Maintenance of plant species diversity on dairy farms.

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MAINTENANCE OF PLANT SPECIES DIVERSITY ON DAIRY FARMS

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CONTENTS

1

GENERAL INTRODUCTION

1.1 Impoverishment of plant species diversity in peat areas

Agricultural developments have led to a considerable decrease in diversity of plant species in western Europe (Rat von Sach-verständigen für Umweltfragen, 1985; Wolff-Straub, 1985a). The peat areas of the western Netherlands, which are among the most intensively exploited areas of western Europe, are no exception. The long and narrow grassland lots in the reclaimed peat bogs are used for dairy farming, which has intensified considerably in recent decades (Van Burg et al., 1980). Only a few decades ago species-rich and flower-rich hayfields and pastures were far from scarce in the western lowlands (De Vries, 1953; Van der Voo, 1965; Westhoff et al., 1971; De Boer, 1982). However, they have been largely replaced by species-poor pastures with a *Poo-Lolietum* vegetation (De Boer, 1982; Janssen & De Heer, 1983). The water in the ditches which separate the lots has become eutrophic and is often completely covered by a blanket of *Spirodela polyrhiza* and *Lemna spp.* (De Groot et al., 1987), leaving few opportunities for the growth of other plant species. On the ditch banks, remnants of the mesotrophic grassland communities can still be found (Melman et al., 1988). But the vegetation of these ditch banks is also becoming more and more impoverished. Many species that until recently were common in the farming landscape are declining, such as *Caltha palustris, Lychnis flos-cuculi, Carex nigra, Carex disticha* and *Anthoxanthum odoratum*, whereas only a few species such as *Polygonum hydropiper* and *Elymus repens* are increasing (Clausman & Groen, 1987). As a result of the intensive farming only remnants of species-rich plant communities are to be found.

1.2 Conservation strategies in the Netherlands

For some years governmental and other organizations in the Netherlands have been trying to diminish the species-impoverishing influence of agriculture. Several conservation strategies can be distinguished, associated with different objectives and with different opinions about the relation between man and nature. The strategies range from the conservation of nature areas without any human intervention to the maintenance of wild plant and animal species in an intensively man-exploited environment:

(1) The nature development approach. This approach states that exploitation by man cannot be combined with nature conservation. Therefore, this strategy is not aimed at farming landscapes, but argues for the preservation or creation of large, entirely "natural" areas. The aim is to conserve complete and natural ecosystems without human intervention (Van de Veen, 1985). As far as the peat areas are concerned, it has been proposed that farmland be inundated in order to restore the original marshes in these areas. This might stimulate peat-forming processes to resume and will instigate "natural" developments, which should result in a fenland area resembling the landscape before its reclamation and cultivation by man.

(2) The approach outlined in the Policy Document on Agriculture and Nature Conservation (the so-called "Relatienota"). In 1975 the Dutch government published a policy document on environmentally sensitive areas, which describes the current conservation policy in the rural areas of the Netherlands. This approach is based on the opinion that only the former farming practices benefit the wildlife, but that modern agriculture and nature conservation are fundamentally conflicting functions. Therefore, the strategy opts for the conservation and restoration of the former farming landscapes with their associated extensive forms of agriculture and diversity of wildlife in a limited number of areas and for modern agriculture in all other rural areas. The Policy Document on Agriculture and Nature Conservation deals with the establishment of nature reserves and with the drawing up of management agreements with farmers in certain areas, whereby farmers are persuaded to restrict their use of fertilizer, manure or herbicides, etc. to protect nature and landscape; agricultural losses are financially compensated for (Ministry of Agriculture & Fisheries, 1987; De Boer & Reyrink, 1988).

(3) The "integration" approach. In contrast to the two former strategies, this approach starts from the expectation that adaptations of modern agriculture can provide opportunities for wild species to remain in all rural areas. The aim is to have as many wild species as possible within an adapted agriculture, with the object of integrating economic, social, environmental and conservational objectives at the same time (Van der Weijden et al., 1984; Ebel & Hentschel, 1987; OECD, 1989; Van der Weijden, 1990).

