Acta Bot. Neerl. 29(5/6), November 1980, p. 359–376.

THE CAREX FLORA OF VARIED LANDSCAPES IN THE NETHERLANDS: AN EXAMPLE OF DECREASING ECOLOGICAL DIVERSITY

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SUMMARY

The *Carex* floras of five inland landscapes in The Netherlands (*fig. 1*) are compared to each other, with emphasis on phytogeographical, syntaxonomical and ecological aspects (*table 1*). Moreover, changes in the distribution frequencies of the *Carex* species have been analysed by comparing two sets of frequency data to each other (census periods 1900–1949 and 1950–1975; cf. *table 3*). A strong decrease is noticed in many species: both in species occurring in The Netherlands at the margin of their phytogeographical range and in species occurring near the central parts of their range (*table 4*). In relation to habitat (*table 5*) little decrease is found in the species groups of dynamical and eutrophic environments; on the contrary, a dramatic decline can be observed in many species associated to complex, stable (semi-) natural habitats (e.g. *Carex dioica*: *fig. 2*). It is argued, that the real decrease of many *Carex* species is much more severe than is indicated by the current census methods. At least 20 out of the 59 species of the Netherlands *Carex* flora are threatened to such an extent, that probably they will only survive in a (very) few fitting Nature Reserves. The impoverishment of the *Carex* flora significantly reflects the recent changes in the Dutch flora as a whole. The high indicator value of *Carex* species makes their disappearance the more regrettable from a scientific point of view.

1. INTRODUCTION

Carex L. is the most variegated genus of the Netherlands flora: there are 59 native species in The Netherlands (HEUKELS & VAN OOSTSTROOM 1975). The present study aims at the description of five inland regions rich in *Carex* species. The *Carex* spectra of these regions are compared to each other with respect to phytogeographical, phytosociological and ecological aspects. Moreover, the recent distribution data have been compared to literature data from the past, and it is discussed to what extent changes in the *Carex* flora are indicative for changes in plant communities as a whole in The Netherlands during the past decades.

2. METHODS AND STUDY AREA

From 1973 onwards the author has studied the distribution, ecology and phytosociology of the *Carex* species in landscapes with (semi-)natural brook systems in The Netherlands. This study is more extensively documented in DE BRUIJN 1977. The research comprises detailed vegetation surveys (including relevés) as well as intensive search for known and new provenances of rare *Carex* species,

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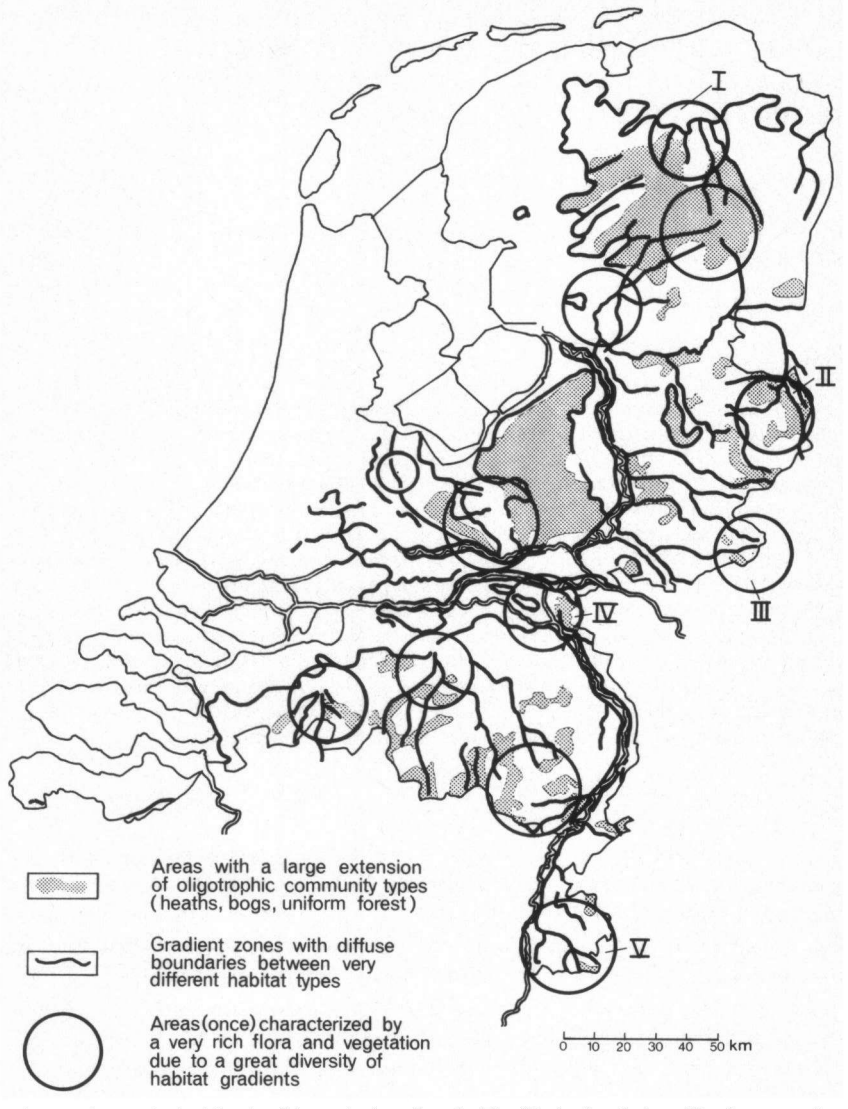

Fig. 1. The ecological basis of botanical variety in The Netherlands (outside the coastal region). Study areas are indicated (I = North Drenthe, II = East Twente, III = Winterswijk, IV = Nijmegen, V = South Limburg). Re-drawn from VAN LEEUWEN (in WESTHOFF et al. 1970).

