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Potential For Vegetation Regeneration In The Middle Course Of The Drentsche A Brook Valley (The Netherlands)

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Synopsis

Possibilities for nature development, especially of mesotrophic marsh plant communities, in a middle course area with deep mineral-rich seepage water of a Dutch brook valley are discussed. After the cessation of fertilizer applications, grazing and hay-making are practised. Cattle hardly graze the relatively wet brook valley and in large areas well developed *Calthion palustris* communities transformed into *Carex acutiformis* tall forb communities. Relics of *Calthion palustris* communities could only maintain themselves in places where the mineral-rich groundwater rises high up in the profile. *Calthion palustris* communities developed well by hay-making in places where the mineral-rich groundwater reached the topsoil. *Juncus acutiflorus* stands developed in places where mineral-rich deep seepage water was replaced by mineral-poor superficial seepage water as a result of deep ditches. In places with desiccation *Holcus lanatus* stands developed.
It is concluded that changes in the vegetation must be seen in the light of both groundwater management and vegetation management. Possibilities for the development of endangered mesotrophic marsh plant communities can be found in the stimulation of the seepage of deep groundwater by blocking up all the ditches by filling them with the adjacent dried peat layers. The hydraulic head of more than one meter will prevent further earthening of the peat top soil in the brook valley. Then the natural potential of the area will be used maximally.

groundwater management, mesotrophic marshes, nature development, vegetation management

1. <u>Introduction</u>

Areas which vary greatly in soil type, relief and hydrology, provide interesting possibilities for nature development. The question arises as to which vegetation can be developed and what means are necessary to achieve it. This article concentrates especially on the lasting development of marsh species, in particular, those from areas which were mineral-rich but poor in nutrients, namely from mesotrophic marshes. This is an important management aim as these species are very threatened in the Netherlands. The hydrological characteristics of the middle course of a stream valley and the human interferences in the hydrological conditions are, therefore, described. Investigations were also carried out to find whether vegetation regeneration could be influenced through management with grazing and hay-making.

2. <u>Defining The Problem</u>

The brook valley reserve of the Drentsche A consists of relatively high lying sandy plateaus between which there are lower lying eroded areas filled up by peat. The average annual precipitation is 812 mm and the evaporation is 477 mm. Seventy-seven percent of the 335 mm residue precipitation goes into the drainage systems, 14 % washes away superficially and 9 % is added to the groundwater (STREEFKERK & VAN HOORN 1985).
The water which infiltrates does this in different ways. Some of it hits impervious layers of boulder clay and flows over these layers to the brook valley. As it has only been in the ground for a short

time it has little chance of picking up minerals. This shallow, mineral-poor ground water is referred to as "atmocline", because its composition is very similar to that of rainwater. The rest of the infiltrated groundwater seeps deeper into the ground and, partly due to the length of time it is in the ground, becomes enriched with Ca^{2+} and HCO_3^-. This deep groundwater stream eventually reaches the brook valley in the form of seepage water. This deep, mineral-rich groundwater is referred to as "lithocline" (SENSU VAN WIRDUM 1980).
The distribution of vegetation types along the length of a brook valley, from its source to the lower courses and perpendicular to the brook, is in relation to the groundwater table and the composition of the groundwater (Fig. 1). Deep, mineral-rich groundwater plays a predominant role in the middle course (GROOTJANS 1980).

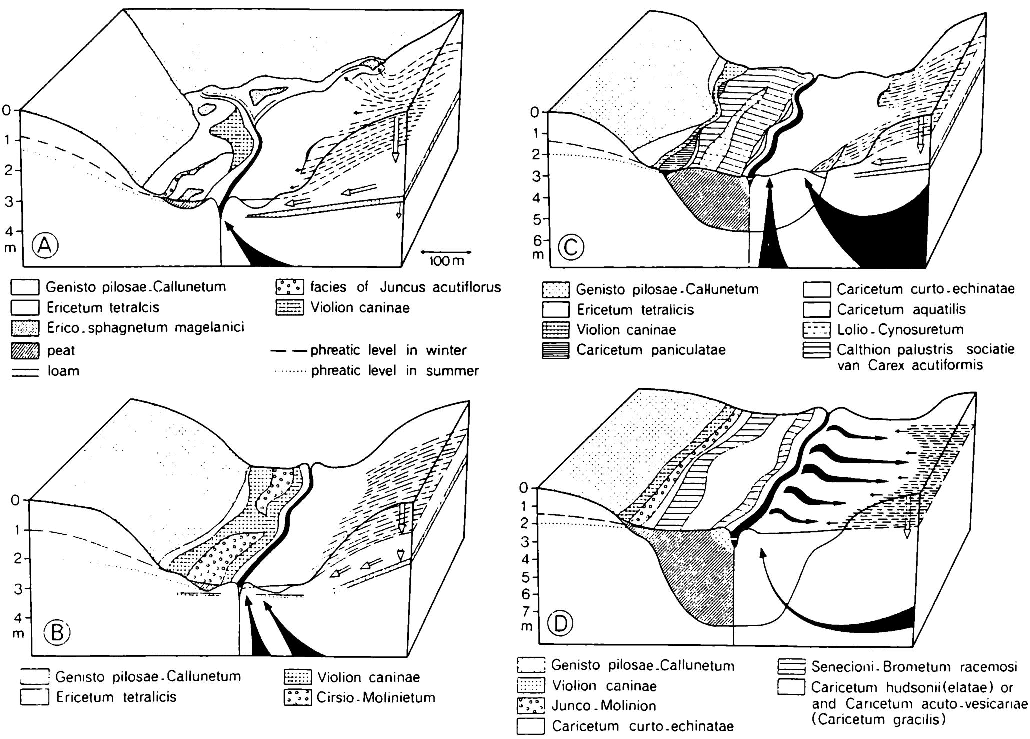

Fig. 1: Cross section of a brook valley with the occurring types of vegetation in relation to the hydrological conditions. White posts indicate shallow atmocline groundwater, black posts deep lithocline groundwater or water overflowing from the brook. The influence of atmocline groundwater prevails at the source (A) and in the upper course (B), that of lithocline groundwater in the middle course (C) and overflow water in the lower course (D) (after GROOTJANS 1980).