In practice, these conservation strategies are complementary. The first two strategies are difficult to achieve on a large scale, because they are expensive, especially near the urbanized zones where land prices are high, and also because of farmer resistance. The peat grassland areas in the Netherlands cover about 300,000 ha and only a few percentages of these areas has so far been safeguarded by nature reserves (about 3,000 ha) and management agreements (about 5,000 ha), and floristic objectives are pursued in only part of the protected sites. Therefore, these strategies cannot stop the overall decline of plant species diversity in the peat areas and the integration strategy should be used to maintain wildlife diversity in the greatest part of the present-day farming landscapes.

The integration strategy will be far less expensive, since it implies no withdrawal of areas from agriculture. For farmers, it might be attractive, since they need not adapt their practices radically. On the other hand, the conservational objectives of the integration approach are more confined than those which might be realized in nature reserves. Wild plant species demanding special conditions that are hard to achieve within modern farming can only be conserved in nature reserves.

Still, the plant communities of the reclaimed peat bogs are internationally relatively rare and therefore important from the view of maintaining species diversity (Clausman & Van Wijngaarden, 1984; Melman et al., 1988). Besides, the maintenance of a diversity of plant species enhances the recreational interest of the rural landscape and is important for the diversity of the fauna, including beneficial insects. Furthermore, species-rich landscape elements, such as ditch banks, might function as connecting structures between nature reserves (Melman et al., 1988). Other functions of the preservation of species richness include the genetic reservoir function, the stabilizing of the landscape and the protection against erosion (see e.g. Sykora & Liebrand, 1987; Ministry of Agriculture & Fisheries, 1989). Though these last-mentioned arguments might generally be valid, it is difficult to prove their importance for special cases like the peat areas.

1.3 Aim of the study

The study described in this thesis was done to support the integration approach; it focused on the conservational prospects of pastures and ditch banks on present-day dairy farms in the peat areas of the Dutch provinces of Zuid-Holland and Utrecht.

To support the integration strategy, management regimes that favour the plant species diversity without severely restricting dairy farming practice need to be developed for grasslands and ditch banks. Such an approach has already been proposed with respect to managing meadow birds (Jongsma, 1980; Jongsma & Van Strien, 1983; Van Kessel & Parmentier, 1984), managing farmland gamebirds such as partridges (Sotherton et al., 1989) and managing the flora on the borders of arable fields (Wolff-Straub, 1985b). Besides, as far as the ditch banks are concerned, this approach corresponds with the increasing attention being paid to management of the vegetation of linear landscape elements in rural areas, such as road verges, hedges, river dikes and all kinds of water courses (Zonderwijk, 1979, 1990; Ruthsatz & Haber, 1981; Gäbler, 1985; Kuntze, 1985; Sykora & Liebrand, 1987).

To be able to assess which measures will produce an optimal management regime it is necessary to know the specific effects of a variety of agricultural factors. Since we have to take the farmer's aims into account, we also ought to know how much the agricultural factors need to change before the floristic richness improves substantially. Thus, we need to be able to quantify the relations between agricultural factors and their effects in current dairy farming practice (Jongsma, 1980).

The primary **aim of this study** was to ascertain dose-effect relationships between specific farming practices and floristic parameters of grasslands and ditch banks. In addition, I paid some attention to the agricultural implications of certain changes in vegetation management, because this helps to identify the optimal results for all interests.

Several opinions occur on what is the proper management of the flora of grasslands and ditch banks. For example, Van Dam (1981) and Oomes (1983) believe that nitrogen inputs should be cut drastically, to levels less than 50-100 kg N ha^{-1} yr^{-1} to achieve a great species diversity in grassland. Van Gelder (1986) recommends using farmyard manure instead of slurry. As regards promoting ditch bank vegetation, De Boer (1984) advises maintaining a high water level in the ditches and Beltman (1984) recommends that the ditches be cleaned manually or with a so-called "mowing-basket". However, the validity of some of those recommendations is open to question, because few studies have been done in the peat areas on the specific and quantitative effects of agricultural factors (see also Van Strien, 1983). Later in this thesis, some of these contentions will be confirmed, but others will be refuted.

1.4 Study area

The peat areas in the Netherlands are found in the provinces of Friesland, Overijssel, Utrecht, Noord-Holland and Zuid-Holland (for their locations see Terwan, 1988). In this study 150 dairy farms in the reclaimed peat landscape in Zuid-Holland and Utrecht were involved; in a part of the study 100 farms were involved (for the location of study sites see fig. 1 in Chapter 3). This open landscape lies one to several metres below the sea level and is surrounded by two arms of the Randstad conurbation which contains the cities of Amsterdam and Rotterdam.