particularly in following five regions (*fig. 1*): N. Drenthe (I), E. Twente (II), Winterswijk region (III), Nijmegen region (IV) and S. Limburg (V). These regions have in common a great diversity of environmental gradients: usually based on the existence of gradual transitions from higher oligotrophic areas (bogs, heathland, uniform forests) to lower meso- and eutrophic areas (marshland, river- and brook valleys), as shown in *fig. 1*. In fact the five study areas

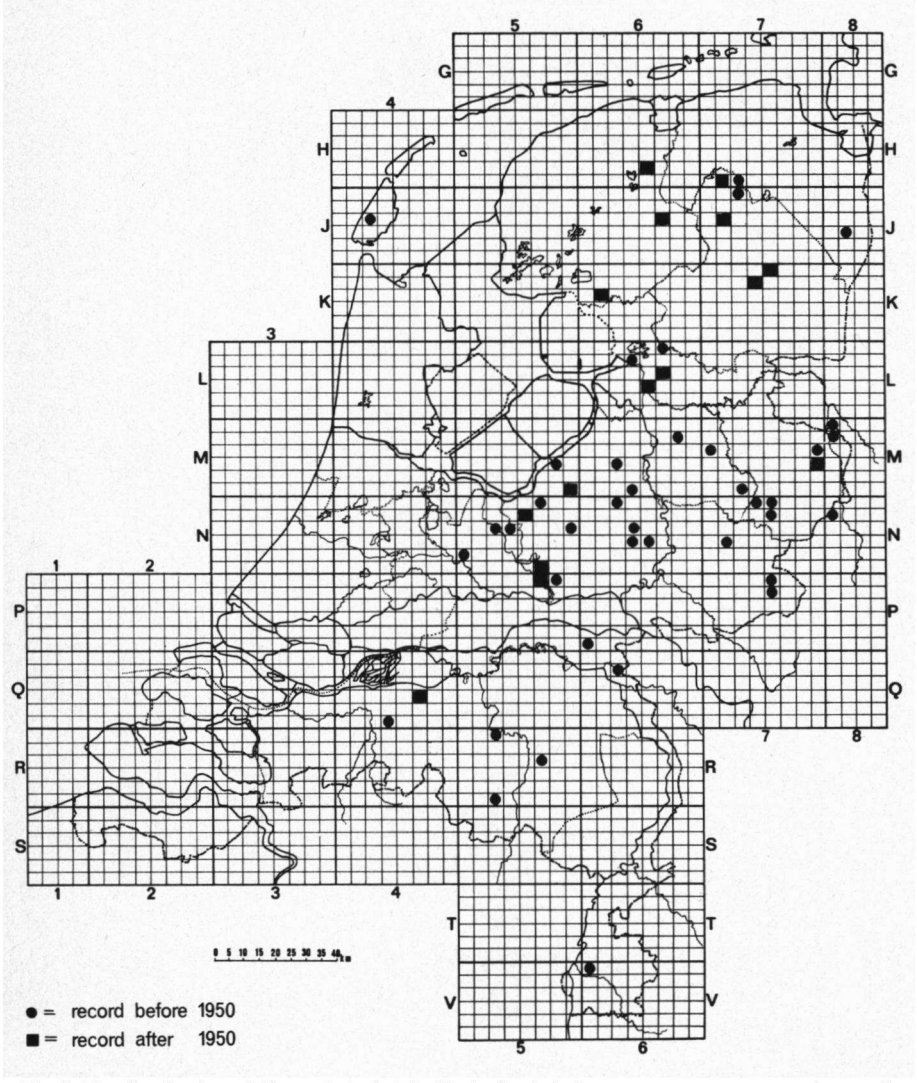

Fig. 2. The distribution of *Carex dioica* in The Netherlands before and after 1950. From ADEMA (in MENNEMA et al. in preparation).

represent well the semi-natural landscapes on the higher grounds in The Netherlands (WESTHOFF et al. 1973).

In this paper the nomenclature of taxa is according to HEUKELS & VAN OOSTSTROOM (1975), the nomenclature of syntaxa is according WESTHOFF & DEN HELD (1969). Phytogeographical distribution of the various *Carex* spp. is based on MEUSEL et al. (1965), while the characterization of their occurrence in The Netherlands in relation to geographical range is derived from HENGEVELD & HAECK (in prep.).

Table 1. Statistical review of the *Carex* flora of the study regions.

Species	Socio-ecological and syntaxonomical group		Phytogeography		Distribution frequency in The Netherlands		Occurrence in the five study regions				
	A–1	A–2	B–1	B–2	C–1	C–2	I	II	III	IV	V
Carex hirta	2a	16 Ab	Eur	sub-centr	7	7	+	+	+	+	+
– otrubae	2a	16 Ab	Eur	sub-centr	6	6	+	+	+	+	+
– vulpina	2a	16 Ab10	Eur-WAs	sub-centr	3	2	–	–	–	+	+
– ovalis	2a	30 Aa	Eur-(WSib)	sub-centr	7	6	+	+	+	+	+
– pseudocyperus	4c	19 Ac	Eur-WAs	sub-centr	7	6	+	+	+	+	+
– acutiformis	4c	19 Ca	Eur-WAs	sub-centr	6	6	+	+	+	+	+
– paniculata	4c	19 Ca2	Eur	sub-centr	6	6	+	+	+	+	+
– hudsonii	4c	19 Ca3	Eur	sub-marg	6	5	+	+	+	+	+
– riparia	4c	19 Ca4	Eur-WAs	sub-centr	7	7	+	+	+	+	+
– acuta	4c	19 Ca5	Eur-Sib	sub-centr	7	7	+	+	+	+	+
– aquatilis	4c	19 Ca5	circpol	marginal	3	3	+	–	–	–	–
– vesicaria	4c	19 Ca5	circpol	sub-centr	6	4	+	+	+	+	+
– disticha	5b	25 Aa3	Eur-Sib	sub-centr	7	6	+	+	+	+	+
– arenaria	6b	20 Ba2	Eur	sub-centr	7	7	+	+	+	+	–
– ligerica	6b	20 Bb	Eur	marginal	4	3	–	–	–	+	–
– praecox	6b	20 Bb	Euras	marginal	2	1	–	–	–	+	–
– caryophyllea	6c	21 Aa	Eur-WSib	sub-marg	4	3	–	+	+	+	+
– demissa	7a	27	Eur	sub-centr	5	4	+	+	+	+	+
– lasiocarpa	7a	27	circpol	marginal	5	4	+	+	+	+	(+)
– nigra	7a	27 Aa	Eur-)WAs)	sub-centr	7	6	+	+	+	+	+
– curta	7a	27 Aa1	circpol	sub-centr	6	5	+	+	+	+	+
– echinata	7a	27 Aa1	Eur	sub-centr	6	5	+	+	+	+	+
– rostrata	7a		circpol	sub-centr	6	5	+	+	+	+	+
– cespitosa	7a		Euras	sub-marg	0	1	+	–	–	–	–
– diandra	7b	27	Circpol	sub-marg	4	3	+	+	+	+	+
– flava	7b	27 Ba	Eur-(WAs)	sub-centr	3	1	–	–	–	–	+
– lepidocarpa	7b	27 Ba	Eur	central	2	1	–	–	–	–	?

