Phytosociological and floristic evaluation of a 15-year ecological management of roadside verges in the Netherlands

Fytocenologické a floristické změny ve vegetaci silničních okrajů v Nizozemsku v průběhu 15 let

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Dedicated to the memory of Slavomil Hejný

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This paper investigates and evaluates the effects of ecological management on the vegetation of roadside verges in the Netherlands, conducted by the Ministry of Transport (Public Works Department). A total of 545 relevés, made between 1986 and 1988, were re-examined in 2001. Data were analysed for changes in number of species, rarity of species, red list (endangered) species and syntaxonomical species groups. The total number of species almost did not change. Common species increased while rare species decreased. The red list species declined by 40%. Species from shrub and woodland, from fertile, wet soils and from nitrophilous fringes increased, while species characteristic of relatively open and nutrient-poor habitats and some pioneer communities decreased. Plant communities were valued, and phytosociological changes were evaluated, using the deductive method of Kopecký and Hejný and knowledge about vulnerability, rarity and replaceability. In 44.5% of the 465 evaluated relevés, the vegetation value remained unchanged, in 23.0% it decreased and in 32.5% it increased. The different trends tended to counterbalance one another, resulting in an unchanged mean vegetation value. The increase in vegetation value is mainly due to the increase in relevés containing species rich *Arrhenatheretum*-subassociations. The decrease is mainly due to a decrease in moist heath, dry sandy pioneer communities and grasslands on relatively poor soils, and the increase of species-poor nitrophilous tall herb communities and woody vegetation. In some of the verges studied, the vegetation value decreased as a result of inappropriate management and construction. Suggestions for improvement are given. Local successes indicate that appropriate management can considerably improve the botanical value of roadside verges, and consequently their value for other life forms.

Keywords: Ecological management, roadside verges, vegetation value, deductive method, vegetation change, The Netherlands

Introduction

The importance of roadside verges for plant communities and plant species has been studied by many authors, e.g. Williams-Ellis (1967), Hansen & Jensen (1972), Olschowy (1975), Ellenberg et al. (1981), Duvigneaud (1982), Krause (1982), Gilgen (1983), Wegelin (1984), Brandes (1988), Rattay-Prade (1988), Stottele & Schmidt (1988, 1989) and Stottele (1991). The books of Kaule (1986), Dowdeswell (1987) and Röser (1988) present an overview of the ecological function and importance of conservation of small elements in the landscape.

In England, public interest in the conservation of the flora and fauna of roadside verges developed in the fifties. This interest was a reaction to the concern over the increasing use of herbicides (Way 1977). In 1978 Kopecký presented the first complete phytosociological overview of road verges in the Orlické Hory mountains in the former Czechoslovakia, which was followed by overviews of the plant communities of Dutch and Belgian roadside verges (Sýkora et al. 1993, Zwaenepoel 1998).

The area covered by roadside habitats in the Netherlands was estimated at approximately 60,000 ha in 1993 (Schaffers 2000). This represents 1.7% of the total land area of the Netherlands; a considerable area when compared to the 4.2% covered by designated nature areas. The total length of non-urban roads in the Netherlands is approximately 70,000 km (Centraal Bureau voor de Statistiek 1997a, 1997b).

About two-thirds of the Dutch land surface is used for intensive agriculture. Here, biodiversity is low and many species are restricted to river dikes, and verges of roads, railways and water courses (Sýkora et al. 1989). With the exception of a few nature reserves, extensively managed grasslands are now found only on roadside verges (Sýkora et al. 1993). As refuges, roadside verges contribute to the conservation of nature. Roadside verges, if properly managed and constructed, can therefore make a valuable contribution to the size and distribution of nature areas. To restrict nature conservation solely to designated nature reserves is insufficient. Improvement of the ecological quality of the immediate surroundings of areas used by humans should be of continuous concern.

Despite a national policy aimed at conserving and improving nature, biodiversity is still decreasing. Rare species become rarer and common species are stable or increasing in abundance (Bink et al. 1994). In addition to eutrophication, acidification and desiccation, the decrease in biodiversity is attributed to the isolation and fragmentation of nature reserves and of species populations. To counteract fragmentation, the Dutch Government published a "Nature Policy Plan (Natuurbeleidsplan)" (Anonymous 1990), which proposed the establishment of dispersal corridors between fragmented areas. Roadside verges were to play an important role as ecological corridors. For plant species, however, roadside verges can only function as corridors when the type of vegetation and environmental conditions correspond to the fragmented elements to be connected. To meet these conditions, ecological management of road verges needs to be carefully planned and implemented.

Aside from functioning as corridors, roadside verges can provide suitable habitats for endangered plant communities and species. During the inventory of plant communities on Dutch roadside verges, 69 different plant communities were distinguished, belonging to 13 syntaxonomical classes and 16 orders (Sýkora et al. 1993). However, many plant communities were only fragmentarily developed. More than half (55%, 798 species) of the Dutch phanerogam flora are found in roadside verges, 17% (139 species) of which are rare in the Netherlands. Moreover, 123 species of mosses and lichens were recorded. Several types of roadside verges are also important habitats for fungi (Keizer 1993).

