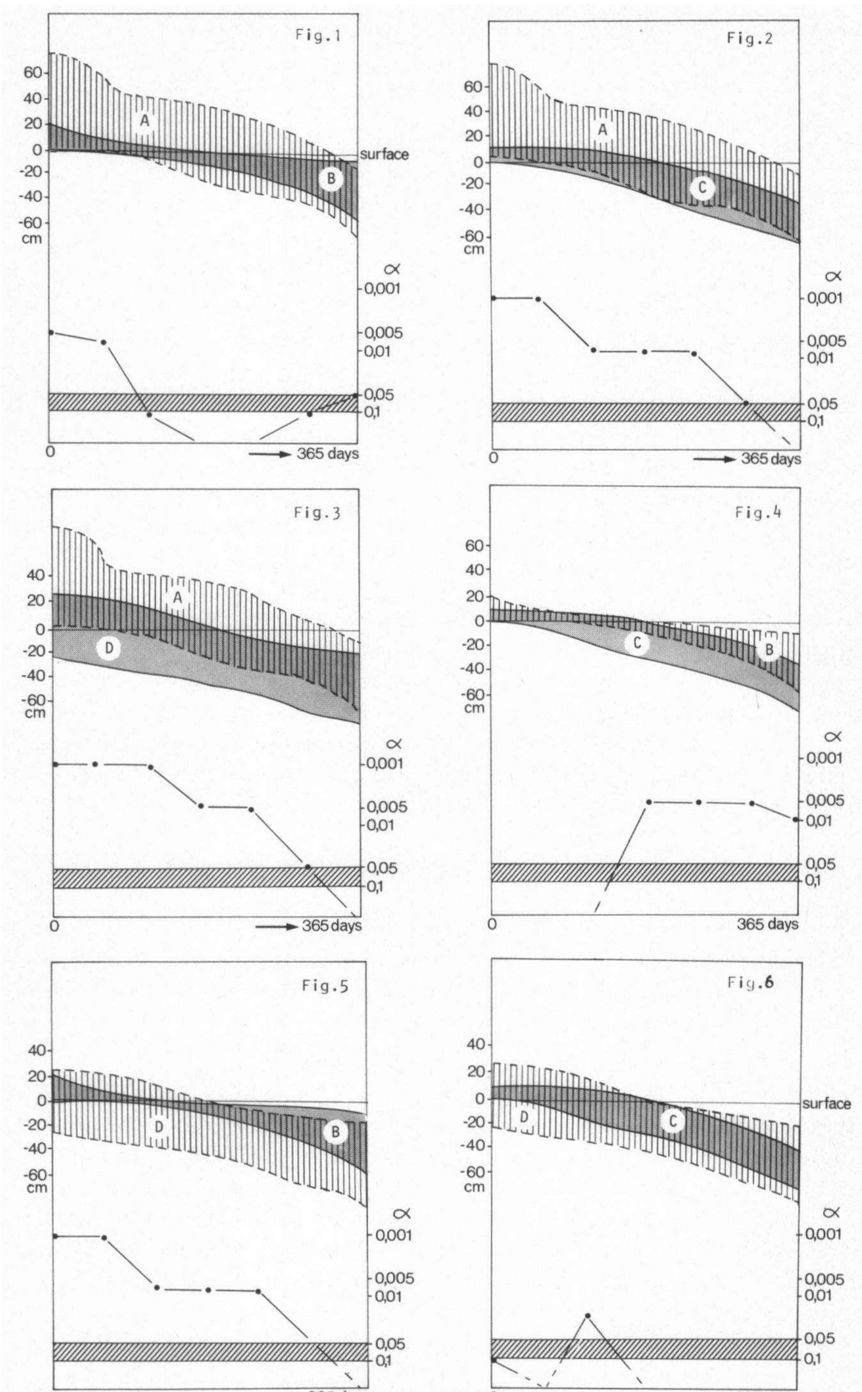

Fig. 1–6. Comparison of duration line bundles of four types of wet meadow vegetation. Results of the statistical analysis (abscissa) are indicated underneath in each figure.
A = *Caricetum gracilis typicum;* B = *Caricetum curto-echinatae typicum;* C = *Cirsio-Molinietum peucedanetosum;* D = *Senecio-Brometum racemosi caricetosum nigrae;*