–	distans	7b		Eur	sub-marg	5	5	–	–	–	–	+
–	flacca	7b		Eur	central	6	5	+	+	+	+	+
–	dioica	7b	27 Ba2	circpol	sub-marg	4	3	+	+	(+)	(+)	(+)
–	appropinquata	7c	19 Ca6	Eur-WAs	sub-marg	3	3	+	+	–	–	–
–	panicea	7c	25 Ac1	Eur-(WAs)	sub-centr	7	6	+	+	+	+	+
–	hostiana	7c	25 Ac1	Eur	sub-centr	5	3	+	+	+	+	+
–	pulicaris	7c	27 Ba	Eur	sub-centr	5	4	+	+	+	+	+
–	serotina	7c		circpol	sub-centr	5	3	+	+	+	+	+
–	tomentosa	7c		Eur-WAs	sub-marg	2	0	–	–	–	(+)	–
–	limosa	7d	28 Aa2	circpol	marginal	3	1	+	–	+	(+)	(+)
–	pilulifera	7e	30	Eur	sub-centr	7	5	+	+	+	+	+
–	spicata	8b	17 Ab	Eur-(WAs)	sub-centr	6	6	–	+	+	+	+
–	muricata	8b	17 Ab	Eur-(WAs)	sub-centr	2	2	–	–	–	+	–
–	pallescens	8b	30 Aa	Eur-WSib	sub-centr	5	4	+	+	+	+	+
–	divulsa	8c	34 Ab4	Eur	sub-centr	2	2	–	–	–	+	+
–	polyphylla	8c	34 Ab4	Eur	sub-centr	2	2	–	–	–	+	+
–	elongata	9a	35 Aa1	Eur-WSib	sub-marg	5	4	+	+	+	+	+
–	strigosa	9a	38 Aa1	Eur	sub-marg	2	1	–	–	–	+	+
–	pendula	9a	38 Aa1	Eur	sub-marg	1	1	–	–	–	–	+
–	remota	9a		Eur	sub-centr	6	6	+	+	+	+	+
–	sylvatica	9b	38 A	Eur	sub-centr	4	4	+	+	+	+	+
–	brizoides	9b	38 Aa	Eur	marginal	2	2	+	–	–	–	+
–	digitata	9d	38 Ab1	Eur	sub-marg	2	2	–	–	–	–	+
–	reichenbachii	9e		Eur	sub-centr	2	3	–	–	–	+	–

A–1 = Socio-ecological group (according to ARNOLDS & VAN DER MAAREL 1979)
A–2 = Syntaxonomical group (according to WESTHOFF & DEN HELD 1969)
B–1 = Phytogeographical distribution (Eurosiberian Region) (according to MEUSEL et al. 1965)
B–2 = Position of The Netherlands relative to geographical range (according to HENGEVELD & HAECK in prep.)
C–1 = Distribution frequency in The Netherlands in the period 1900–1949 (according to ARNOLDS & VAN DER MEIJDEN 1976)
C–2 = Distribution frequency in The Netherlands in the period 1950–1975 (according to ARNOLDS & VAN DER MEIJDEN 1976)
I–V = study regions (see *fig. 1*)
(+) = present in the period 1900–1949 (not afterwards)
\+ = present in the period 1950–1975
– = absent

3. RESULTS OF THE INVENTORIES

In the five study areas 51 out of the 59 Netherlands *Carex* species have been found: see *table 1*. From the remaining eight species five are (nearly) completely restricted to the coastal area in The Netherlands (*C. extensa*, *C. trinervis*, *C. divisa*, *C. punctata*, *C. hartmanii*), three of them are inland species (*C. buxbaumii*, *C. laevigata*, *C. ericetorum*). Most of them are limited to very specific habitats, and therefore extremely rare (cf. WESTHOFF & KETNER 1967). These eight species are left out of consideration in this paper.

Regarding the five selected areas it turns out that in N. Drenthe (I), E. Twente (II) and in the Winterswijk region (III) 30–35 *Carex* species are found, whereas in the Nijmegen region (IV) and in S. Limburg (V) as many as 40–45 species are found. Differences between these areas will be discussed below.

3.1. North Drenthe

This region is an originally rather oligotrophic Pleistocene landscape (boulder clay plain covered by aeolian sands) criss-crossed by many brook systems (filled up with rather eutrophic peat sediments). Until the beginning of this century the Drenthe Plateau was covered by vast bogs and heathlands, which now have been reclaimed for the most part. During the past decades also the semi-natural valley communities (litter fens, valley bogs, brook swamps) have largely been destroyed due to artifical drainage operations and the widespread use of fertilizers. Fortunately, some relics of these centuries-old landscape types have been preserved as nature reserves and are being maintained according to ancient agricultural practices.