The interest in the ecological values of roadside verges began around 1970 and resulted in a change in environmental management policy. In 1981 the government stated in a policy document that the construction and management of roadside verges should aim at the encouragement of species rich natural communities (Anonymous 1981). Because of developments in Dutch society, which favoured the conservation of nature, the ecological management of roadside verges was incorporated into the policy of the Ministry of Transport, Public Works and Water Management. The next important and positive step is the intention officially expressed by the government in the "National Traffic and Transport Plan 2001–2020 (Nationaal Verkeers- en Vervoersplan 2001–2020, Beleidsvoornemen-Deel C)" which reads as follows: "The government will ecologically manage the main infrastructure of roadside verges where this is useful from an ecological and restoration point of view[1]"

Roadside verges can only function as corridors or as suitable habitats for endangered plant communities and species if properly and successfully managed. Although roadside verges in the Netherlands have been ecologically managed for many years, the success of this management, i.e. its effect on botanical and on vegetation value has not been studied. In regional districts, the results of management are evaluated from time to time by local managers. In this paper, we present the results of the first countrywide re-inventory and evaluation. It is based on a comparison of relevés made in verges of national main roads in the years 1986–1988 and again in 2001.

The main purpose of this study is the evaluation of the ecological management of roadside verges in terms of changes in flora and vegetation and consequently in their botanical and vegetation value. The main question posed is, can ecological management be an effective tool for the conservation and development of rare plant species and plant communities?

The following specific questions are posed: 1. Did the total number of species change? 2. Did the number of rare and red list species change? 3. Which specific syntaxonomic species groups increased, or decreased? 4. Did highly productive nitrophilous tall vegetation increase or decrease? 5. Did the management cause desired changes in vegetation value?

Methods

Sampling of vegetation data

In 1986, 1987 and 1988, a total of 2552 relevés were made in verges along various types of roads (highways, secondary and tertiary roads and in some cases even unpaved roads) all over the Netherlands (Sýkora et al. 1993). Sample sites were selected according to the Braun-Blanquet method (Westhoff & Van der Maarel 1973, Van der Maarel 1975) in order to cover as much variation in vegetation as possible (Sýkora et al. 1989, Szwed & Sýkora 1996). Consequently the sample sites were not evenly or randomly distributed over the Dutch roadside verges.

Of the total database containing 2552 relevés, only the 545 along highways (national roads) were sampled again in 2001. Since sites of 44 of the relevés were destroyed due to road (re)construction, or were not refound, a total of 501 relevés were re-sampled (Fig. 1). Although there are no data on the area of roadside verges covered by the different plant communities, it can be easily estimated as was done by Sýkora et al. (1993). The number of relevés made in each plant community is related to their rarity in Dutch roadside verges. For instance in 1986-88, 56 relevés were made in the common *Arrhenatherion* vegetation, whereas only 5 relevés were made in the rather rare *Calthion* vegetation. Number of relevés recorded in each community and the successional changes that occurred during the study period are given in Table 3.

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[1] Original Dutch text "Het rijk zal alle bermen van de hoofdinfrastructuur ecologisch beheren waar dit natuurtechnisch zinvol is", translation by the authors.

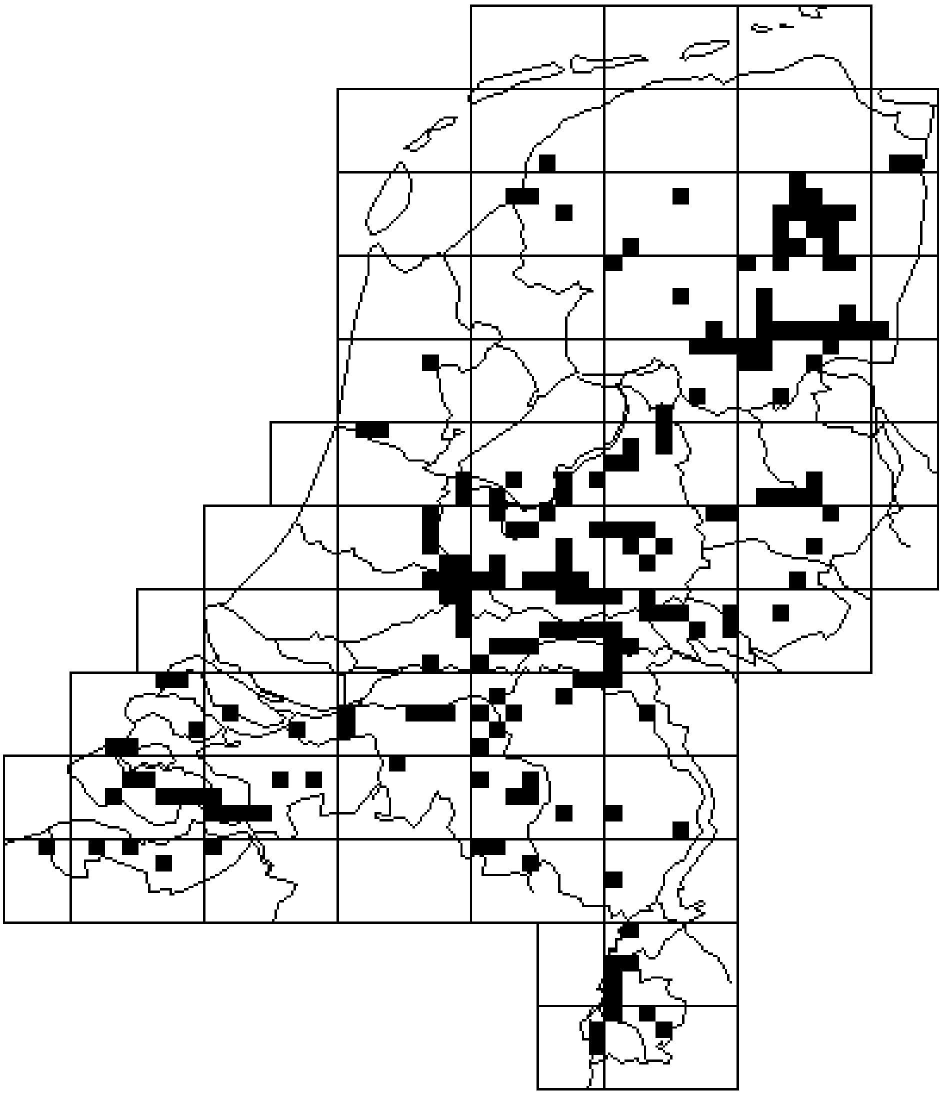

Fig. 1. – Distribution of the 545 repeated relevés along the national highways of the Netherlands.