Land in the brook valley reserve of the Drentsche A is acquired and managed by the State Forestry Commission because of its great value in the field of nature conservation. In the Netherlands it is particularly vegetation types and plant species which are characteristic of wet, nutrient-poor conditions which are seriously endangered. The wet meadows bordering on the brook had been cut for centuries. The authorities in charge of the management, therefore, tried to continue this practice without fertilizer applications in order to maintain or to restore the characteristic plant communities.

The acreage in the brook valley reserve which is to be regenerated has continually increased, whilst the means of achieving this have not kept pace with the area needing this management. When the sandy plateau was acquired, it was decided that grazing was the best form of management, as it is much cheaper than cutting. At the time the State Forestry Commission looked on the commencement of grazing on the plateau and adjacent brook meadows, as a precarious experiment. This was because the cattle were expected to avoid the brook meadows and that the development of tall forb communities would occur. In fact an area of the brook valley, with patches of well developed *Calthion palustris* communities, was sacrificed for the sake of the experiment. Before the grazing experiment started, it was found that the groundwater tables were too low for communities of *Calthion palustris* to develop successfully in other parts of the brook meadows (KOENE & VEERMAN 1978).
The changes in the vegetation, resulting from hay-making or grazing, must then also be seen in the light of groundwater management. Two factors play a role here. The height of the groundwater influences both the cutting and grazing practices, since it determines the accessibility of the area, and the vegetation, because of the water supply. The composition of the groundwater also affects the habitat of the vegetation, as it influences acidity and the availability of nutrients. When developments in vegetation are being contemplated the place of groundwater management in relation to grazing and cutting will have to be considered.

3. The Study Area

The study area (approx. 25 ha) is situated in the middle course of the brook valley reserve of the Drentsche A at the junction of the Gasterense and Taarlose Diep between Taarlo and Oudemolen (Fig. 2).

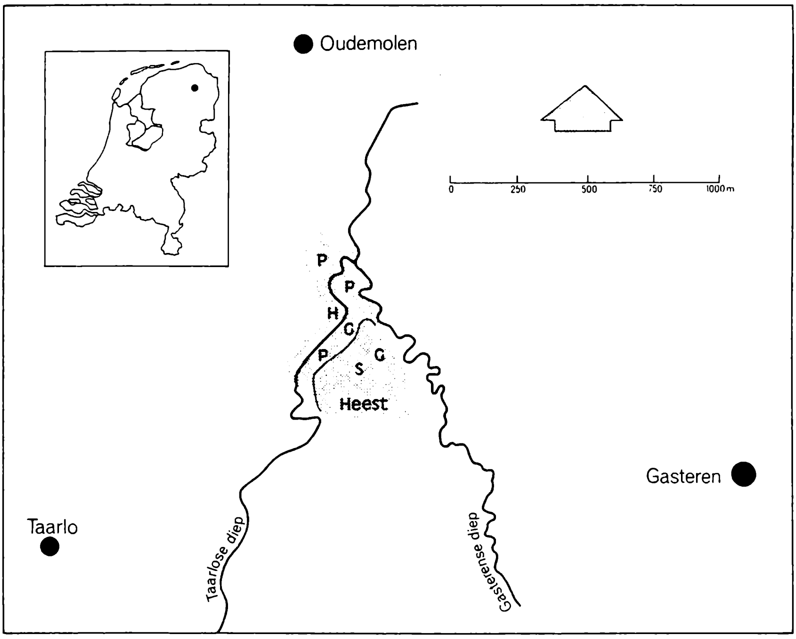

Fig. 2: The study area at the junction of the Gasterense Diep and the Taarlose Diep in the catchment area of the Drentsche A, with the adjacent valley meadows (P) and the sandy plateau in between (S). H: hay-making, G: grazing

A part of the area features wet meadows, which were acquired by the State in 1971 and have since then been grazed or cut without fertilizer applications. Another part of the area is a sandy plateau "De Heest", which up until 1976 was used by a farmer who applied fertilizers. In 1976 the whole area, including the wet meadows, started to be grazed in the summer with sheep and the tall forbs were cut locally. In 1979 the grazing was taken over by cattle (approximately 1/ha) and no more cutting took place.
There are also wet meadows to the west of the Taarlose Diep. The southern ones of these were acquired in 1967 and the northern ones in 1971. After their acquisition they were no longer fertilized but hay-making did continue.

4. Geohydrological Circumstances

On the plateau between Gasteren and the Gasterense Diep (Fig. 2) the hydraulic head, i. e. the difference in groundwater tables between the deep and shallow filters, is minus 20 cm, which shows that infiltration has taken place here (Fig. 3 A). The hydraulic head in the brook valley of the Gasterense Diep is 30 cm and it is as high as 100 cm in the Taarlose Diep brook valley (Fig. 3 B).

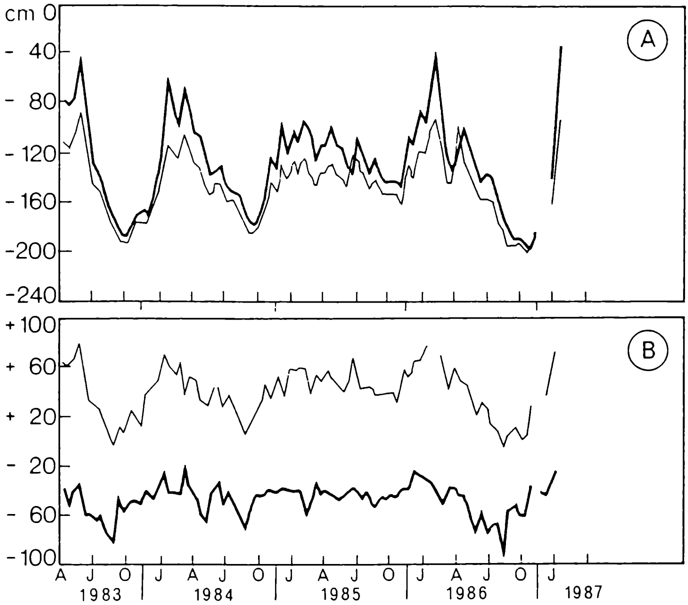

Fig. 3: Groundwater tables with respect to NAP in a high filter (solid line) and in a low filter (broken line) on the plateau between Gasteren and the Gasterense Diep (A) and the valley of the Taarlose Diep (B) (after GROOTJANS & al. 1987)