The peat bogs that were reclaimed to form the present landscape were formed after the last glacial period. The soil consists of eutrophic or mesotrophic peat. Near the rivers that intersect the landscape the peat is overlain by river clay deposits (Bijlsma, 1982). From about the tenth century onwards the reclamation and cultivation of the wild fenlands started, bringing about many changes in the landscape. Farmland took the place of marsh-land, and an open landscape with long and narrow fields and with only few trees resulted. An extensive network of shallow ditches, canals, other water courses and dykes arose, thereby creating the present-day and characteristic "polder" landscape. With a total length of thousands of km, ditches and ditch banks are a prominent part of this landscape. Farms and other buildings, such as windmills to keep the reclaimed polders drained, were built. To prevent the low-lying landscape being flooded by the sea and rivers the people set up special organizations called water boards to control dyking and drainage; these are still in existence. The reclaimed fenlands subsided due to dehydration and decomposition of the peat. As a result of this subsidence and the rise in the sea level, the soil became too wet for arable farming. Therefore, from about the fifteenth century dairy farming became the dominant farming activity, with pastures and hayfields on the wet peat soil (Van der Linden, 1982; Van der Molen, 1982).

The farming practices in the pre-industrial Low Countries brought about plant communities with high species diversity, because of the differences in land use and nutrient supply. The most species-rich communities, such as hayfields with *Cirsio-Molinietum*, almost completely disappeared in 1920-1930 as a result of better drainage control and the introduction of artificial fertilizer (De Boer, 1982). With a few exceptions, they were replaced by new hayfield plant communities, such as *Calthion palustris* which were often species-rich and colourful, with e.g. *Lychnis flos-cuculi*. From about 1950 onwards, species-rich communities were replaced by a species-poor *Poo-Lolietum* vegetation (Westhoff et al., 1971; De Boer, 1982; Janssen & De Heer, 1983). Nowadays remnants of the species-rich communities are mainly found on ditch banks.

1.5 Outline of the thesis

Chapter 2 deals with the study design. The effects of agricultural factors on the grassland vegetation on dairy farms in the peat areas are discussed in chapter 3. Chapter 4 deals with the effects of agricultural and other factors on the vegetation of the ditch banks. In chapter 5 I focused on the effects of ditch management on the vegetation of ditch banks. Since farmers expected weed problems to increase if the management of ditch banks was aimed at achieving a species-rich vegetation, I studied possible weed problems related to species-rich banks (chapter 6).

In chapter 7 a statistical method is described that is appropriate to assess the effects of agricultural factors on individual plant species. I was forced to use this method because more sophisticated statistical methods failed, because there were so many zero values for the cover of many plant species in the data set. This method is used in chapter 4 and 5 to test the effects on individual plant species; other vegetation parameters were tested by means of analysis of variance.

In chapter 8 attention is given to the prospects for vegetation management on modern dairy farms.

2

STUDY DESIGN

2.1 Transverse study design

The conventional way of studying dose-effect relationships in vegetation science is by performing field experiments, but I opted for a non-experimental, descriptive analytical study. Because non-experimental designs are not very common in dose-effect studies in vegetation science, I will describe this approach in more detail and explain how it differs from experimental field studies.

Non-experimental or descriptive analytical studies can be transverse, in the case of comparison of different areas in space, or longitudinal, in the case of comparing one area at different points in time. Longitudinal effect studies are difficult to perform, because they require data on the situation both before and after the change in the factor studied. Transverse studies are far more common (Ward, 1978; Van der Zande, 1984; Udo de Haes & Ter Keurs, 1986; Verstrael, 1987).

My study was a transverse study consisting of spatial, simultaneous comparisons of the vegetation at different doses of the agricultural factors. I focused on the relations between agricultural factors and vegetation parameters and for the time being neglected the mechanisms of the effects, which were considered a black box.