For estimating the quantitative occurrence of each species, the refined Braun-Blanquet scale (Barkman et al. 1964) was used. In general, the size of a relevé was 25 m^2. In 1986–1988, relevés were selected so that the principle of homogeneity could be applied. In 2001 homogeneity was not taken into consideration, but the exact location and shape of a plot was reconstructed using maps and notes from the first period. In 1986–1988 the relevés were made by L. de Nijs, in 2001 by J. M. Kalwij and P.-J.Keizer, who were advised by L. de Nijs. In both periods the research was supervised by K. V. Sýkora. Relevés were made from May to the end of August.

The names of phanerogams follow the Dutch flora (Meijden 1996).

Evaluation of changes

The species lists from both periods were compared and the distribution of the species in each rarity class in 1990 analysed. These rarity classes, so called hour square frequency classes (hsfc), are based on a total of 1677 grid cells of 25 km^2 each, so called hour squares (Centraal Bureau voor de Statistiek 1991). The rarity classes are defined on the basis of the occurrence of species in the grid cells as follows: extremely rare (species present in 1–3 grid cells); very rare (4–10); rare (11–29); rather rare (30–79); less common (80–189); rather common (190–410); common (411–710); very common (711–1210); extremely common (1211–1677).

The Red List of threatened species in the Netherlands was used (Van der Meijden et al. 2000).

Syntaxonomical species groups were based on Westhoff & Held (1969) recorded in a software database (Centraal Bureau voor de Statistiek 1991). A syntaxonomic species group consists of the character species of one syntaxon. The classification of Westhoff & Held (1969) was used as it is available in computerized form. We did not use the most recent overview of the plant communities of the Netherlands (Schaminée et al. 1996, Schaminée et al. 1998), because a detailed syntaxonomical treatment was not the purpose of our study, which was to evaluate the general botanical value and vegetation value of roadside verges by considering changes in syntaxonomic species groups that occurred in roadside verges.

Value of the vegetation

Each relevé was assigned to an association, or if that was not possible to the next highest level of classification, according to Schaminée et al. (1989) and Schaminée et al. (1995) using SYNDIAT software (Pot 1997, Pot 2001). The suggestions made by SYNDIAT were critically examined and either accepted or rejected and changed for each relevé.

Based on our opinion and the criteria given below, each of the plant communities was assigned a value judgement. Each plant community was evaluated and the vegetation value scored according to the following scale: 1 – very high; 2 – high; 3 – medium; 4 – low; 5 – very low.

The significance of the vegetation type for the presence of rare species, the vulnerability of the community (sensitivity to eutrophication, disturbance, mismanagement), its rarity and replaceability were taken into account in the assessment of the vegetation values of each vegetation type. Of course rarity is used as applicable in the Netherlands. Unfortunately a red list of plant communities is not yet available for the Netherlands. The sensitivity to eutrophication, disturbance and mismanagement was based on knowledge of the synecology of the plant communities. For instance *Ranunculo-Senecionetum* and *Ericetum tetralicis* are vulnerable, rare, and difficult to restore, consequently their value is very high (Value 1). In contrast *Ranunculo-Alopecuretum* and *Tanaceto-Artemisietum* occur on nutrient-rich soils, are much less vulnerable, more easily restored and rather common. Consequently they have a medium value (3).

Another important criterion was the degree of saturation of plant communities, as defined by the deductive method (Kopecký 1977, 1978, 1984, 1986, 1988, Kopecký & Hejný 1971, 1974, 1978, 1990). A plant community is considered to be phytosociologically saturated, if it can be assigned to the association level, because sufficient number of character species of that level are present. With increasing disturbance, and sometimes also due to natural dynamics, character species of lower classification levels disappear, and plant communities can only be assigned to the level of alliance, order or class. We consider the vegetation value to decrease during this process. Taking this into account, unsaturated plant communities are given low values. For instance from *Arrhenatheretum luzuletosum*, to fragmentary communities of *Arrhenatherion*, to fragmentary communities of *Molinio-Arrhenatheretea* the value decreases form high to medium to low. Consequently the value of communities at the same level of hierarchy can be different, e.g. *Nardo-Galion* has a high value (1) while *Galio-Alliarion* has a very low value (5). All criteria were used and weighted based on our knowledge and data in the literature. Since this method is rather vague, with no clear formulas or decision rules, the values are given in Table 3.

The vegetation values were used to calculate the temporal changes and compare the number of relevés per value class. A change of relevé value by 4 classes was the maximum, 3 strong, 2 moderate and 1 slight.

Apart from the term vegetation value, exclusively used for vegetation types, i.e. species combinations, we also use "botanical value". The latter is used in a wider, floristic sense, i.e. the presence of rare or endangered species independent of vegetation type.

The number of relevés containing highly productive vegetation, i.e. tall, mostly nitrophilous herbs and shrubs in both periods were compared (for a list of the communities considered to belong to this category see Table 1). One of the communities in this list could not be assigned to any syntaxon and as it was dominated by *Juncus conglomeratus,* it was named *Juncus conglomeratus* facies. A facies is not defined in terms of diagnostic species and is not part of a formal hierarchy (Westhoff & Van der Maarel 1973).