This shows that seepage occurs in the brook valleys. The brook valleys which border upon the sandy plateau "De Heest" are affected by a strong groundwater stream, which can reach the groundlevel unimpeded. This stream goes through a peat layer at least 2 m thick. There are few places in the north of the Netherlands where the seepage intensity is quite as great as here (EVERTS & DE VRIES 1991).
The composition of the groundwater confirms that deep seepage occurs of mineral-rich groundwater in the brook valley. There are, namely, high levels of Ca^{2+} and HCO_3^- (Fig. 4).

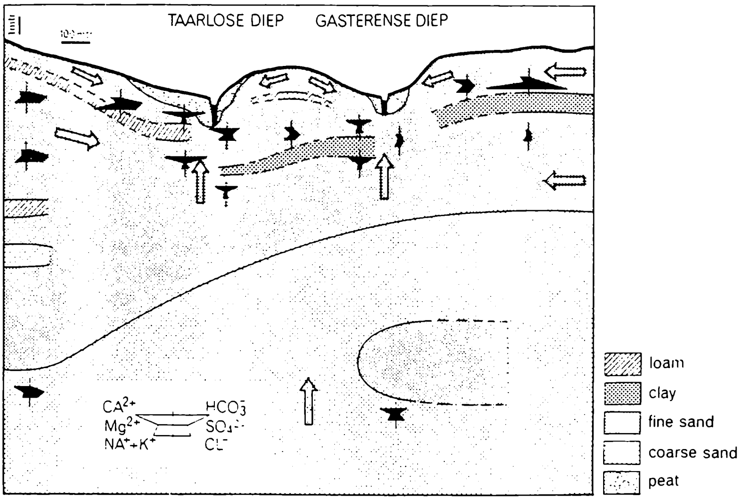

Fig. 4: Geological transect of the study area with groundwater flows and groundwater quality (Ca^{2+}, HCO_3^-, Mg^{2+}, SO_4^{2+}, Na^+, K^+, Cl^-), measured in April 1984 (after GROOTJANS & al. 1987)

The composition of this groundwater corresponds 90-100 % with the groundwater from the deeper aquifers (approx. 100 m) (GROOTJANS & al. 1987). The origin of this water is unknown, but it is "old groundwater" which has found its way into the brook valley via deep stream tubes from the surrounding plateaus. It is clear that differences in seepage/infiltration, in the study area, go together with differences in the composition of ions in the groundwater.
The groundwater found high up in the flanks of the brook valley has only recently infiltrated into the ground and it is moderately to very strongly polluted, most likely as a result of intensive application of fertilizers. E. g., groundwater coming from the direction of Gasteren contains almost 100 mg nitrate/l (Fig. 5).

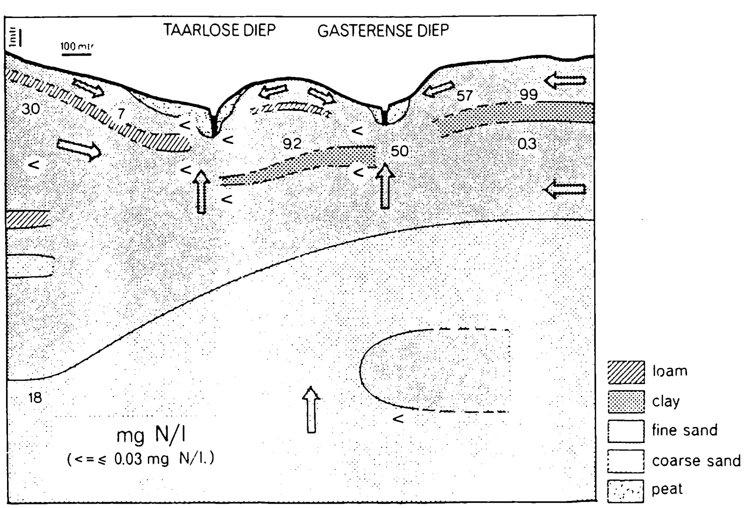

Fig. 5: Geological transect of the study area showing groundwater flows and nitrogen content in mg nitrate/l (< = ≤ 0.03 mg nitrate/l) measured in April 1984 (after GROOTJANS & al. 1987)

This is twice the amount of nitrate which is thought to be permissible in drinking water. A layer of boulder clay prevents infiltration to the depths and the polluted water, therefore, reaches the brook valley. It is thanks to the strong flow of clean, calcium-rich groundwater out of the deep subsoil, that the polluted groundwater from the agricultural areas doesn't reach the centre of the brook valley.

5. Groundwater Management

The wet meadows along the brook were traversed by deep drainage ditches which, thus allowing for unobstructed drainage of the hinterland. This means that the top layer of the peat is to a greater or lesser extent earthened. The peat can be classified as "Made" peat of "Vlier" peat (VAN HEUVELN 1980). After the acquisition of the area the State Forestry Commission maintained the dividing ditches, building dams with culverts. The dams were necessary to carry out the mowing management. The culverts were situated at a higher level than the original ditch bed, which resulted in a degree of moistening in the valley grasslands. Many of the ditches to the west of the Taarlose Diep have been maintained to a certain depth in aid of the drainage of the hinterland up to the present day, which is forced by the authorities in charge of the water management. Since the start of grazing, there has been no maintenance of the ditches to the east of the Taarlose Diep. Some of the culverts are still functioning well.
The hydrological feeding of the different parts of the study area is investigated using readings from the electric conductivity (EC) in a vertical section of peat. In waterlogged organic soils this is a good indication of the mineral content of the groundwater (Table 1) as has been measured in another brook valley (GROOTJANS & al. 1988).