The flora is comparatively rich in boreal and atlantic species (BARKMAN & WESTHOFF 1969). Within The Netherlands at least three *Carex* species have their optimum in the Drenthe district: (i) *C. aquatilis*, a sub-arctic (!) species apparently being overlooked in the past (BAKKER 1957); (ii) *C. appropinquata*, in The Netherlands always considered to be a rare species, but recently found in about 20 places in fens and hay-fields (influenced by seepage) in the basin of the Drentsche A (map in DE BRUIJN 1977), while it also has been spotted in the valleys of the Peizer Diep and the Hunze; (iii) the boreal *C. cespitosa*, in 1973 discovered in former beds of the Hunze (DE BOER 1974) and in a single locality in the valley of the Drentsche A (these are the only known provenances in The Netherlands).

In 1973 the boreal *C. limosa* was observed for the last time by the late Prof. D. Bakker and the author in an oligotrophic valley bog (*Erico-Sphagnetum magellanici/Scheuchzerietum*) in the basin of the Drentsche A; this beautiful species is on the verge of extinction in our country. Recently the rare *C. dioica* has been discovered in a mesotrophic fen peatland (influenced by seepage) in the valley of the Peizer Diep, together with some 15(!) other *Carex* spp. In this area *Carex dioica* is found together with *C. appropinquata*, *C. pulicaris* and *Orchis incarnata*, representing a rare inland community (*Parnassio-Caricetum pulicaris*) belonging to the alliance *Caricion davallianae*. Moreover *C. dioica* is found in

combination with *C. pulicaris*, *C. hostiana*, *Parnassia palustris* and *Cirsium dissectum* in the valley of the Oostervoortse Diep. In The Netherlands *C. dioica* is one of the most sensitive vascular plants (WESTHOFF et al. 1973): restricted to stable complex gradient zones and becoming rarer and rarer (cf. *figs. 1* and *2*). In The Netherlands the subboreal species *C. diandra* and *C. lasiocarpa* have a somewhat wider ecological amplitude. In N. Drenthe communities rich in both species are found in mesotrophic swamps bordering some lakes, e.g. Zuidlaardermeer (SMITTENBERG 1972), and in some places in quivering fen peatland, e.g. Wilde Veen (HOEKSTRA et al. 1977). So far none of these sites have been declared a Nature Reserve...

3.2. East Twente

Twente is a Pleistocene landscape comparable to the Drenthe region, but with more surface relief and hence with a more small-scale pattern of land use. Botanically East Twente had a very good reputation on account of its wet moorlands, fens and brook swamps rich in *Carex* species (WESTHOFF 1949, VAN DIJK 1965).

From a phytogeographical point of view the flora of E. Twente is characterized by a number of (sub-)continental species (VAN SOEST in HEUKELS & VAN OOSTSTROOM 1975). Thus *C. sylvatica*, *C. pallescens* and *C. elongata* are more common in Twente than in Drenthe. On the contrary, the boreal element has always been less developed than in the previous area. For instance *C. aquatilis* and *C. limosa* have never been found, whereas *C. appropinquata* is only known from the Voltherbroek (VAN LEEUWEN in BAKKER 1966). In former days *C. dioica* was not rare in Twente. In this region it was spotted in 1970 for the last time by E. J. WEEDA (pers. comm.) in a strictly protected nature reserve; in this particular area *C. diandra*, *C. pulicaris*, *C. flacca*, *C. hostiana* and some 5 other *Carex* spp. are still found, together with the rare *Eriophorum latifolium*, *Pinguicula vulgaris* (now probably extinct), *Orchis incarnata* and some 40 other species. Phytosociologically this community can be classified as a transition of the *Parnassio-Caricetum pulicaris* to the *Cirsio-Molinietum orchietosum* (alliance *Junco-Molinion*). Within The Netherlands *C. hostiana* had its greatest density in E. Twente (MENNEMA et al., in prep.), growing in base-rich moorland and *Junco-Molinion* fens, nearly always together with *C. pulicaris*. Although having a wider ecological tolerance than *C. dioica*, nowadays *C. hostiana* and *C. pulicaris* have survived only in a very few places in Twente, in stations together with some species with delicately balanced ecological requirements, e.g. *Scutellaria minor*, *Parnassia palustris* and *Juncus alpino-articulatus* ssp. *arthrophyllus* (cf. WEEDA 1977). Also *C. serotina* ssp. *serotina* – a taxon mainly confined to inland pioneer communities of the alliance *Nanocyperion flavescentis* – is getting increasingly scarce.

C. spicata (absent in N. Drenthe) is regularly found on dry grassy slopes in E. Twente; moreover, in a few places along the Dinkel *C. caryophyllea* is found in occasionally grazed dry grassland on river dunes and small dams.

3.3. Winterwijk

The surroundings of Winterswijk constitute an agricultural landscape with many natural elements. Old arable land and meadows are alternating with remains of original woodland, heath and fens (now nearly fully reclaimed) and a large ombrotrophic bog (Korenburgerveen) with adjoining mesotrophic marshland.

The flora of this region comprises even fewer boreal elements than the previous area. Nevertheless, in the Korenburgerveen *C. limosa* has been found together with the boreal-montane species *Harrimarbya paludosa* (SLOFF 1940). Near Winterswijk limestone from the Trias crops out; outside S. Limburg (see section 3.5) the surface occurrence of hard rock is such an exceptional feature in The Netherlands, that part of this area has been declared Nature Reserve. On pure limestone a pioneer community dominated by *Carex flacca* and *Tussilago farfara* occurs. Adjacent to the limestone a wet *Erica-Molinia* heathland community (rich in *Cyperaceae*, *Graminae* and herbs) is found. Floristically it is "carexterized" by the combination of *C. panicea*, *C. flacca*, *C. hostiana*, *C. pulicaris* and *C. serotina* ssp. *serotina;* phytosociologically it likely belongs to the *Ericetum tetralicis orchietosum* with gradual transitions to communities belonging to the *Junco-Molinion* and the *Violion caninae*. In the adjoining *Carpinion* coppice-wood *C. pallescens* and *C. sylvatica* thrive, in combination with some (sub-)continental species including the rare *Selinum carvifolia*.