Table 1. – Comparison of the number of relevés with species-poor nitrophilous tall vegetation or with woody species in 1986–88 and 2001. Saturated plant communities and fragmentary communities, even when from one class, are presented separately (e.g. *Tanaceto-Artemisietum* and the fragmentary *Artemisietea* community). / = transitional community.

Nitrophilous tall-herb/shrub/wood communities	1986-88	2001	Difference
Phragmitetea	0	5	5
Molinio-Arrhenatheretea	20	23	3
Alopecurion pratensis	8	18	10
Artemisietea vulgaris	8	5	–3
Tanaceto-Artemisietum	4	20	16
Convolvulo-Filipenduletea	3	9	6
Galio-Urticetea	9	8	–1
Galio-Alliarion	0	3	3
Arrhenatheretum/Valeriano-Filipenduletum	1	0	–1
Juncus conglomeratus facies	0	1	1
Shrub or wood	1	13	12
Total number of relevés	54	105	51

Results

In 2001, 410 phanerogams were found, compared to 409 in 1986–1988. In the time between the studies, 76 species disappeared, and 77 new species appeared.

Between 1986–88 and 2001 there was an increase in "common species" (rarity class 7, Fig. 2). The categories "rather common" (rarity class 6) and "very common" (rarity class 8) increased by only one and two species, respectively. In contrast, the categories "very rare" (rarity class 2) to "less common" (rarity class 5) decreased.

Over the period there was a decrease in the number of species in all Red List categories (Fig. 3), with the strongest decline in endangered species (RL 3). The total number of Red List species declined by 18 (40%).

The majority of nitrophilous tall vegetation is highly unsaturated and was assigned to higher classification levels. One community is transitional between two associations and one vegetation type dominated by *Juncus conglomeratus*. The proportion of relevés with tall herbs or shrubs nearly doubled, especially the fragmentary *Alopecurion pratensis* community, the *Tanaceto-Artemisietum* and the shrub/wood vegetation (Table 1).

In particular syntaxa the species richness changed (Table 2). While the number of species of shrubs and trees, and sites with fertile wet soils and nitrophilous fringes clearly increased, there was a decline in character species of plant communities of infertile sites, such as small-sedge poor-fen vegetation on acid soils, small-sedge rich-fen vegetation on

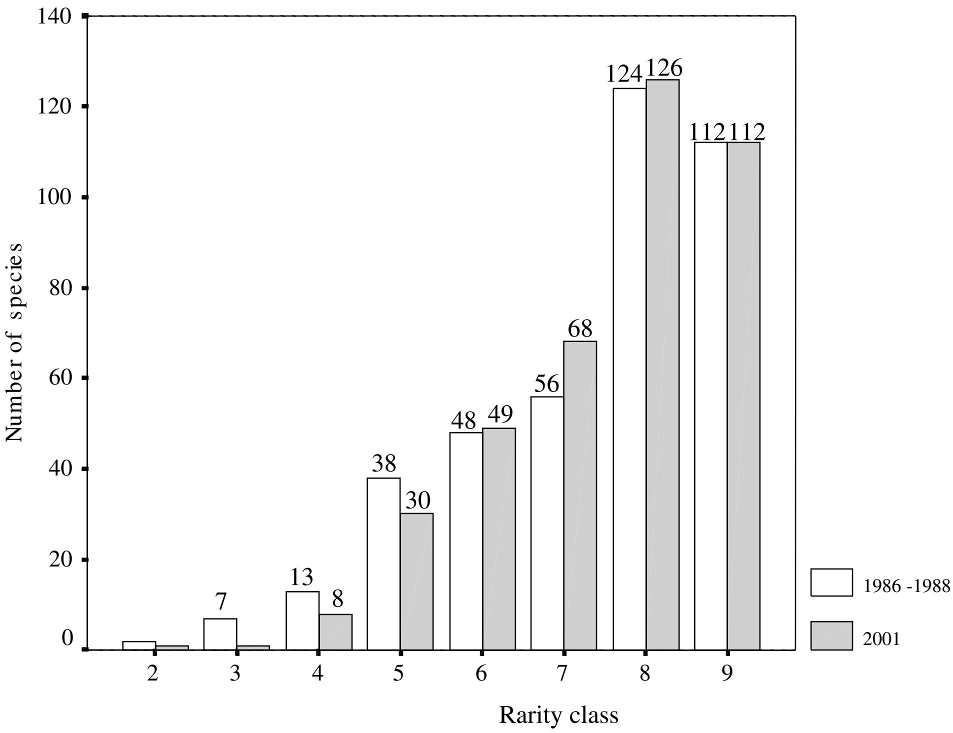

Fig. 2. – Number of species per rarity class in the years 1986–88 and 2001, respectively. Rarity class 2 = very rare, 3 = rare, 4 = rather rare, 5 = less common, 6 = rather common, 7 = common, 8 = very common, 9 = extremely common.