Table 1: Chemical composition of the groundwater in a Drenthian brook valley (after GROOTJANS & al. 1988)

	Shallow groundwater (0.5 - 2.8 m below surface)								Deep groundwater in aquifer near the fringe of the Pleistocene Plateau (67 - 130 m)
	Type I		Type II		Type III		Type IV		
	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.	
pH	4.7		5.6		6.6		6.7		
Ca^{2+} ($meq.l^{-1}$)	0.24	0.08	0.77	0.04	2.64	0.05	3.94	0.04	3.55
Mg^{2+} ($meq.l^{-1}$)	0.15	0.04	0.29	0.01	0.59	0.02	0.96	0.06	0.52
Na^{+} ($meq.l^{-1}$)	0.21	0.08	0.39	0.02	0.49	0.06	0.93	0.16	0.56
K^{+} ($meq.l^{-1}$)	0.05	0.02	0.07	0.01	0.09	0.01	0.18	0.08	0.04
HCO_3^- ($meq.l^{-1}$)	0.11	0.09	0.97	0.10	2.68	0.07	4.80	0.08	4.23
Cl^- ($meq.l^{-1}$)	0.24	0.08	0.43	0.05	0.65	0.04	1.22	0.22	0.53
SO_4^{2-} ($meq.l^{-1}$)	0.34	0.04	0.37	0.05	0.26	0.03	0.20	0.10	0.09
EC_{25} ($\mu S.cm^{-1}$)	86	7	162	7	347	8	535	27	461
	n = 6		n = 33		n = 54		n = 12		n = 5

Five transects of peat, taken perpendicular to the brook, had readings taken to a depth of 180 cm, using an EC/temperature probe (Fig. 6).

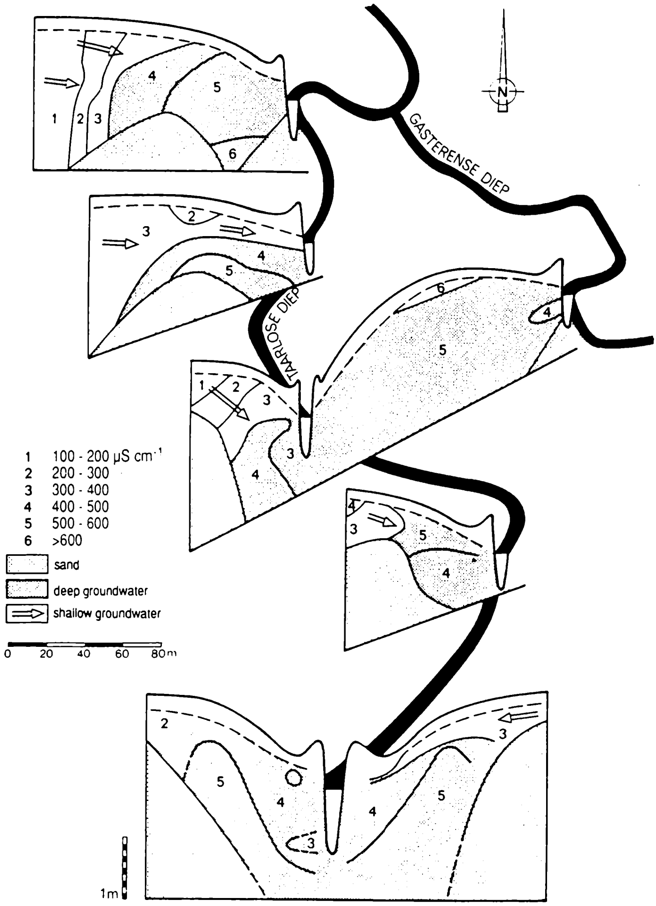

Fig. 6: Cross sections of the study area with a classification of groundwater types according to the electric conductivity in June 1989

The EC readings were classified in groups and interpreted according to the hydrological feeding which was mentioned earlier. Consequently the following picture evolves:

- to the northwest of the Taarlose Diep (transect 1) the mineral-rich groundwater only rises high up in the profile near the brook. A mineral-poor groundwater current forces its way deep into the brook valley from the flank. In transects 2 and 3 the mineral-rich groundwater is even forced right away.
- in the cross section the mineral rich groundwater rises unhindered up between the two brooks in the peat layer. The high EC-values in the top layer of the peat (classification 6) are probably an effect of a strong acidification in the unsaturated zone, which resulted in a lot of calcium being released out of the peat.
- to the southwest of the Taarlose Diep (cross sections 4 and 5) the groundwater also rose to soil surface. The low values around the brook are probably caused by an increase in the mixing of sand in the peat. This could also be as a result of flooding, or from the strong earthening of the peat here. The effects of dilution from rainwater are recordable on the east flank.

6. Changes In The Vegetation

The composition of the different types of vegetation is shown in Table 2. The distribution of these types in 1974 and 1989 is shown respectively in fig. 7 A and 7 B. From Table 2 one can deduce whether a particular vegetation type was found in 1974 and/or 1989 and whether it was found in the cut and/or grazed part of the study area in 1989.