In the Winterswijk region the *Carex* flora of river dunes is completely missing, and so are *Carex* species typical of the borders ("fringe") of woodland.

3.4. Nijmegen

The Nijmegen region is very rich from a geomorphological, hydrological and cultural-historical point of view (WESTHOFF et al. 1973). This has resulted in the presence of different types of landscapes: wooded ice-pushed ridges, riverine areas along the Meuse and the Waal, and an inland sand dune area with heath pools near Hatert. Above all, the gradual transitions between these various landscapes render a great diversity of environmental gradients resulting in a very rich flora with a great number of *Carex* species.

The boreal species *C. limosa* and *C. dioica* have disappeared before 1950. In former days *C. tomentosa* was growing in a few places in the basin of the Rhine in the Nijmegen region (KERN & REICHGELT 1924), the only known provenances of this continental species in The Netherlands; now *C. tomentosa* seems to have disappeared completely, without having been studied with regard to its ecology (...). In the Nijmegen region *C. vulpina* is still occurring in the valley of the Meuse. This Eurasiatic species is rare in The Netherlands: in its distribution it is restricted to a part of the riverine area, in its habitat it is confined to rather complex situations ("stable convergent gradient zones", according to VAN LEEUWEN in WESTHOFF et al. 1970, 1971).

On river dunes and dams along the Meuse and the Waal an ecological series of *Carex* spp. on dry sandy soils occurs: *C. arenaria*, *C. ligerica*, *C. praecox* and *C. caryophyllea*, in the given order ranging phytosociologically from pioneer com-

munities of bare sand (denudated soils, due to overgrazing) to species-rich grassland communities (occasionally grazed or mown). Most interesting is *C. praecox*, a rare continental species with some northwestern outposts in the Dutch riverine area (including Millingerwaard), apparently being favoured by the micro-climate of river dunes and dams.

Remarkable is the relatively large number of *Carex* spp., which typically occur in the fringe of woodland and scrub. E.g. *C. polyphylla*, *C. divulsa*, *C. muricata* and *C. reichenbachii*. Specimens attributed to *C. polyphylla* and *C. divulsa* have been found at Plasmolen (KERN & REICHGELT 1954), but not any more during the past ten years. *C. muricata* (= *C. pairaei*) is known from a few places along the edges of woodland on the ridges bordering river valleys. Furthermore, near Hatert *C. reichenbachii* has been found, a species with an insufficiently known distribution; over the years it has been spotted in some very scattered places in The Netherlands, usually appearing in large populations. Further studies on the (presumably slightly different) ecology of these species are needed. In the Nijmegen region the ecological group of *Carex* species characteristic of rich woods on calcareous and base-rich soils is only represented by *C. strigosa* (still known from a small brook valley near Beek).

3.5. South Limburg

S. Limburg is an elevated plateau (lifted Cretaceous sediments), dissected by a river (Meuse) and criss-crossed by some rivulets (Geul, Gulp) and many brooks. This region is distinguished by the surface occurrence of very old rocky sediments and by some types of soils (e.g. rendzina) found hardly anywhere else in The Netherlands. S. Limburg has a long history of human occupation. Arable land, orchards and meadows are alternating with magnificent remains of former woodland (often on the steep slopes of the valleys).

In the *Carex* flora of S. Limburg a number of boreal species are lacking (cf. *table 1*). Moreover, the atlantic species *C. arenaria* is absent (having a littoral phytogeographical distribution). Very characteristic are chalk grassland communities on slopes. These are related to the dry grasslands on river dunes: both grassland types belong to the alliance *Mesobromion*. A species both have in common is *C. caryophyllea*, which is abundantly found (just like *C. flacca*) in unfertilized chalk grassland on slopes in S. Limburg. Here alsc *C. divulsa* and *C. polyphylla* can still be found in a very few places in the fringe of scrubland, particularly in communities of the alliance *Berberidion*. Recently both species have been found along the southern edges of the Savelsbos (W. DE VEEN, pers. comm.).

In S. Limburg some interesting *Carex* specimens belonging to the section *Extensae* have been found in meadows influenced by seepage and in base-rich woods. *C. flava* (s.l.) has been collected in several places; earlier *C. flava* (s.s.) as well as *C. lepidocarpa* were supposed to occur, but after taxonomical revision (VONK 1979) all the herbarium material turned out to belong to *C. flava* (s.s.). *C. distans* which in The Netherlands normally is confined to the coastal area, has been found in marshy places along wood-paths in the unique wet woods

(Alno-Padion) between Bunde and Elsloo (KERN & REICHGELT 1954); unfortunately, this species has not been found any more in this area during the past decade[1]. Recently in the vicinity in the Meuse valley *C. vulpina* has been recorded.

In S. Limburg some rare woodland *Carex* spp. have been found in addition to the common *C. sylvatica*. For instance *C. brizoides* – in its ecology somewhat comparable to *C. reichenbachii* – thrives in one locality in woodland *(Alno-Padion)* near Vaals, linked up with the continental area of this species; in contrast in Drenthe *C. brizoides* has been found in isolated stations. In a few places in S. Limburg *C. strigosa* is still occurring in wet woods on base-rich soils, particularly in glades and along runnels in spring areas *(Carici remotae-Fraxinetum)*. Moreover, in the wet woods on the steep slopes of the Meuse valley at Bunde, the ornamental *C. pendula* is found; recently a new provenance has been spotted at the Netherlands-Belgian border. Another characteristic *Carex* species of the S. Limburg woods is *C. digitata*, being restricted to the fringe of scrub and the edges of *Carpinion* woods on rendzina soils, typically in communities rich in orchids (*Orchio-Cornetum; Stellario-Carpinetum orchietosum*). During the past ten years *C. digitata* has been recorded only from a very few places, particularly from the Nature Reserve Savelsbos (cf. VAN DEN BROEK & DIEMONT 1966).