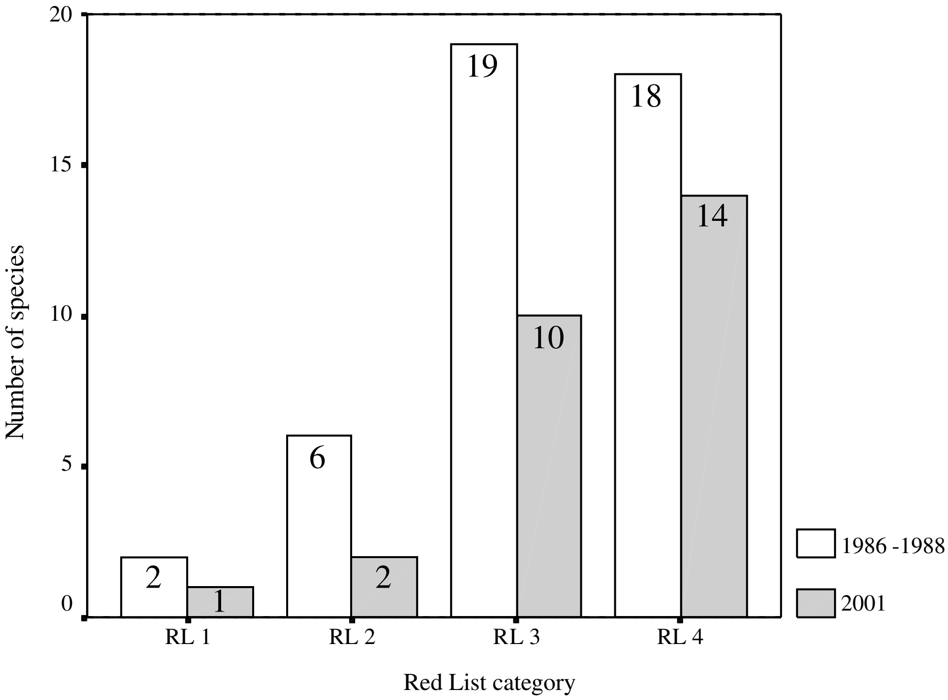

Fig. 3. – The number of Red List species encountered in 1986–88 and 2001 respectively, per category. RL1 = very strongly endangered, RL2 = strongly endangered, RL3 = endangered, RL4 = potentially endangered.

Table 2. – Change in number of species per syntaxonomic species group. The difference between species numbers recorded in 1986–1988 and 2001 is shown for each unit.

Number of species decreased		Number of species increased	
Origanetalia	4	*Prunetalia spinosae*	6
Aphanion	3	*Nasturtio-Glycerietalia*	4
Caricion davallianae	3	*Querco-Fagetea*	4
Mesobromion	3	*Salicion albae*	3
Ericion tetralicis	2	*Carpinion betuli*	2
Koelerio-Corynephoretea	2	*Alno-Padion*	2
Caricion curto-nigrae	2	*Galio-Alliarion + Aegopodion*	2
Fagetalia sylvaticae	2	*Seacalietea*	1
Arction	2	*Phragmitetea*	1
Agropyro-Rumicion (= *Lolio-Potentillion*)	1	*Potametea*	1
Chenopodietea	1	*Nanocyperion*	1
Sisymbrietalia	1	*Polygono-Coronopion*	1
Sisymbrion	1	*Artemisietea*	1
Onopordion	1	*Filipendulion*	1
Plantaginetea majoris	1	*Violion caninae*	1
Lolio-Plantaginion	1	*Sambuco-Salicion*	1
Epilobietalia	1		
Festuco-Sedetalia	1		
Thero-Airion	1		
Sedo-Cerastion	1		
Molinio-Arrhenatheretea	1		
Arrhenatherion	1		
Vaccinio-Genistetalia	1		
Polygono-Chenopodion	1		

Table 3. – Listing of plant communities ordered by vegetation value for both 1986–88 and 2001. Change in a plant community is indicated by connecting lines.
1–2 relevés ——— ; 3–5 ——— ; 6–10 ——— ; 11–15 ——— ; >15 ——— .
Vegetation value class 1 = very high, 2 = high, 3 = medium, 4 = low, 5 = very low.