Table 2: Synoptic table of the occurring plant communities in the study area in 1974 and in 1989, respectively (see also Fig. 7). The legend should be read from dark to light symbols: dominant in all relevés, occurring in all relevés, occurring in more than 50 % of the relevés, occurring in less than 50 % of the relevés, respectively. Management in 1989, H: hay-making, G: grazing

Plant community	2a	2a	2b	3	3	4	6	1	5	4	6	4	7
Occurrence in 1974	+	+	-	+	-	+	+	+	+	+	+	+	+
Occurrence in 1989	+	+	+	+	+	+	+	+	-	+	+	+	+
Management in 1989	H	G	G	H/G	G	H	H	G	-	G	H/G	G	H/G
Mentha aquatica	.	░	.	-	-	-	.	.	.	.	.	.	-
Eleocharis palustris	-	.	.	.	.	.	.	░	.	.	.	.	.
Equisetum palustre	░	.	-	░	░	-	-	░	.	.	.	.	.
Equisetum fluviatile	.	▓	.	.	.	.	.	░	.	.	.	.	-
Caltha palustris	░	▓	▓	.	-	.	.	-	.	.	.	.	-
Lychnis flos-cuculi	-	-	-	.	.	-	.	.	.	.	.	.	.
Myosotis scorpioides	-	-	░	.	.	-	-	.	.	-	.	.	-
Crepis paludosa	▮	.	.	.	.	.	.	.	.	.	.	.	.
Carex acutiformis	▮	▓	-	▓	░	-	.	.	.	.	.	.	-
Filipendula ulmaria	▓	▮	▮	▓	▮	░	-	.	.	.	.	.	░
Glyceria maxima	.	-	▮	▓	▓	.	░	.	.	.	.	.	.
Phalaris arundinacea	.	.	.	.	-	-	-	.	.	.	.	.	░
Agrostis stolonifera	.	-	.	.	.	.	░	▮	-	-	░	░	.
Alopecurus geniculatus	.	.	.	.	.	.	░	░	░	░	-	░	.
Glyceria fluitans	.	.	.	.	.	.	.	▮	-	▓	-	.	.
Ranunculus flammula	.	.	.	.	.	.	.	░	.	░	.	.	.
Rhinanthus angustifolius	.	-	-	.	.	░	░	.	.	.	.	.	-
Cynosurus cristatus	.	.	.	.	.	░	.	.	-	-	.	░	-
Bellis perennis	.	.	.	.	.	.	.	.	.	░	-	.	.
Leontodon autumnalis	.	.	.	.	.	.	.	.	.	-	-	.	.
Trifolium repens	.	.	.	.	.	-	.	.	▓	-	░	-	.
Plantago major	.	.	.	.	.	.	.	.	-	-	-	.	-
Lolium perenne	.	.	.	.	.	.	.	.	▮	.	▓	▓	.
Dactylis glomerata	.	.	.	.	.	.	.	.	-	.	-	.	░
Heracleum sphondylium	.	.	.	.	-	.	.	.	.	.	.	.	░
Alopecurus pratensis	.	.	.	.	.	.	.	.	.	.	.	.	▓
Juncus effusus	.	░	.	-	.	▓	-	░	.	░	-	░	░
Holcus lanatus	.	-	▓	.	░	▓	▮	.	▓	▓	▮	▮	░
Anthoxanthum odoratum	.	-	.	.	.	░	.	.	.	-	.	░	░
Plantago lanceolata	.	.	░	.	.	▓	░	.	.	-	-	-	░
Ranunculus repens	.	.	-	.	.	▓	░	░	-	▓	░	░	░
Festuca rubra	▓	.	.	.	.	░	.	.	.	-	-	.	░
Agrostis capillaris	.	.	.	.	.	-	.	.	-	.	-	.	.

▮ = dominating in all relevés
▓ = occurring in all relevés
░ = occurring in > 50% of all relevés
- = occurring in < 50% of all relevés

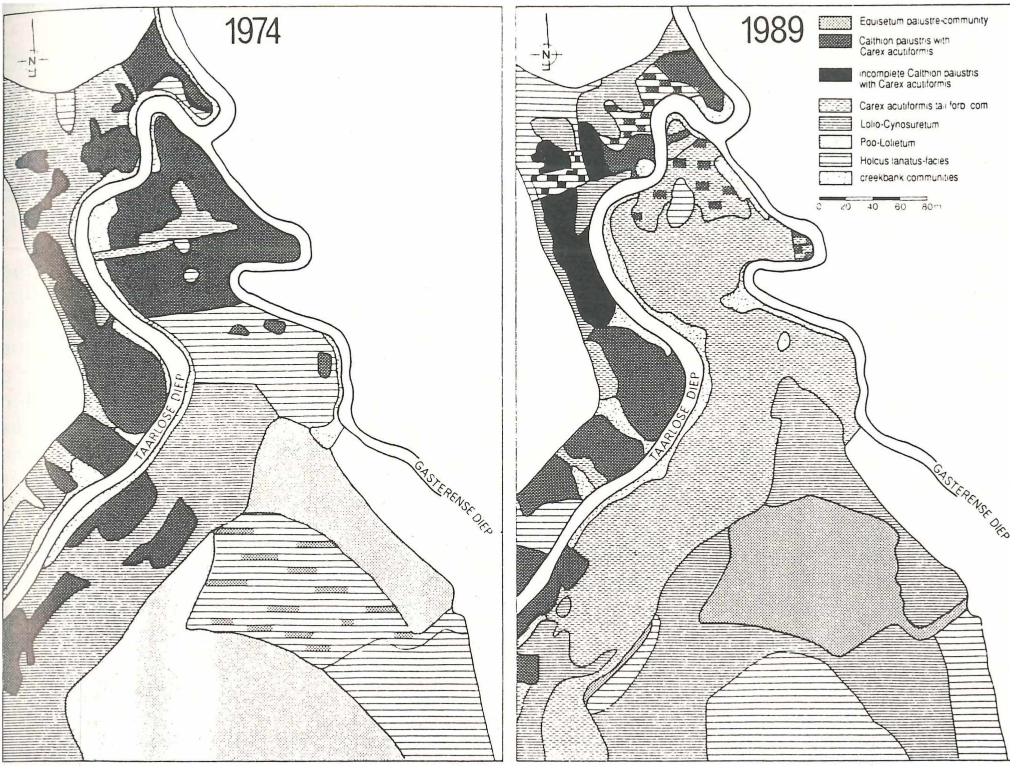

Fig. 7: Simplified vegetation map of the study area in A: 1974 and B: 1989. 1: community with *Equisetum palustre*, 2 A: *Calthion palustris* with *Carex acutiformis*, 2 B: incomplete *Calthion palustris* with *Carex acutiformis*. 3: tall forb community with *Carex acutiformis*, 4: *Lolio-Cynosuretum*, 5: *Poo-Lolietum*, 6: *Holcus lanatus* stands, 7: stream bank- and remaining communities.