4. ANALYSIS OF THE DECREASE IN THE DUTCH CAREX FLORA

4.1. Introduction

In The Netherlands, as in many other European countries, many plant species have decreased seriously in the last fifty years (WESTHOFF 1956, VAN LEEUWEN 1966, WESTHOFF et al. 1970, 1971, 1973, LONDO 1978). This process will be discussed below. Because the rarity of a species in a definite area is mainly related to its phytogeographical range and habitat requirements (WESTHOFF 1958, BARKMAN 1968), these aspects will be considered as well.

4.2. Decreases quantified

In The Netherland reliable data on the occurrence of plant species exist from 1900 onwards. The distribution frequency of each species over the 1673 squares of the national 5 × 5 km^2 grid is expressed in a logarithmic scale running from 0 (i.e. extinct) to 9 (very common) (VAN DER MAAREL 1971). Recently the results of two census-periods (1900–1949 and 1950–1975) have been evaluated by ARNOLDS & VAN DER MEIJDEN (1976). In the census of 1900–1949 the distribution of the species over the 10 frequency classes is lognormal or bell-shaped (PRESTON 1948), the frequency classes 5 and 4 containing the highest numbers of species (cf. *table 2*). The comparison of the two sets of frequency data reveals that only 7 % of

[1] *Carex distans* belongs to the socio-ecological group 3c (= salt marshes) according to ARNOLDS & VAN DER MEIJDEN (1976). On account of its inland occurrence in S. Limburg, in *table 1* of this paper *C. distans* has been classified in the same socio-ecological group (7b) as *C. flava* and *C. lepidocarpa* (cf. JERMY & TUTIN 1968).

Table 2. Changes in the distribution frequencies of the plant species in The Netherlands (1900–1949 census compared to 1950–1975 census).

	Frequency class										Total	
	9	8	7	6	5	4	3	2	1	0	n	%
Number of species (period 1900–1949)	78	130	159	203	240	247	201	149	106	37	1550	*100*
increase %	–	*4*	*1*	*2*	*4*	*6*	*5*	*16*	*14*	*82*	113	*7*
stable %	*88*	*58*	*43*	*32*	*29*	*33*	*41*	*37*	*44*	*18*	617	*40*
decrease %	*12*	*38*	*56*	*66*	*67*	*61*	*54*	*47*	*42*	–	820	*53*
Number of species (period 1950–1975)	75	80	118	147	189	263	250	201	142	85	1550	*100*

the species have increased (especially neophytes and species of disturbed environments); about 40% of the species have remained more or less stable. However, 53% of the species have decreased to such an extent, that they entered into a lower frequency class. As a result the bell-shape distribution has been transformed, the highest number of species now being found in frequency classes 4 and 3 (cf. *table 2*).

The data on the distribution of 51 *Carex* species of the two inventories lead to a comparable conclusion (*table 3*): as much as 45% of the *Carex* species decrease one frequency class and 14% of the species even shift two classes. The earlier distribution (1900–1949) shows two peaks (*table 3*), i.e. one in the frequency classes 7–5 (common species) and another in class 2 (rare species). At the last census (1950–1975) many species have become rarer, entering lower classes which results in a rather even distribution. This process is visualised in *fig. 3*, where the *Carex* species have been divided into two groups: (i) the rare species,

Table 3. Changes in the distribution frequencies of 51 *Carex* species in The Netherlands (1900–1949 census compared to 1950–1975 census). Shifts concern one (* = two) class(es).

	Frequency class										Total	
	9	8	7	6	5	4	3	2	1	0	n	%
Number of species (period 1900–1949)	–	–	10	11	8	5	5	10	1	1	51	*100*
increase	–	–	–	–	–	–	–	1	–	1	2	*4*
stable	–	–	4	5	1	1	2	5	1	–	19	*37*
decrease	–	–	5	5	5	4	1	3	–	–	23	*45*
decrease*	–	–	1	1	2	–	2	1	–	–	7	*14*
Number of species (period 1950–1975)	–	–	4	10	7	7	9	6	7	1	51	*100*

occurring only in 10 squares or less of the national grid (frequency classes 0–2), and (ii) the more common species (frequency classes 3–7). Both groups then have been divided into two subgroups, in order to demonstrate the shifts since 1900–1949 (cf. *fig. 3*)[1]. Within the group of the common species, several have moved from the classes 6 and 5 into the classes 4 and 3 (a shift in the opposite direction does not occur); at the same time several rare species move from class 2 into the classes 1 or 0, demonstrating the decrease in the Dutch *Carex* flora as well.

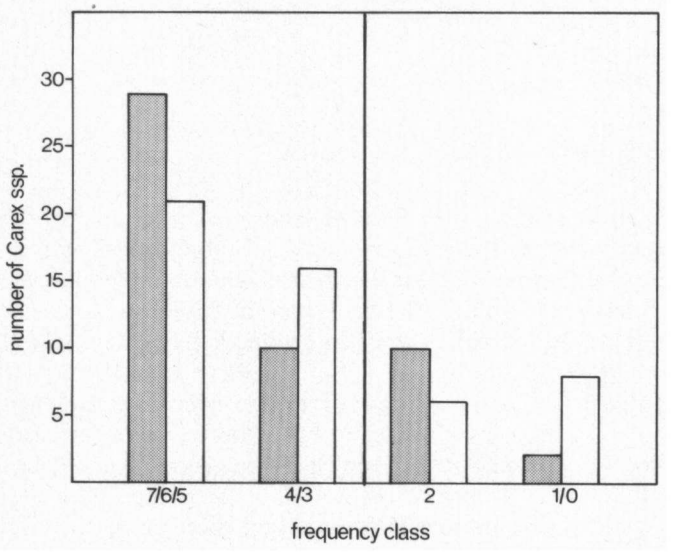

Fig. 3. Changes in the distribution frequencies within two groups of *Carex* species (frequency classes 3–7 and 0–2). Data of the 1900–1949 census (grey columns) are compared to data of the 1950–1975 census (white columns).