1986-88	value	change	2001
Lycopodio-Rhynchosporetum	1		Lycopodio-Rhynchosporetum
Ericetum tetralicis	1		Ericetum tetralicis
Spergulo-Corynephoretum	1		Spergulo-Corynephoretum
Ornithopodo-Corynephoretum	1		Ornithopodo-Corynephoretum
Festuco-Thymetum serpylli	1		Festuco-Thymetum serpylli
Medicagini-Avenetum	1		Medicagini-Avenetum
Ranunculo-Senecionetum	1		Ranunculo-Senecionetum
Galio hercynici-Festucetum ovinae	1		Galio-Festucetum
Caricion nigrae	2		Caricion nigrae
Ericion tetralicis	2		Ericion tetralicis
Triglochino-Agrostietum	2		Triglochino-Agrostietum
Trifolio fragiferi-Agrostietum	2		Trifolio fragiferi-Agrostietum
Corynephorion canescetis	2		Corynephorion canescetis
Sedo-Cerastion	2		Sedo-Cerastion
Junco-Molinion	2		Junco-Molinion
Calthion	2		Calthion
Arrhenatheretum typicum	2		Arrhenatheretum typicum
Arrhenatheretum festucetosum arundinaceae	2		Arrhenatheretum festucetosum arundinaceae
Arrhenatheretum luzuletosum	2		Arrhenatheretum luzuletosum
Nardo-Galion	2		Nardo-Galion
Genisto-Callunetum	2		Genisto-Callunetum
Lolio-Potentillion anserinae	3		Lolio-Potentillion anserinae
Ranunculo-Alopecuretum	3		Ranunculo-Alopecuretum
Plantagini-Festucion	3		Plantagini-Festucion
Molinietalia	3		Molinietalia
Arrhenatheretalia	3		Arrhenatheretalia
Arrhenatherion	3		Arrhenatherion
Lolio-Cynosuretum	3		Lolio-Cynosuretum
Calluno-Genistion	3		Calluno-Genistion
Tanaceto-Artemisietum	3		Tanaceto-Artemisietum
Trifolio-Festucetalia/Lolio-Potentillion	3		T.-Festucetalia/L.-Potentillion
Trifolio-Festucetalia/Molinietalia	3		Trifolio-Festucetalia/Molinietalia
Nardetea/Calluno-Ulicetea	3		Nardetea/Calluno-Ulicetea
Lolio-Potentillion/Arrhenatherion	3		L.-Potentillion/Arrhenatherion
K.-Corynephoretea/Ranunculo-Alopecuretum	3		K-Corynephoretea/R-Alopecuretum
Alopecurion/Molinietalia	3		Alopecurion/Molinietalia
Arrhenatheretalia/Trifolio-Festucetalia	3		Arrhenatheretalia/T.-Festucetalia
M-Arrhenatheretea/Lolio-Potentillion	3		M-Arrhenatheretea/L.-Potentillion
Melampyrion pratensis	3		Melampyrion pratensis
Juncus conglomeratus facies	3		Juncus conglomeratus facies
Rhinanthus facies	3		Rhinanthus facies
Nasturtio-Glycerietalia	4		Nasturtio-Glycerietalia
Polygonion avicularis	4		Polygonion avicularis
Plantagini-Lolietum	4		Plantagini-Lolietum
Coronopodo-Matricarietum	4		Coronopodo-Matricarietum
Koelerio-Corynephoretea	4		Koelerio-Corynephoretea
Trifolio-Festucetalia	4		Trifolio-Festucetalia
Molinio-Arrhenatheretea	4		Molinio-Arrhenatheretea
Alopecurion pratensis	4		Alopecurion pratensis
Calluno-Ulicetea	4		Calluno-Ulicetea
Artemisietea vulgaris	4		Artemisietea vulgaris
Convolvulo-Filipenduletea	4		Convolvulo-Filipenduletea
Caricetum gracilis/Molinio-Arrhenatheretea	4		Caricetum gracilis/M-Arrhenatheretea
Plantaginetea/Cynosurion	4		Plantaginetea/Cynosurion
Trifolio-Festucetalia/Plantagini-Lolietum	4		Trifolio-Festucetalia/P-Lolietum
Arrhenatheretum/V-Filipenduletum	4		Arrhenatheretum/V-Filipenduletum
Holcus mollis facies	4		Holcus mollis facies
Phragmitetea	5		Phragmitetea
Galio-Urticetea	5		Galio-Urticetea
Galio-Alliarion	5		Galio-Alliarion
Scrub/wood	5		Scrub/wood

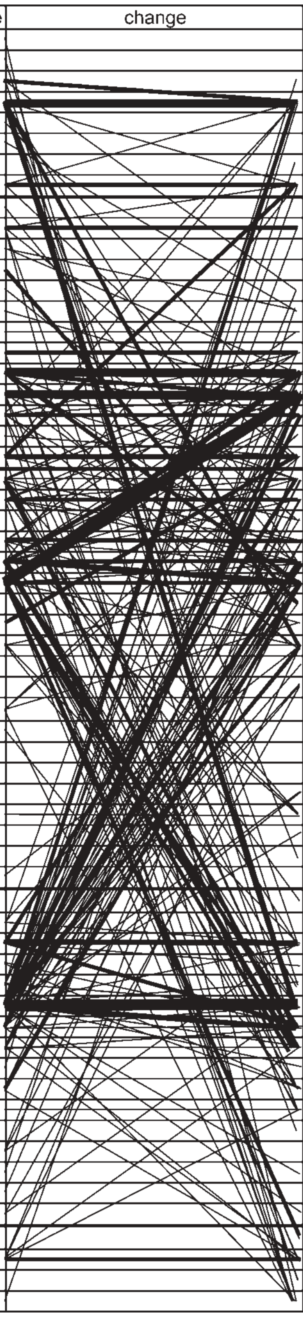

Table 4. – Percentage and number of relevés that changed in vegetation value between 1986–1988 and 2001. The number and percentage of the relevés that were not traced, lost due to road works, or not valued because it was impossible to define them syntaxonomically are also presented. A change of relevé value by 4 classes was considered as the maximum, by 3 classes strong, by 2 classes moderate and by 1 slight.

	%	No.		%	No.
No change	38	207			
			Maximum decrease	0.2	1
Strong increase	2.2	12	Strong decrease	3.7	20
Moderate increase	3.8	21	Moderate decrease	5.0	27
Slight increase	21.7	118	Slight decrease	10.8	59
Total increase	27.7	151	Total decrease	19.7	107
No value judgement	6.7	36			
Not traceable	5.0	27			
Lost by road engineering works	3.1	17			

calcareous oligotrophic flushes, soligeneous mires on peats or peaty mineral soils, wet heath, chalk grasslands, infertile dry sandy grasslands, pioneer communities, herbaceous vegetation of sunny edges of woodland on relatively infertile calcareous soils.

The plant communities of the roadside verges are listed and ordered according to their vegetation value in Table 3, where the changes are also indicated.

Table 4 summarizes the changes in vegetation value. The vegetation value of 207 of the relevés remained unchanged, that of 151 increased and 107 decreased. The higher number of relevés with an increased vegetation value is due to the category "slight increase". Those with a moderate to maximum decrease in value (48) outnumber those with a moderate to strong increase (33).

Overall, increase and decrease counterbalance each other, resulting in an almost equal mean vegetation value in both periods (2.94 in 1986–1988 and 2.90 in 2001).