6.1 Grazing in the brook valley

The vegetation on the peat is, in fact, hardly grazed any more. This was apparent from counted dung patches as early as 1981. The wetter the land, the fewer patches found. If the cattle do enter the wetter area, it is late in the growing season (SJOUKES & FIJN 1982). On the plateau there are variations in the grazing intensity. These differences can be deduced by looking at the vegetation, namely, the greater the proportion of short turf (lower than 5 cm), the greater the grazing intensity (VAN DEN BOS & BAKKER 1990).

The *Lolio-Cynosuretum* and large parts of the well developed *Calthion palustris* communities with *Carex acutiformis* transformed into a species-poor *Carex acutiformis* - tall forb community (Fig. 7 A, 7 B and Table 2). This transition was illustrated in an analysis of permanent plots which showed a reduction (Fig. 8 A) in elements of the *Calthion palustris*, namely *Caltha palustris*, *Bromus racemosus*, *Myosotis palustris*, *Lychnis flos-cuculi* and *Crepis paludosa*. The following low hayfield species have also disappeared: *Ranunculus repens*, *Anthoxanthum odoratum*, *Bellis perennis*, *Ajuga reptans*, *Taraxacum spec.*, *Juncus articulatus* and *Leontodon autumnalis*. Tall forbs increased greatly in abundancy, namely, *Glyceria maxima*, *Carex acutiformis*, *Filipendula ulmaria* and *Cirsium palustre*. The number of species decreased from 28 to 13 on 4 m^2.

Relics of the former *Calthion palustris* (Fig. 7 A, 7 B and Table 2) are only found at the junction of the two brooks, where the mineral-rich groundwater rises high up in the profile (Fig. 6). At this point even orchids hold their own amidst the tall *Filipendula ulmaria*.

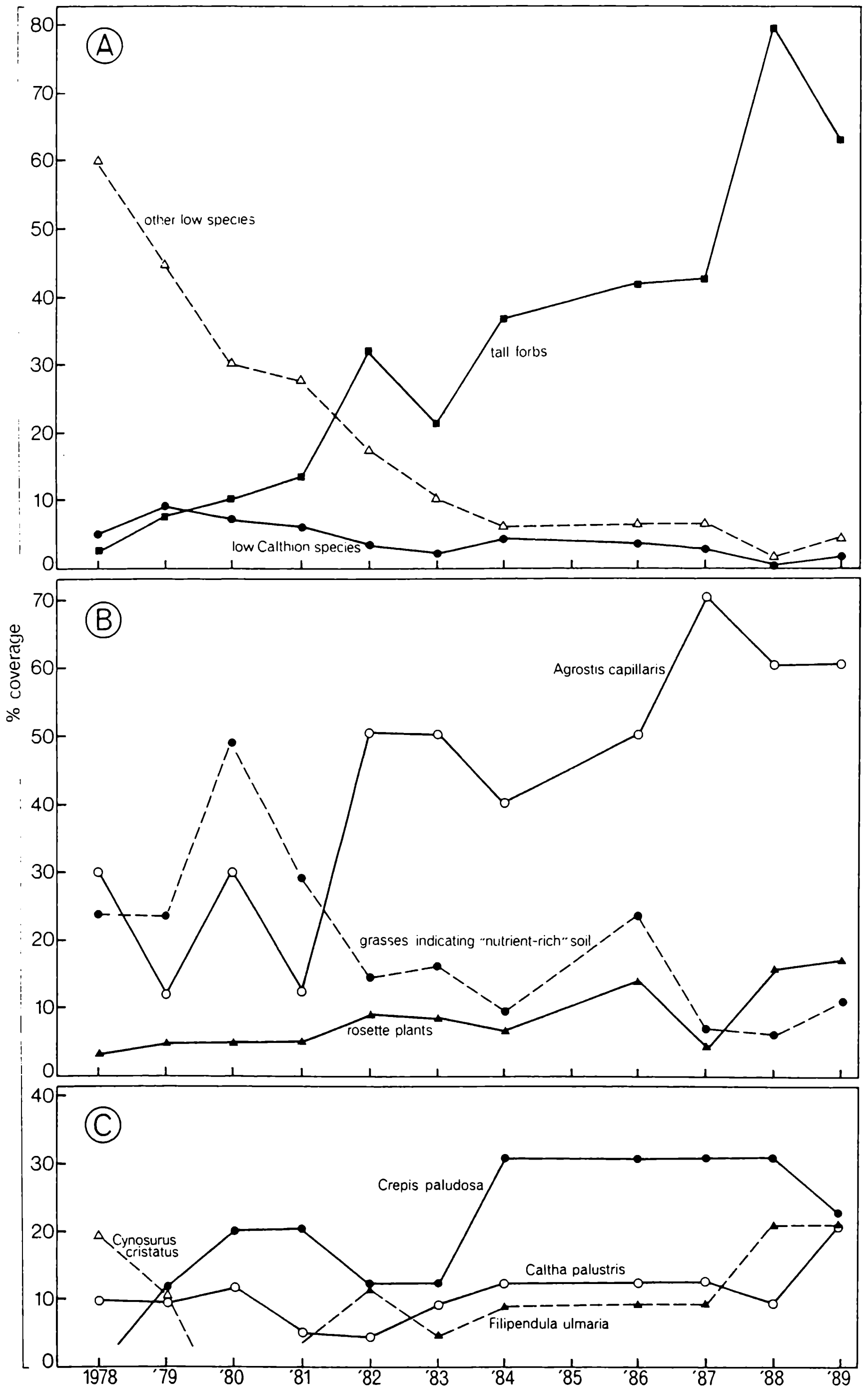

Fig. 8: Changes in the cover percentages of the dominant species in the vegetation in permanent plots (2 m x 2 m) in A: hardly grazed valley grassland, B: heavily grazed dry plateau, C: cut valley grassland