4.3. Phytogeographical aspects

A phytogeographical characterization of each of the species of the Netherlands flora is given by HENGEVELD & HAECK (in prep.). They distinguish 4 categories: species in The Netherlands occurring either in the centre or in the margin of their phytogeographical range (being called central and marginal species, respectively) and two intermediate categories (sub-central and submarginal species). For each of the *Carex* species this characterization is indicated in *table 1* (column B-2). From a comparison of the two Netherlands flora inventories (1900–1949 and 1950–1975) HAECK and HENGEVELD draw two general conclusions. Firstly, the marginal-area category contains relatively many rare species, whereas the central-area category comprises many common species; the two intermediate

[1] When the data of the two census-periods are compared to each other, the boundary between the two groups (i.e. between the frequency classes 3 and 2) is only crossed by four species (*C. limosa*, *C. flava*, *C. vulpina* and *C. reichenbachii*). For sake of clarity these species have been left out of consideration in the following computations.

Table 4. Changes in the distribution frequencies (1900–1949 census compared to 1950–1975 census) within two groups of *Carex* species (frequency classes 3–7 and 0–2) in relation to phytographical range.

Range category	period 1900–1949		period 1950–1975		Total number of *Carex* species (frequency class 3–7)
	frequency class 7/6/5	4/3	frequency class 7/6/5	4/3	
central	1	–	1	–	1 *(3%)*
sub-central	24	1	18	7	25 *(69%)*
sub-marginal	3	4	2	5	7 *(20%)*
marginal	1	2	–	3	3 *(8%)*

Range category	period 1900–1949		period 1950–1975		Total number of *Carex* species (frequency class 0–2)
	frequency class 2	1/0	frequency class 2	1/0	
central	1	–	–	1	1 *(9%)*
sub-central	3	–	3	–	3 *(27%)*
sub-marginal	3	2	1	4	5 *(46%)*
marginal	2	–	1	1	2 *(18%)*

categories take up a corresponding position. Secondly, both rare and common species have decreased during the past decades.

In the following the *Carex* flora has been analysed with regard to these aspects (*table 4*), using the two sets of frequency data. As in *fig. 3*, the *Carex* spp. have been divided into two groups, i.e. the frequency classes 0–2 and 3–7. Again two conclusions are to be made (cf. *table 4*):

1. The group of common species contains 72% (sub)central and 28% (sub)marginal species. On the contrary, the group of rare species contains 36% (sub)centrals and as much as 64% (sub)marginals.
2. The decrease affects both rare and common *Carex* species.

In view of these facts, it can be stated that the changes in the Netherlands *Carex* flora in relation to the phytogeographical range of the species strikingly reflect the general improverishing trends in the Netherlands flora.

4.4. Ecological aspects

Several authors have used socio-ecological groups (sensu ARNOLDS & VAN DER MAAREL 1979) in order to investigate the decrease of plant species in relation to habitat types. When the census-data of 1900–1949 are compared to the data of 1950–1975, the strongest decrease is found among the species groups of oligotrophic habitats (i.e. heathland, wet or dry acid grasslands, nutrient-poor waters), and among the species of lime rich habitats (e.g. marshes, sloping grasslands, borders of woods on chalk). Among the groups with fewer decreasing species one can find eutrophic waters, manured grasslands and ruderal or pioneer community types (cf. PLATE 1978, HENGEVELD & HAECK in prep.).

Table 5. Changes in the distribution frequencies (1900–1949 census compared to 1950–1975 census) within two groups of *Carex* spp. (frequency classes 3–7 and 0–2) in relation to habitat.

Socio-ecological group and habitat type	period 1900–1949		period 1950–1975		Total number of *Carex* spp. (frequency (class 3–7)	period 1900–1949		period 1950–1975		Total number of *Carex* spp. (frequency class 0–2)
	frequency class		frequency class			frequency class		frequency class		
	7/6/5	4/3	7/6/5	4/3		2	1/0	2	1/0	
2. highly fluctuating environments	3	–	3	–	3 *(8%)*	–	–	–	–	– *(–)*
4. waters and eutrophic marshes	7	1	6	2	8 *(22%)*	–	–	–	–	– *(–)*
5. marshy eutrophic grassland	1	–	1	–	1 *(3%)*	–	–	–	–	– *(–)*
6. dry grasslands (neutral to base-rich)	1	2	1	2	3 *(8%)*	1	–	–	1	1 *(9%)*
7. swamps, base-rich fens, wet heathlands and bogs	12	3	7	8	15 *(42%)*	2	1	–	3	3 *(27%)*
8. fringes of scrub and woodland	2	–	1	1	2 *(6%)*	3	–	3	–	3 *(27%)*
9. woods	3	1	2	2	4 *(11%)*	3	1	2	2	4 *(37%)*

In *table 5* the decrease of *Carex* species is related to habitat. Again we consider the rare species (frequency classes 0–2) and the more common species (frequency classes 3–7) separately. This reveals various trends:

1. The group of rare *Carex* spp. exclusively contains species belonging to the ecological groups 6 to 9, i.e. species associated to complex, stable environments (cf. WESTHOFF & DEN HELD 1969). In addition, the group of the common *Carex* spp. also contains many species of dynamic and eutrophic habitats, i.e. the ecological groups 2, 4 and 5 (sensu ARNOLDS & VAN DER MAAREL 1979).
2. When the two sets of frequency data (1900–1949 and 1950–1975) are compared to each other, the species of dynamic and eutrophic habitats show no (or only a slight) decrease. On the contrary, many species characteristic of stable and ecologically complex habitats have decreased seriously.

Again it can be concluded, that the pattern of decrease in the *Carex* flora strikingly reflects the recent changes in the Netherlands flora as a whole.