The vegetation values of relevés assigned very low values in 1986–1988 increased over time by 90.0% and those assigned high values also increased by 40.8%. A decrease was recorded in the remaining categories, i.e. very high (12.8%), medium (12.2%), and low (21.6%).

The following changes in representation of plant communities occurred:

1. Communities with a very high vegetation value (1) decreased due to the disappearance of *Lycopodio-Rhynchosporetum*, *Ericetum tetralicis*, *Festuco-Thymetum serpylli* and *Medicagini-Avenetum*, and decrease of *Spergulo-Corynephoretum* and *Ornithopodo-Corynephoretum* (Table 3). However, *Galio hercynici-Festucetum ovinae* increased. This community consists of grass-heathlands on acidic, nutrient poor mineral soils, which developed from *Genisto-Callunetum, Ornithopodo-Corynephoretum* and fragmentary *Trifolio-Festucetalia* and *Ericion* communities (Table 3).
2. Communities with a high vegetation value (2) increased, almost exclusively due to the increase of saturated, species-rich *Arrhenatheretum* subassociations, i.e. *festucetosum*

arundinaceae, typicum and *luzuletosum campestris*, and *Calthion*. *Sedo-Cerastion* increased slightly, *Genisto anglicae-Callunetum* did not change and *Ericion* decreased.
3. Communities with a medium value (3) decreased strongly due to a decrease in *Arrhenetheretalia* and *Arrhenatherion* fragmentary communities. *Tanaceto-Artemisietum* increased from 4 to 20 relevés, developing mainly from fragmentary *Trifolio-Festucetalia, Arrhenatherion, Galio-Urticetea* communities, *Ornithopodo-Corynephoretum* and *Arrhenatheretum*.
4. Communities with a low vegetation value (4) mainly decreased due to the considerable decrease in fragmentary communities of *Koelerio-Corynephoretea* and *Trifolio-Festucetalia ovinae*; *Alopecurion* and *Convulvulo-Filipenduletea* increased.
5. Communities with a very low vegetation value (5) increased due to the increase of woody species and fragmentary *Phragmitetea* communities.

Discussion

Over the time span of the study the total number of species hardly changed. However, the total number of species is of less importance than the botanical value of these species. Rarity, ecology and syntaxonomical species groups are better indicators of botanical value.

The increase in the number of common species and the decrease in rare and threatened species is a negative trend. The decrease is in accordance with the changes in syntaxa. Plant communities with rare and Red List species have decreased, while those that are unsuitable for these species and are made up of more common species have increased.

As can be expected, so-called rare species, are by definition rare in the Netherlands and more so in roadside verges. The fewer the sites the greater the chance that these species will disappear from the total list of species found. Common species have to disappear from many more sites before they are no longer found. The disappearance of rare species, even if more likely, is still a negative phenomenon. Consequently, sites with rare species (hot spots) should be given more attention and special care. Possibly rare species might even increase when ecological management and construction are more intensively applied.

The decrease in threatened species could be a result of changes in habitat conditions and local extinction of populations, without re-colonization of the habitats due to a lack of neighbouring seed sources (Fischer 1982, Ullman 1984). Our observations show that roadside verges are now less used as a habitat by endangered species than previously.

The deductive method of vegetation classification introduced by Kopecký & Hejný (1978) is a very useful tool for nature management. The degree of saturation of plant communities, a criterion of this method, can be used to judge vegetation change in detail. As character species of lower syntaxonomic levels, like association and alliance, have narrower ecological amplitudes than those of higher taxonomic levels, saturated communities tend to have more rare species than fragmentary communities from which the character species of subordinate levels have disappeared. Of course if a fragmentary community typically contains rare species, its value increases. In this study rare species were restricted to more or less saturated communities.

In this study both increases and decreases in vegetation value were detected. Sites that changed were equally distributed over the verges of the Dutch national trunk roads. Relevés with very high vegetation values decreased slightly due to a decrease in moist heath vegetation, open or closed dry sandy pioneer communities and grasslands on poor to moderate fertile soils. Species that are characteristic of relatively open and nutrient-poor habitats and some pioneer communities are vulnerable and difficult to maintain under current vegetation management. Open pioneer communities disappeared due to natural succession in the absence of disturbance. In the past, these communities commonly developed in the acid and nutrient-poor drift sands of roadside verges of newly built roads. These pioneer communities can be restored by intentional disturbance. For moist heath communities, a constant hydrological regime and the presence of oligotrophic water is a prerequisite. Because of atmospheric nutrient deposition the preservation of these moist heath communities is very difficult, even in nature reserves.

The strong increase in the number of relevés with high vegetation values is almost exclusively due to an increase in saturated, species-rich *Arrhenatheretum* subassociations (hay meadows on relatively fertile and dry soils). This stresses the importance of roadside verges for the protection of species-rich hay meadows.

This vegetation type has declined dramatically nationally and is now almost entirely restricted to roadside verges and river dikes. In addition, since these grasslands also form important habitats for a significant range of insects and other arthropods (Free et al. 1975, Munk 1986, Vieth 1990, Mungira & Thomas 1992, Raemakers et al. 2001), maintaining and protecting them should be a priority for all managers of roadside verges. This restoration of these grasslands is possible, but only when properly managed. The majority of relevés with saturated subassociations developed out of fragmentary communities of *Arrhenatherion* (32 relevés), *Arrhenatheretalia* (8) and even *Molinio-Arrhenatheretea* (7), as a result of regular mowing and removal of hay. This accords with the results of Mederake (1991), which showed an increase in species number and a decrease in species indicating disturbance in regularly mown roadside verges. Small herbs with low competitive ability were favoured.