6.2 Grazing on the plateau

On the dry parts of the plateau, the *Poo-Lolietum* transformed into a *Lolio-Cynosuretum*, which points to impoverishment of the soil (Fig. 7 A, 7 B and Table 2). This development did not take place equally at different places. The cattle like to rest in the driest parts, resulting in a great deal of dung patches and establishment of tall forbs resulted. In 1989 all the vegetation was higher than 5 cm. The establishment of tall forbs manifested itself in the successive dominance of *Cirsium arvense*, *Elymus repens*, *Urtica dioica* and *Holcus lanatus*. These species grow tall, resulting in the disappearance of low species, in particular, *Alopecurus geniculatus*, *Trifolium repens* and *Plantago major*. The number of species on 4 m^2 decreased from 16 to 9 between 1978 and 1989.
Intensive grazing occurs on the western edge of the plateau. In 1989 90 % of the vegetation was lower than 5 cm. The impoverishment of the soil manifests itself in a reduction in species which are an indication of a nutrient-rich soil, namely, *Lolium perenne*, *Poa pratensis* and *Poa trivialis* (Fig. 8 B) and an increase in *Agrostis capillaris* which is an indicator of a moderately nutrient-rich soil. An indication of the high grazing intensity, is the increase in rosette plants such as *Leontodon autumnalis*, *Taraxacum spec.* and *Plantago major*. Other low growing species also hold their own. The number of species on 4 m^2 has more or less remained the same (approx. 16).
On the relatively wet eastern edge of the plateau the facies of *Holcus lanatus* holds its own or the *Equisetum palustre* community is beginning to dominate in places (Fig. 7 A, 7 B and Table 2). There is moderate grazing here. In 1989 50 % of the vegetation was shorter than 5 cm. The fact that, to a large extent, the grazers keep the vegetation low, is demonstrated by the increase or appearance of low growing species such as *Ranunculus repens*, *Cardamine pratensis* and *Bellis perennis*.

6.3 Hay-making

Towards the southwest of the Taarlose Diep, where the deep mineral-rich groundwater rises high in the profile (Fig. 6), in places *Lolio-Cynosuretum* transforms into well developed *Calthion palustris* with *Carex acutiformis* (Fig. 7 A, 7 B and Table 2). This coincides with a decrease of the proportion of *Glyceria maxima* and *Cynosurus cristatus* (Fig. 8 C) in the vegetation whilst *Crepis paludosa* and *Phyteum nigrum* increase. This points to impoverishment of the soil. Unlike in the grazed area, *Calthion palustris* holds its own. The increase in *Filipendula ulmaria* in 1988 and 1989 can be put down to the fact that the swath was left after cutting in the preceding wet summers. A degree of establishment of tall forbs is an immediate result of this as well as in reduction in the number of species namely, from 31 in 1987 to 25 per 4 m^2 in 1989. The number of species is, however, markedly higher than with grazing.
The development of the vegetation was much less successful to the northwest of the Taarlose Diep. Here, the facies of *Holcus lanatus* did not transform into a well developed *Calthion palustris* with *Carex acutiformis* (Fig. 7 A, 7 B). Along the flank of the brook valley, where shallow, mineral-poor groundwater forces its way deep into the brook valley (Fig. 6) the *Calthion palustris* communities with *Carex acutiformis*, which had been present in 1974, had disappeared and *Juncus acutiflorus* had appeared. *Glyceria maxima*, however, manages to survive, despite a hay-making management regime. The vegetation here has not dried up, but appears to show some acidification, although impoverishment of the soil has hardly occurred. The vegetation along the deep drainage ditches has remained at the *Holcus lanatus* stage or at a stage with a lot of *Plantago lanceolata* and *Anthoxanthum odoratum*. Communities of sand outcrops have, therefore, found a permanent site on the peat. Plants of *Rhinanthus angustifolius* and *Cynosurus cristatus* are found on slightly less dry areas. These areas are also species-rich. *Calthion palustris* communities have only held their own in the close vicinity of the brook, where mineral-rich groundwater rises high in the profile (Fig. 6). The *Carex aquatilis* community, in a large seepage area near the stream, has receded since 1974. *Carex disticha* has spread. This points to an increase in fluctuations in the groundwater table.

7. Standing Crop And Litter

In order to gain insight into the quantities of available nutrients, in July 1989 the standing crop of the living above-ground biomass of a number of types of vegetation was determined. A multiple range test, according to Tukey, was carried out on appearant differences between the types of vegetation (ANOVA). The standing crop of the *Holcus lanatus* stand, adjacent to the drainage ditches, was significantly the highest (Fig. 9).
This might have been the result of mineralization from the peat and the collection of material from the ditches, left after cleaning. The standing crops of the *Glyceria maxima* and *Scirpus sylvaticus* stands in the grazed area were significantly higher than any of the other stands which were cut. This difference is possibly caused by the mineralization of litter, of which there is a lot, because neither of the two stands are grazed much. The standing crop of the *Plantago lanceolata* stand was the lowest of all the communities which were cut. The peat is, most likely, so earthened on these dry patches, that the nutrients have been washed away (and this has restricted the production).
The amount of litter in the *Scirpus sylvaticus* stand is significantly less than that in the *Glyceria maxima* stand. It is possible that in places with seepage from deep groundwater a stronger decomposition takes place in the calcium-rich environment of the *Scirpus sylvaticus* stand.
The data and interpretations of the differences in the standing crop are still limited and the hypotheses which arises from them still need to be tested further.