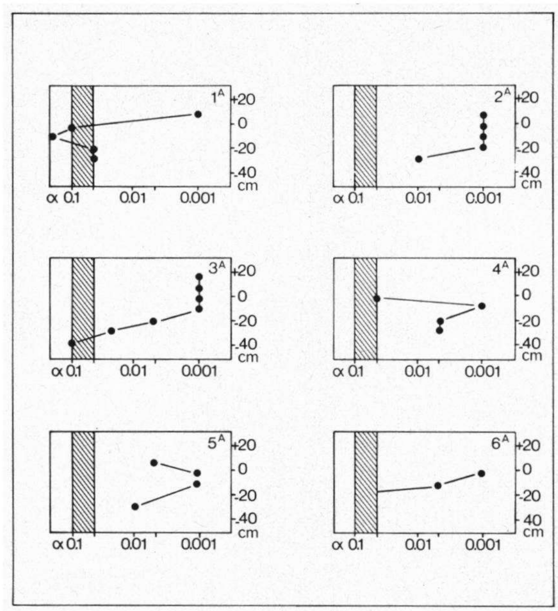

Fig. 1a–6a. Comparison of duration line bundles of four types of wet meadow vegetation: results of the statistical analysis (ordinate).

"De Reitma" are presented. This vegetation, belonging to the *Cirsio-Molinietum peucedanetosum* has been affected by drainage, especially since 1971 (Grootjans et al. 1979, Romeyn 1980). The beginning of a relatively dry period, lasting almost 6 years is also marked by 1971. Especially 1975 and even more so 1976 were extremely dry (Prov. Waterstaat Drenthe 1977). A further analysis of artificial versus climate induced drainage will not be given here.

3.2.1. Changes in the vegetation (*table 3*).

The Cirsio-Molinietum vegetation has been studied in two permanent plots during ten years. The results of observations in one plot are shown in *table 3*. Since 1971, characteristic species of the *Cirsio-Molinietum* viz. *Carex pulicaris*, *Carex hostiana* (a.o.) disappeared or declined in cover. There is also a marked decline in cover of the moss layer.

Not shown in this permanent plot is the pronounced decline of some moss species, e.g. *Calliergonella cuspidata* and species of the *Parnassio-Caricetum pulicaris*, viz. *Carex dioica* and *Parnassia palustris*, mainly present in the Reserve until 1973. Species belonging to the *Caricetum curto-echinatae* viz. *Hydrocotyle vulgaris*, *Mentha aquatica* and *Valeriana dioica* also decreased, while *Festuca ovina* and locally *Molinia coerulea*, *Holcus lanatus*, *Succisa pratensis*, *Anthoxanthum odoratum* and *Rhytidiadelphus squarrosus* increased considerably in numbers. After some very dry seasons, especially in 1976, *Ranunculus flammula*, *Agrostis canina* and locally *Mentha arvensis* and *Holcus lanatus*

Table 3. Response of a *Cirsio-Molinietum* vegetation after drainage, studied in a permanent plot during 12 years. Corresponding ground water data are depicted in *fig. 8*.