Fig. 1 shows the study design. Tree sets of factors are distinguished: dose factors, confounders and condition factors. The agricultural or dose factors studied are: the amount of nitrogen from fertilizer and animal manure applied, the type of manure, the mowing and grazing regime, the water level in the ditches and the groundwater level, the method and frequency of ditch cleaning and the dressing with peat mud from dredging. Though slope aspect cannot be adapted, we studied its influence as if it was a dose factor. All factors mentioned were expected to affect the vegetation of the fields or the ditch banks (Perring, 1959; Ennik, 1965; Heddle, 1967; Kruijne et al., 1967; Klapp, 1971; Rorison, 1971; Traczyk et al., 1976; De Boer, 1977; Silvertown, 1980; Lakhani & Davis, 1982; Elberse et al.,1983; Sykora & Liebrand, 1987).

Confounders or nuisance factors may affect the effect parameters and therefore influence

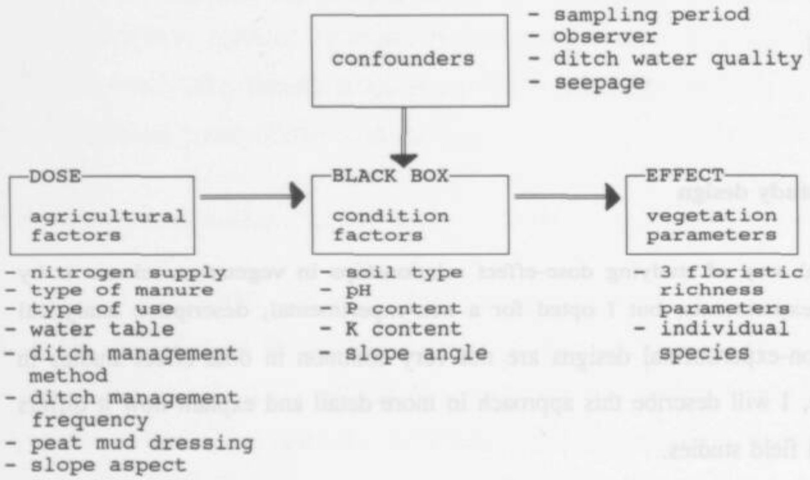

Fig. 1. The study design.

the dose-effect relations studied. They include the sampling period, the observer, the ditch water quality and the seepage (Grootjans, 1985; Kirby et al., 1986). The influence of these confounders was eliminated either statistically, in the case of sampling period and observer, or by a proper choice of the study plots, in the case of ditch water quality and seepage. A priori, ditch water quality was expected not to have any major effect on the vegetation of the ditch banks (Melman, 1990). To minimize the possible effects of ditch water quality, however, all study plots were chosen more than 250 m from the farm houses to avoid the influence of waste water. Also the neighbourhood of pumping-stations discharging nutrient-rich water into the polders was avoided. Recent studies indicate the importance of the groundwater quality on herbaceous marsh plant species in certain areas. The role of calcium- and iron-rich ("lithocline") seepage in brook systems seems to be particularly important (Grootjans, 1985; Barendregt et al., 1986). However, lithocline seepage is not common in the flat study area; choride-rich or nutrient-rich seepage is more common (Werkgroep Midden West-Nederland, 1976). To exclude the influence of this factor, all locations with significant seepage were avoided. In addition, other confounders were excluded by discarding plots that could be affected by factors not involved in this study, such as the dumping of rubbish.

Condition factors are factors that belong to the black box system, such as nutrient status. I paid attention to the following condition factors: type of peat soil, pH, P and K content of the topsoil. In addition, the slope angle was regarded as a condition factor, since this factor might be part of the mechanisms of the effects of the dose factors studied.

The effect parameters used in this study are discussed in 2.4.

2.2 Transverse versus experimental design

Below five differences between a transverse set-up and field experiments are discussed.

(1) Transverse studies suffer from the risk of not taking confounders into account. For instance, when a transverse study covers different areas, unexpected differences between these areas might cause misleading conclusions about the effects of a dose factor. Experiments may also suffer from confounders, especially when the relationships studied require large plots and a long period, but often to a much lesser extent than transverse studies. This means that experiments are considered to prove causal relations, whereas the causality of the relations in transverse studies is less self-evident.

(2) Conclusions from a transverse design can be generalized more easily than the results of experiments. In transverse studies a multifactor approach covering many plots is possible, whereas in any larger scale experiment often only a limited number of factors and plots can be involved. As a result, a transverse design often covers more locations, conditions and combinations of factors than experiments requiring the same effort.