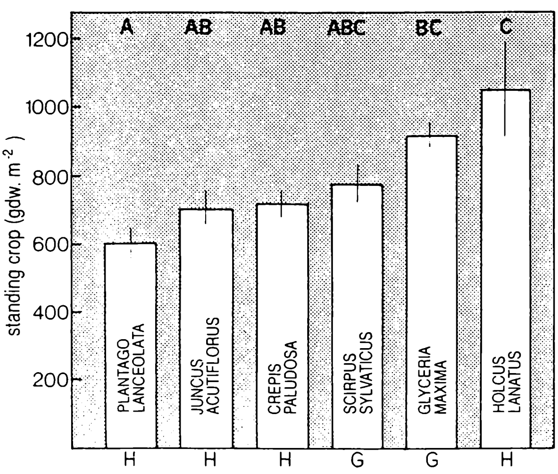

Fig. 9: Above-ground standing crop (± S.E.) in different stands in July 1990 with hay-making (H) or grazing (G). Different symbols indicate significant differences ($P < 0.05$).

8. Disturbed Groundwater Gradients

All the available data point in the same direction. The deep drainage ditches, result in the fast discharge of the calcium-rich and clean groundwater out of the aquifers whereas the calcium-poor and polluted groundwater is "sucked in" to the area from the flanks. This is not a recent occurrence. The deep ditches have been there for decades. It now, however, appears that the continued development of the marsh vegetation has stagnated in a large part of the brook valley, because of the "shift" in the groundwater gradient. No solution has, in fact, even been found for the problem of "excess water" in these areas. Not in the lowest areas or along the flanks, as the water supply is far too great. In the direct vicinity of the ditches, a great deal of damage does, however, occur from drying.
The replacement of groundwater by precipitation water was not observed in the wet meadows between the brooks but the development of the marsh communities had also stagnated here. This is linked to the cessation of cutting of the vegetation but the establishment of tall forbs which results is greatly stimulated by the drainage ditches which are still functioning. The draining

leads to decomposition of the peat which, in turn, results in an increase in available nitrogen. In this area, during the vegetation season, the mineralization can rise to levels far greater than 100 kg N/ha (KOENE & VEERMAN 1978).

9. Dilemmas

A number of dilemmas arise for the authority in charge of the management in an area with a lot of seepage, such as around "de Heest". The groundwater tables must be increased in order to prevent dehydration. This, however, results in patches which are difficult to cut in a "hilly" peat landscape. Adapted mowing machines are only a part of the solution. These types of areas must, as well as having a cutting regime also have trenches in order to prevent superficial acidification by precipitation water (KEMMERS & JANSEN 1985).
A return to a cutting regime would certainly be of some value in an area with tall forbs but this requires a substantial input of manpower and resources. In the current situation the resumption of a cutting regime here would often mean fewer opportunities in other areas in the reserve.

10. Regeneration Possibilities

In order to solve dilemmas like the above-mentioned, suggestions about management measures, which could give nature development a new impulse, are given here. The different possibilities are shown in Table 3.

Table 3: Different possibilities for vegetation development in wet and dry habitats by hay-making and grazing

	Hay-making	Grazing
Wet	*Calthion palustris*	"Mexotrophic marsh"
Dry	*Holcus lanatus/Plantage lanceolata*	Tall forbs/ruderals

In the first place, the seepage of deep groundwater between the two brooks and northwest of the Taarlose Diep, should not be reduced but stimulated. Maximal use can then be made of clean calcium-rich groundwater, the very thing which stops the earthening of peat in large parts of the area. It would also be desirable to, with the exception of a few areas around the edge, block up all the ditches by filling them with the adjacent dried peat layers. The groundwater which is seeping up would find its own way to the brook because of the hydrolic head in the peat (more than 1 meter higher than the brook level in the summer). There is virtually no danger of the rainwater stagnating.
A second possibility is to dam the ditches, that run into the brook by establishing a spillway. This situation is cheaper, but it is less suitable for the task of rewetting the higher peat layers. The lowest lying areas would under such a regime, be permanently inundated, which would allow for the building of a mesotrophic marsh with species such as *Equisetum fluviatile, Carex rostrata, Carex aquatilis, Menyanthes trifoliata* and perhaps even with *Carex diandra* or *Carex appropinquata*.
The establishment of tall forbs in the marsh would not come to an immediate halt. It is not possible to prevent tall forbs remaining for a very long time, especially on the higher parts. It is, however, likely that large patches, with a vegetation from a more nutrient-poor soil, would appear. The establishment of tall forbs would get less along the edges, because the litter which was produced would be decomposed much quicker in the calcium-rich environments (Fig. 10).

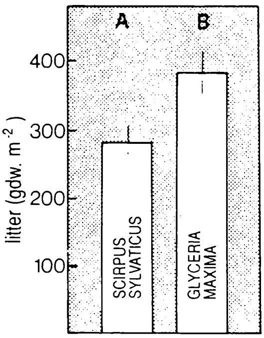

Fig. 10: Amount of litter (± S.E.) in two stands in July 1990 under grazing. Different symbols indicate significant differences ($P < 0.05$).

This does, it is true, result in an increased release of nutrients but this does not mean an increased availability of nutrients for the plants because, particularly phosphate bonds to iron from the deep groundwater. In order to increase the possibilities of developing a mesotrophic marsh, it would be highly recommended that the earthened and sometimes extremely dried top layer should be removed before the groundwater table is raised.

In the area, the accessability of the edges of the marshland which would be created in the wet meadows between both brooks and northwest of the Taarlose Diep adjacent to the existing alder carr, should be improved. In concrete terms this means that the banks must remain accessable for cattle and/or mowing machines and that the original bridge over the Gasterense Diep would have to be repaired. It should then be possible to cut along the edges of the marsh, allowing for accessability with a view to developing of *Calthion palustris* communities. For that purpose shallow trenches would have to be dug to remove precipitation water immediately and to maintain a degree of carrying capacity for animals and/or machinery.

With the management suggested above, more use would be made of the natural potential of the area, grazing would take place where it would be most successful and a part of the existing natural value be maintained or regenerated by means of a hay-making regime. The lasting development of very endangered marsh species can, in this way become a tangible proposition. After an initial period there is no necessity to invest in such an area for a long time. That is also profit.

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