	1966	1967	1969	1970	1971	1972	1973	1975	1976	1977	1978	1979
Date	15–7	3–7	2–7	23–6	14–6	3–7	18–6	27–6	14–7	7–7	14–7	2–7
Total cover (%)	100	100	90	95	100	100	95	95	85	90	100	100
Herbs and grasses	80	90	90	95	95	95	95	95	85	90	100	100
Mosses	75	60	60	50	75	?	40	1	1	1	1	1
Carex panicea	4.3	3.3	4.3	3.3.	3.3	3.4	2a.2	2b.3	2b.3	2a.2–3	2b.1–2	2b.3
Carex hostiana	3.4	3.3.	3.3	2b.3	2b.3	2b.3	2a.2	2b.3	2b.3	2a.2	+.1	+.2
Carex pulicaris	1.1–2	1.1–2	1.1	1.1	1.1	1.1	+.1	+.1				
Carex demissa						r.1						
Salix repens	+.2	+.2	+.2	+.2	+.2		r.1					
Succisa pratensis	+.2	2a.2	+.2	+.2	r.2	r.2	r.2					
Valeriana dioica	+.2	+.2	2a.2	2a.2	2a.2	+.2	2a.2	+.1				
Sieglingia decumbens	+.2	2a.2	+.2	+.2		+.2				+.2	+.2	
Molinia caerulea	2a.2	2a.2	+.2	2a.2	2b.2	2b.3	3.4	3.3	2b.3	3.3	3.3	2b.3
Festuca ovina						+.1	+.1	+.1	2a.2	+.2		
Hydrocotylé vulgaris	2.a1	2a.1	2a.1	2a.1	2b.3							
Mentha aquatica	+.1	+.1	+.1	+.1	+.1	+.1					+.1	
Carex nigra	1.1	+.1–2			+.1		+.1			+.2		
Potentilla palustris	+.2	+.2	+.2	+.2	+.2		+.2	+.2	+.2	+.2	+.2	+.2
Viola palustris			+.1		+.1	+.1	r.1		+.1			
Agrostis canina			+.1	+.1	+.1	+.1	+.1	2a.2	2a.2	+.2	+.1	1.1
Ranunculus flammula	+.1	+.1	+.2	+.2	+.1	+.1	+.1	+.1	2a.2	2a.2	2b.2	2b.3
Galium palustre	+.1	+.1	+.1	+.1	1.1		+.1	+.1		+.2	2a.2	2a.2
Cardamine pratense	+.1	+.1	+.1	1.2	+.1	+.1	+.1	+.1	+.1	+.1	2a.2	2a.3
Holcus lanatus		+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	2a.2	+.2	
Anthoxanthum odoratum		+.1	+.1	+.1	+.1	+.1	+.1	+.1	+.1	2a.2	+.2	+.1
Filipendula ulmaria	+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2
Ranunculus acris	×.1	+.1					+.1		+.1	+.2		+.2
Festuca rubra	1.1	1.1		+.1	1.1	+.1	+.1		+.1	+.1		+.1
Galium uliginosum	+.1	+.1	+.1	+.1	+.1	+.1	+.1	r.1	+.1	+.2		+.2
Equisetum palustre	+.1		+.1	+.1								
Cirsium palustre			+.2		+.2		+.2			r.2		
Lythrum salicaria		+.3										
Salix cinerea	r.2	+.2	+.2	+.2	r.2	r.2						
Eriophorum angustifolium	+.1											+.1
Mentha arvensis												+.1

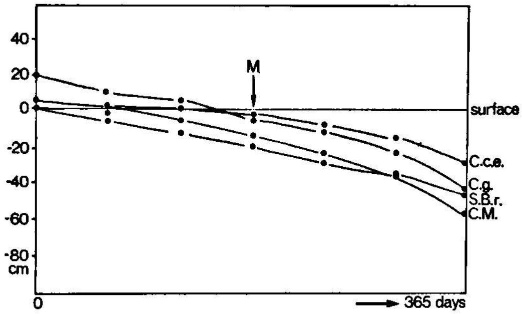

Fig. 7. Characteristic duration lines of four plant communities.
C.g. = *Caricetum gracilis typicum;* C.c.e. = *Caricetum curto-echinatae typicum;* C.M. = *Cirsio-Molinietum peucedanetosum;* S.B.r. = *Senecio-Brometum racemosi caricetosum nigrae.*

increased. In 1977, after spring inundations, the vegetation died off locally, giving rise to even greater spread of *Ranunculus flammula*, *Galium palustre* (locally), *Cardamine pratensis* and *Plantago lanceolata*. After winter and spring inundations in 1978 and 1979 *Festuca ovina*, *Holcus lanatus* and *Plantago lanceolata* disappeared again. There was a slight recovery of growth of *Carex panicea*.