(3) A transverse study is required when the gaps in knowledge also include ignorance of the human behaviour i.e. the ways certain interventions are generally performed in practice. Such gaps in knowledge occurred in this study, for example with respect to the method of the ditch maintenance. The effects of the method of ditch maintenance on ditch banks depend on (1) what machinery is used and (2) how this machinery is used by different farmers. A transverse study may cover both questions, but experiments can hardly cover the variable behaviour of farmers. Some other examples from this study of questions about the behaviour of farmers are whether the banks are affected by manure or fertilizer applied on the fields and whether weed control might be an important factor for the botanical composition of ditch banks in dairy farming practice.

(4) The course and rapidity of the changes in the vegetation that are induced by changes in the management regime remain unknown in a transverse study (with steady-state situations). For studying those changes experiments are required.

(5) Transverse studies can only be performed if appropriate situations are available in practice. That is because a transverse study is restricted to the existing variability of the factor. The effects of doses lower or higher than those that occur in practice, or the effects of factors that are strictly related to other factors have to be studied by experiments. On the other hand, certain relations are difficult to study experimentally, because the factors and conditions cannot be simulated properly; for instance, in the case of ecohydrological studies (see Pedroli, 1987).

Which study design is most appropriate depends on various factors, but especially on the questions the researcher sets out to answer. Also a combination of experimental and transverse approaches might be most appropriate. I opted for a transverse design, because the conclusions would be more easily to generalize and more information would be gained about the variable behaviour of farmers and because there were only a few years available for the study, whereas it was expected that experiments would demand at least 5 years before the vegetation is more or less adapted to the changed management (Van den Bergh, 1979; Korevaar, 1986). By choosing a transverse design no information could be obtained on the rapidity and course of the changes of the vegetation after changing the management. This information was obtained by Melman (1990), who carried out several experiments to solve more specific research questions on ditch bank vegetation in peat areas.

The choice for a transverse design implied that potential confounders should be identified and corrected for to improve the reliability of the results. I enhanced this reliability by carefully selecting the sampling plots:

(1) The plots were selected so that the variability of several confounders was as close to zero as possible (see 2.1 concerning ditch water quality and seepage).

(2) All the selected plots were in a steady-state situation; their management was known to have been more or less constant for at least 5 years, thereby reducing the influence of possible different previous histories. This period is not long enough for the vegetation to adapt completely, especially in the case of extensification from an intensive practice (Van

Duuren et al., 1981; Oomes, 1988). Therefore, plots that were formerly farmed more intensively were only selected if they had had a constant management for about 10 years. Plots which had been re-seeded less than 10 years ago were discarded.

(3) The plots were selected so that it was possible to assess the individual effects of a number of interrelated dose factors. A proper selection was needed, because many of the dose factors tend to go hand in hand in dairy farming practice, such as nitrogen supply and water table. I composed a data set comprising an independent variation of the dose factors and several condition factors. This proved to be very time-consuming; many rare combinations of agricultural factors had to be found, such as a high nitrogen supply on wet fields and a low nitrogen supply on dry fields.

(4) The only plots used were those on which I could get reliable and accurate information on management (see 2.3).

2.3 Reliability of the surveys

Given the large number of study plots and the great number of locations (about 150), it was not feasible to personally record the management regimes during several years. Therefore, most information about the current management regimes was obtained by surveying the farmers. Additional information was obtained from field observations and soil samples. Since these surveys are a vital part of the study, some general remarks about their reliability are needed. The measurements of environmental factors and the method for sampling the vegetation will be described in more detail in the following chapters.

The 150 dairy farmers and site managers of nature reserves surveyed, cooperated well in this study. It has been noticed, however, that surveys among farmers do not always reveal reliable and accurate data about the management regime (Snijders, 1977). Because reliable data are very important, I improved the reliability of the surveys by performing several post-survey checks.

The questionnaires requested information about the entire holding, such as about the farm area, the herd and possible import and export of manure. In addition, there were questions about the management regime of one or more selected parcels and ditch banks. They included questions on mowing and grazing regimes, use of herbicides and dressings of manure and fertilizer. Furthermore, respondants were asked about the ditch management, which implied method, frequency and timing of ditch cleaning, as well as the frequency and timing of dredging.