Due to eutrophication and/or irregular management or even the absence of management, nitrophilous tall perennial herbs increase and start to dominate the vegetation, ousting smaller species (Heindl 1992). Although continental ruderal tall-herb communities can be species-rich, many nitrophilous, closed, tall-herb communities are species-poor, consist of common species only and are considered to have a low vegetation value (Pigott et al. 2000). This appeared to be the case in the tall herb communities in the roadside verges in this study. Shrub and tree encroachment also decreases the vegetation value as they oust species rich low vegetation, are species-poor themselves consisting of very common species only.

Suggestion for management

Based on this research and on field observations the following improvements for management are suggested:

1. Only local and unfertilized soil material should be used when (re)constructing roads. Covering roadside verges with a fertile top layer (black soil), often applied after (re)construction of the verges, leads to highly productive vegetation types with a low vegetation value (Mederake 1991).
2. Large amounts of nutrients are leached from grass cuttings during the first few weeks. Therefore, when soil impoverishment is an objective, grass cuttings must be removed

within 1 or 2 weeks (Schaffers et al. 1998). Hay removal reduces the effect of atmospheric deposition of nutrients. In the Netherlands, nitrogen deposition ranges between 35 and 75 $kg \cdot N \cdot ha^{-1} \cdot year^{-1}$ and in forest margins in intensively used agricultural areas, depositions of 100 to 150 $kg \cdot N \cdot ha^{-1} \cdot year^{-1}$ have been measured (Meent et al. 1984, Breemen et al. 1988, Leijn et al. 1989, Bobbink et al. 1990, Dam 1990, Ivens 1990, Houdijk & Roelofs 1991, Bobbink et al. 1992, 1995, Heij & Schneider 1995).

3. Hay should be removed (Parr & Way 1988). Where organic matter accumulates, it stimulates species poor tall-herb communities. The layer of litter hinders germination and establishment of poorly competing species (Watt 1970). Mineralization of litter leads to soil enrichment. As organic matter has a strong water absorbing capacity, the moisture in the topsoil increases and production is promoted (Mederake 1991). Reintroduction of mowing successfully restored and improved neglected ruderalized grasslands (Liebrand 1999).
4. Vegetation management should be continuous (Way1970, 1977). If verges are not mown, the vegetation gradually turns into tall-herb communities, shrub and ultimately forest. An example is the *Lycopodio-Rhynchosporetum,* a plant community with a very high value, which turned into a *Salix-Betula* shrub. This could have been prevented by mowing and occasional turf removal. Other examples of relevés turning into scrub are fragmentary communities of the *Ericion, Trifolio-Festucetalia, Arrhenatherion, Calluno-Genistion* and *Nardetea/Calluno-Ulicetea*. Other examples are *Arrhenatheretum luzuletosum, Ranunculo-Alopecuretum* and *Genisto-Callunetum.* Clearly, knowledge on the appropriate management of special and valuable vegetation types should be improved among roadside managers.
5. Often management is neglected. The management measures should be applied correctly, for example regarding mowing periods, frequency and methods.
6. Mud from ditches should not be deposited on roadside verges.
7. Treading, cars, rotary cultivators and excavation works (for instance laying of cables) compact and disturb soil, and should be reduced. On nutrient and humus poor, relatively acid sand, mechanical disturbance can promote the (re)development of the *Ornithopodo-* and *Violo-Corynephoretum*.
8. Supervision of management so that bad vegetation management can be corrected, is necessary. Knowledge of where sites of special interest ("hot spots") are located and their optimum management must be communicated to local managers.

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Souhrn

V práci je vyhodnocen vliv managementu prováděného nizozemským ministerstvem dopravy na vegetaci silničních okrajů. 545 vegetačních snímků pořízených v letech 1986–1988 bylo znovu lokalizováno v roce 2001 a srovnáno s výchozím stavem. Byly sledovány změny v počtu druhů se zřetelem na výskyt vzácných druhů uvedených na červeném seznamu a syntaxonomických druhových skupin. Celkový počet zjištěných druhů se za sledované období téměř nezměnil; přibylo druhů běžných, naopak ubyly vzácné. Vymizelo 40 % druhů z červeného seznamu, které byly přítomny v 80. letech 20. století. Zvýšilo se zastoupení druhů křovin a lesních stádií z úživných vlhkých půd a druhů typických pro dusíkatými živinami bohaté lemy, ustoupily druhy otevřených, živinami chudých stanovišť a druhy časných sukcesních stádií. Jednotlivým rostlinným společenstvům byla pomocí pětičlenné stupnice přiřazena tzv. „vegetační hodnota“, beroucí v potaz jejich vzácnost, nahraditelnost a stabilitu výskytu. Ve 44.5 % snímků hodnocených syntaxonomicky deduktivní metodou Hejného a Kopeckého se tato hodnota nezměnila, u 23.0 % se snížila, v 32.5 % případů zvýšila. Celkově stabilní hodnota této charakteristiky je dána působením rozličných protichůdných trendů. Nárůst je do značné míry způsoben zvýšením zastoupení druhově bohatých porostů asociace *Arrhenatheretum elatioris* a jejích subasociací. Pokles vegetační hodnoty je vyvolán ústupem vlhkých vřesovišť, pionýrských společenstev písčitých půd a travinných porostů na relativně chudých půdách a současným nárůstem druhově chudých nitrofilních společenstev vysokých bylin a dřevin. V některých případech poklesla hodnota v důsledku nevhodného managementu. V závěru článku jsou předloženy návrh, jak maximalizovat vegetační hodnotu silničních okrajů a je zdůrazněna role vhodného managementu.

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