In general most characteristic and most rare species disappeared, although in the beginning the existing fine grained pattern of the vegetation was preserved. Until 1975 the changes in the vegetation were more or less gradual. Then after very dry summers followed by inundations, the changes became more dramatic and lead to a course grained pattern of the vegetation. Some species like *Ranunculus flammula*, *Galium palustre*, *Molinia coerulea*, *Agrostis canina* and *Carex panicea* formed large patches that created distinct boundaries in the vegetation

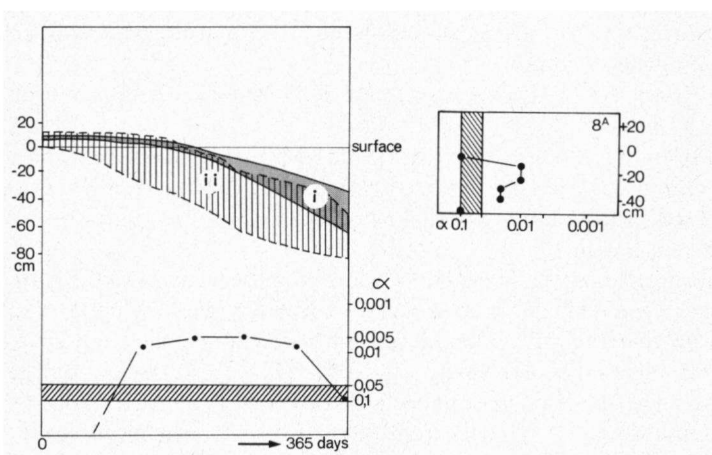

Fig. 8. Comparison of duration lines obtained from measurements in a five year period (i), preceding an interference in hydrology, with duration lines obtained in a seven year period afterwards (ii). Results of the statistical analysis are also depicted.

(cf. VAN LEEUWEN 1966). Heavy rainfall in 1979 made some species of dry habitats disappear again. Species of wet habitats locally reappeared, most of them are characteristic of the *Parvocaricetea*. However, the rare and faithful species did not show up again.

3.2. Changes in ground water regime

Observations of the ground water table in "De Reitma", before 1971 have been grouped into a duration line bundle. Observations after 1971 have been grouped likewise in a separate bundle (*fig. 8*). Statistical analysis revealed that the two bundles differ significantly in most intermediate levels, not in highest or lowest levels. These differences are well expressed in the median ground water levels. After 1971 most duration lines are sigmoid- instead of convex-shaped, indicating that the supply of seepage water was low in summer. The duration line of 1976 is even concave-shaped, which is typical for infiltration sites. The change towards sigmoid-shaped duration lines is also reflected in the decreasing values of $\bar{x}/M$ since 1971, which approaximate 1, or become less than 1 (1976).

4. DISCUSSION

In order to generalize statements on the relation between vegetation and hydrology, a number of conditions must be fulfilled (cf. NIEMANN (1973):

- The stands studied must be clearly characterized, so a large data set of relevés and accompanying ground water observations must be available. Classification below the level of subassociation is recommended.
- All observations of the ground water table, must be included in the analysis of the ground water regime. In vegetation with major ground water influences, the annual course of the ground water table seems to be an appropriate parameter. However, extreme values must not be neglected.
- The area under study must be situated in a climatologically and pedologically homogeneous region.

In our study the conditions mentioned by NIEMANN (1973) have been fulfilled as much as possible.

- Althought classification occurred on the subassociation level, the communities are characterized rather well. A large number of relevés have been used in the classification. The number of ground water observation sites however is much less.

Duration lines were based on 12 or more observations of the water level each year. Some extreme wet and dry years have been included. Except for the *Cirsio-Molinietum peucedanetosum*, all lower limits represent observations of 1976 which was an extremely dry year. The communities studied tended to change towards drier variants (cf. GROOTJANS 1977). The upper limit of the *Caricetum gracilis typicum* represents an extremely wet year. Here the vegetation tended to change towards a *Caricetum ripariae* (BALÁTOVÁ-TULÁCKOVÁ 1968). The upper limit of the *Cirsio-Molinietum* subassociation represents a very wet year (1968).

- Pedological variation, however, is considerable, the stands were found on peat – loam – sandy soils. Clay grounds have been excluded from analysis.
- Not fulfilled is the condition concerning climatological regions, which can lead to misinterpretations of the results. This applies to the *Caricetum gracilis* community in particular since most of the data originate from the ČSSR. In the Netherlands overall ground water levels can be expected to be slightly lower, due to climatological differences (NIEMANN 1973).