Three methods were used to check the reliability of the answers:

(1) Follow-up survey. 93 of the 150 farmers were surveyed twice, after one or more years;

(2) Checks on consistency. The answers were checked for their farming credibility and internal consistency, e.g. by checking if the reported grazing pressure was agriculturally possible. Two important tests of internal consistency were: (i) the manure reported to be applied to the plot studied was compared with the average manure production on the entire farm. The average amount was calculated from information about herd size and possible import and export of manure; (ii) the reported use of the plot studied was compared with the average use of all fields of the farm. The average use was derived from information about the grazing need of the herd. In both tests failures were only noticed if the farmer had reported that the study field was manured or used similarly to his other fields;

(3) Field observations. Several answers could be checked by direct field observations of stocking density, grassland utilization, manure dressing, ditch management, etc. during the approximately 7 visits paid to each plot studied.

Reliability of the information

The farmers' answers proved to be more accurate with respect to farming aspects they considered to be important. Therefore, information acquired in the first survey at the level of the entire farm, such as about the herd size, appeared to correspond very well with the information obtained from the second survey. Questions about the management regime of specific fields more often showed different answers. Such differences about the exploitation of a specific field also frequently appeared from the consistency checks and sometimes from the field observations. Most deviations from the original survey were found with respect to the detailed questions about the management of ditch banks, such as about the manuring of the ditch banks. This was confirmed by the field observations: frequently I found recently manured ditch banks, whereas the farmers reported they did not manure them. The reverse occurred too. This illustrates the agricultural insignificance of the banks.

In contrast, questions about ditch cleaning and dredging tended to be answered accurately. Only a few times did field observations reveal that the method of ditch cleaning was different from the one reported.

All three methods revealed a considerable number of deviations from the information obtained in the first survey. Therefore, performing a survey once, without any further checks, would certainly produce many wrong data. Re-surveying the farmers considerably improved the data set.

Consequences for this study

If deviations from the original survey were detected in one or more answers, the farmer was re-surveyed. Since this was necessary with almost all farmers, it turned out to be very time consuming to get reliable and complete data about the management regimes.

Quite often discrepancies appeared to arise from misunderstandings and could be corrected. Those questions on which many farmers could not give reliable information (e.g. the question on manuring the ditch banks) were left out of the analyses. Furthermore, if a farmer was unable to give reliable information on important questions, such as his use of fertilizer, the whole study plot was discarded.

2.4 Vegetation parameters

Most of the grassland plots had similar vegetation, often a *Poo-Lolietum* vegetation (see Westhoff & den Held, 1969). Therefore, the sampled data were not classified into vegetation types; by far the most variation fell within the same vegetation type. The differences in the vegetation of the ditch banks were much greater. However, many banks supported fragments of different vegetation groups concomitantly. Typical marsh plants, e.g. *Eleocharis palustris*, were found near to species of hayfields, e.g. *Holcus lanatus* or species of pure pastures, e.g *Lolium perenne*. This phenomenon occurs because of the gradient character of banks, ranging from wet and mesotrophic near the ditch water line to drier and eutrophic at the transition to field, over a distance of several metres. Also local disturbances from trampling by cattle or dumping of peat mud from ditches contribute to the mixture of vegetation types. Therefore, it was inappropriate to attempt to distinguish vegetation types (see also Ter Keurs, 1986).

Since the aim was to compare the conservational benefits of different management regimes, the effects of these regimes were evaluated by using explicit evaluation criteria. Evaluation of species is essentially a subjective activity and has been the topic of many debates (see Van der Zande et al., 1981). Many quantitative evaluation indices have been developed in the last 15 years, which fall into three broad categories: diversity indices, indices based on rarity and indices based on other criteria.

(1) Diversity indices. The number of species is one of the most widely used parameters for assessing the conservation value of the vegetation (Margules & Usher, 1981), particularly because of its simplicity. Furthermore, several diversity indices include the abundance of species, e.g. Shannon's index of species diversity (see e.g. Pielou, 1975). The shortcoming of merely taking the numbers of species into account, irrespective of their quality, is evident: common species and rare species are weighted equally (Dony & Denholm, 1985; Götmark et al., 1986; Wheeler, 1988).