4.5. Discussion

Up to now the decrease in the *Carex* flora has been analysed by comparing two sets of frequency data, based on the species occurrence in squares of 5×5 km^2. However, this method is insufficient to demonstrate the real decrease because of various considerations:

1. The interest in and knowledge of plant distribution in The Netherlands have considerably increased during the past decades. This may explain the "increase" of a species like *C. reichenbachii*, and it has also led to the discovery of localities of for instance *C. cespitosa*.
2. Since 1950 a great number of the provenances of nearly all *Carex* species has been lost. (For instance, 22 Carex species used to be found in the brook swamps of "Ottershagen" in NE Twente (WESTHOFF 1949); after re-allotment operations (in the 1950's) about 5 ubiquitous species were left). Therefore, the data on the distribution frequencies of the period 1950–1975 have already become "aged" for a number of species. E.g. *Carex dioica* (*fig. 2*), at present occurring in as little as 7 or 8 squares (5×5 km^2) with only one provenance (and generally less than 10 individuals!) per square, thus its actual distribution frequency corresponding with frequency class 2 (instead of class 3, according to the 1950–1975 data represented in *fig. 2*).
3. The current census methods do not reckon with changes in vitality. E.g. *C. limosa* diminished from over 50 to less than 5 individuals in the period 1965–1975 in its only provenance in the valley of the Drentsche A (W. TEN KLOOSTER, pers. comm.), and nowadays it is completely absent in this area; nevertheless, this provenance has been taken as valid for the whole census-period 1950–1975 (cf. HEUKELS in MENNEMA et al. 1980).
4. The comparison of census-data based on grid-squares of 5×5 km^2 gives insufficient accuracy concerning changes in distribution. In The Netherlands this has been demonstrated on the basis of exact distribution data of *Viscum album* (DE GRAAF 1980): when the data of 1900–1949 were compared to the data of 1950–1975, the current census-method did not indicate a change, but the

inventory based on grid-squares of 1 × 1 km² revealed a decrease of 46%.

It is to be concluded that the current flora statistics in general only superficially indicate the real decrease in the *Carex* flora. The re-arrangement and over-cultivation of the Netherlands landscape appear to be fatal to more and more *Carex* species. This aspect will be considered in the final chapter.

5. CONCLUSIONS

From the foregoing it will be clear, that many *Carex* species are very suitable as phytogeographical and ecological indicators, therefore constituting extremely valuable elements in the Netherlands flora. Consequently, their conservation is a matter of high priority.

Resuming phytogeographical and ecological aspects (sections 4.3 and 4.4), it can be concluded that the decrease has less affected the species groups of dynamic and eutrophic environments; often these comprise *Carex* species of the sub-central area type. Examples are: *C. hirta*, *C. otrubae*, *C. acutiformis*, *C. acuta* and *C. riparia*. On the contrary, the species of more complex and stable environments are much more threatened; strong decreases are found in many rare marginal and sub-marginal species, and also in a number of (originally common) sub-central species. Examples of the (sub)marginals are *C. praecox*, *C. ligerica*, *C. dioica* and *C. tomentosa*; clear examples of the sub-centrals are *C. pilulifera*, *C. serotina* ssp. *serotina* and *C. hostiana* (cf. *table 1*).

Generally spoken, the overall decrease of (sub-)marginal species means the loss of very important indicators (cf. WESTHOFF 1958). The strong decrease of several (originally common) sub-central species demonstrates the very serious affection of our natural environment. This ecologically extremely negative development can be mainly attributed to large-scale activities inherent in our affluent society, which are greatly levelling the (semi-)natural habitats: reclamations and cultivations, agricultural re-allotments, artificial drainage operations, urbanization, abundant use of fertilizers and herbicides, the pollution of air, water, soil etc.

In fact, the position becomes really dramatic for those *Carex* species which are restricted to structurally endangered habitats, such as:

meso-oligotrophic valley-bogs and heath-pools (alliance *Rhynchosporion albae*, *Erico-Sphagnion*) with *C. limosa* and *C. lasiocarpa;*
- mesotrophic fens and quivering fen peatland (*Caricion curto-nigrae*, *Caricion davallianae*) with *C. lasiocarpa*, *C. diandra* and *C. appropinquata*;
- base-rich mires and fens influenced by seepage (*Caricion davallianae*) with *C. appropinquata*, *C. dioica*, *C. pulicaris*, *C. flava* (s.s.) and *C. lepidocarpa* (?);
- litter fens and grassy wet heathlands (*Junco-Molinion*, *Ericion tetralicis*) with *C. pulicaris* and *C. hostiana*;
- occasionally grazed dry grassland on river dunes (*Sedo-Cerastion*, *Mesobromion*) with *C. ligerica*, *C. praecox* and *C. caryophyllea*;
- occasionally grazed or mown vegetations fringing scrub and woodland (*Galio-Alliarion*, *Trifolion medii*, *Carpino-Berberidion*) with *C. muricata*, *C. polyphylla*

and *C. divulsa*;
– rich woods on base-rich clay or limestone soils (*Alno-Padion, Carpinion betuli*) with *C. strigosa, C. pendula* and *C. digitata.*

In The Netherlands these precious plant communities and associated *Carex* species only stand a fair chance of survival in sufficiently large, adequately buffered and carefully maintained Nature Reserves.

ACKNOWLEDGEMENTS

I am deeply indebted to the late Professor Dr. D. Bakker for disclosing to me the fascinating world of *Carex*, and for his trust and encouragement during my study at the University of Groningen. I thank J. P. Bakker and W. Joenje for giving valuable suggestions and help during the preparation of the manuscript. I am grateful to E. J. Weeda for critically reading the manuscript and for giving information about distribution data of some *Carex* spp. Special thanks are due to J. Haeck and R. Hengeveld for supplying some unpublished phytogeographical data, to E. Leeuwinga for drawing the figures, and to M. van Nek for correcting the English text.

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