The results of this study show that the 4 types of meadow have more or less convex duration lines in common, indicating influences of local discharging subsurface- or regional base flow water. Significant differences can be assessed in high, intermediate and low levels, as well as in the duration of flooding.

The *Caricetum gracilis typicum* is characterized by high winter floodings. The levels are at or above the surface during 4–5 months. Due to the high inundations of stream water, silt is deposited in the meadows (ELLENBERG 1978). Overall ground water levels are high. Characteristic duration lines are convex-shaped.

The *Caricetum curto-echinatae typicum* is characterized by prolonged high levels, very close to the surface. No silt is deposited in this community, for the subsurface- and base flow water, responsible for the inundations, is very poor in silt. Summer levels are high. The duration lines are distinctly convex.

The *Senecioni-Brometum racemosi caricetosum nigrae* is characterized by relatively low winter levels. Summer levels are relatively high but median- and mean ground water levels are similar. It seems likely that this community is characterized by modest drainage. This is in contrast to the *Cirsio-Molinietum peucedanetosum*, where high levels are close to the surface until early summer. Compared to the *Caricetum curto-echinatae* and *Senecioni-Brometum* this *Cirsio-Molinietum* subassociation is intermediate with respect to median- and mean ground water levels, as well as the duration of levels close to the surface. Not intermediate are lowest levels; however, differences proved to be not significant.

Mean ground water levels (5–32 cm) of the *Cirsio-Molinietum* stands were in good agreement with values presented by BINK (1978); ($\bar{x} = 10$–35). This author stated that mean lowest levels of *Cirsio-Molinietum* communities on peat grounds should not exceed -40 cm. The oxidized zone should not exceed 30 cm. In our study the mean lowest level was found to be -53 cm.

As a result of both artificial and climate induced drainage, characteristic species in a *Cirsio-Molinietum* vegetation decreased more or less gradual. These changes corresponded with changes from convex towards sigmoid-shaped duration lines, indicating decreased water supply in spring and summer. Significant differences were found in intermediate ground water levels and levels close to the surface.

The analysis leads to assessment of rather detailed characterization of ground water regimes, however, it appears to be unfit to predict changes in the vegetation, not even if one single Nature Reserve is studied. Possibly this ground water level analysis needs further development, for it may not be sensitive enough to detect changes in ground water levels that are small from a hydrological –, but large from an ecological point of view. It should be noted however, that if the measurements of the ground water level would have been more frequent also better results might have been obtained. Moreover BOTH (1979), VAN WIRDUM (1979a, b) and BOTH & VAN WIRDUM (1979) have pointed out that different ways in which the ground water regime affects vegetation should be distinguished in sensitivity analysis. Thus there is an operational relationship if vegetation responds to water supply in a physiological sense. The corresponding hydrological analysis concerns soil physical data, meteorological conditions and ground water levels, ending up with the water flux in the rooted zone during the growing season. A conditional relationship exists if other important fluxes (e.g. nutrients, heat) through the rooted soil zone are changed by an altered hydrological regime. It is important to draw attention to the fact that after a change in hydrology, resulting in a slightly lowered duration line, chemical responses of the soil are evident in enriched soils, when water supply to plants cannot yet be hampered. In organic and clay soils, however, coupling of operational and conditional aspects of water supply exist if the physical soil structure has been changed. In the Nature Reserve "De Reitma" for instance, irreversible drying of the top peat layer had occurred, influencing both water fluxes in the rooted zone and availablility of nutrients such as phosphates and nitrogen (WILLIAMS 1968). A positional relationship may be at work even if no significant differences in local quantitative hydrological data are found. Positionally, the hydrological regime of a neighbouring area can determine the solute composition of water passing the local rooted zone. This is in particular the case if changes in the regional hydrological system divert lateral ground water flow or drastically diminish the average retention time of ground water. In many areas of the Netherlands, for instance, base flow water has been partially replaced by Rhine water. On a more local scale, regional base flow water has been replaced by infiltrating rainwater (cf. GROOTJANS 1980). In those cases vegetation is operationally sensitive to water quality. Again coupling with conditional and operational aspects of water supply exists. Analysis of ground water levels as such is obviously a part of the study of changed ground water regimes, but it is far from always the causal item to be studied from the point of view of vegetation ecology (cf. BLEUTEN 1979).

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