(2) Indices based on rarity. A number of indices based on rarity or on combinations of diversity and rarity is available (see e.g. Götmark et al., 1986; Wheeler, 1988). In the Netherlands national rarity parameters are frequently used, based on the distributional data of plant species using a grid of 5x5 km ("uurhokken", see Van der Maarel, 1971; Reijnen & Wiertz, 1984; Grootjans, 1985; Gremmen, 1986). Nine "uurhokfrequentie-klassen" ("UFK") are distinguished, ranging on a logarithmic scale from extremely rare (UFK = 1) to very common (UFK = 9). Both the logarithmic representation as well as the coarse grid used give more weight to very rare species than to less rare species (Van der Weijden et al., 1978). Scarcely any nationally rare species occurred on the study plots (Fig. 2); many species that are endangered in the peat areas are not rare on the UFK scale, such as *Caltha palustris* (UFK = 7 or common), *Lychnis flos-cuculi* (UFK = 7) or *Anthoxanthum odoratum* (UFK = 9), though those species are also declining in many other areas. That national system of evaluating species was therefore not sufficiently discriminative for my purposes.

Clausman & Van Wijngaarden (1984) developed an evaluation system which includes the regional rarity of species. They determined the regional rarity of plant species on the basis of an extensive survey of the vegetation of Zuid-Holland. Furthermore, the national and world rarity of these species was estimated, as was the rate of decline of the species.

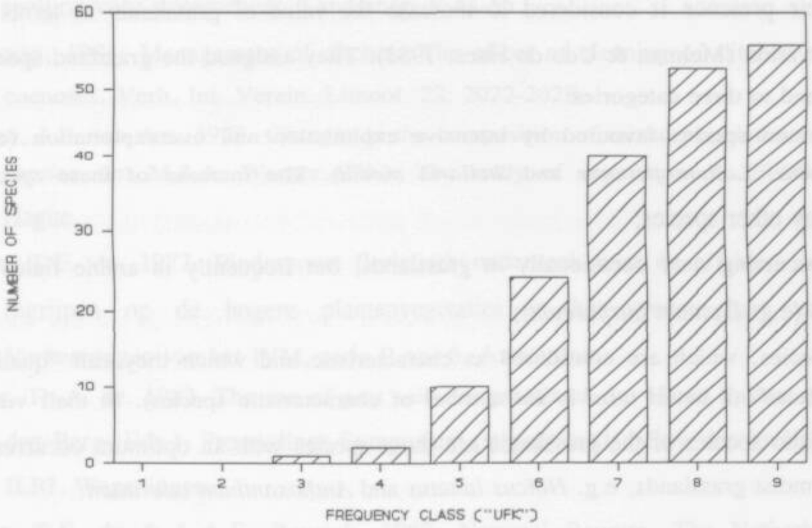

Fig. 2. The distribution of plant species sampled in this study with logarithmic frequency classes (UFK). 1 = extremely rare; 9 = very common. UFK data derived from van der Meijden et al. (1983).

In their evaluation system each plant species is weighted according to both its rarity on the different scales and to its rate of decline. This yields what they call the "nature-value index" of the species. In addition, they distinguish the nature-value index of a sample plot, which they calculated by summing the nature-values of all species present, taking into account the cover percentages (see appendix).

(3) Indices based on other criteria. Many other criteria are used for assessing the nature conservation values of areas and species, e.g. typicalness, vulnerability, threat of human interference (see Margules & Usher (1981) for a review of criteria). Also, attempts have been made to weigh the importance of other interests, such as recreation (see e.g. Schenk, 1983). A drawback of many of the criteria in this category is that the classifications rest strongly upon subjective judgments and therefore lack a sound scientific

basis.

Drijver & Melman (1983) used an evaluation system based on counting all species that are considered to be characteristic of the vegetation of grasslands in the province of Zuid-Holland. Their presence is considered to increase the value of grasslands in terms of nature conservation (Melman & Udo de Haes, 1983). They assigned the grassland species of Zuid-Holland to three categories:

(i) very common species favoured by intensive exploitation and overexploitation (e.g. *Elytrigia repens*, *Lolium perenne* and *Stellaria media*). The increase of these species threatens many other species;

(ii) species occurring only occasionally in grasslands, but frequently in arable fields or other habitats (e.g. *Lamium purpureum*);

(iii) other species, which are considered as characteristic and which they call "quality-indicating species" (a better term is the number of characteristic species). In their view, the characteristic species of the grasslands are those species with an optimum occurrence in normal to moist grasslands, e.g. *Holcus lanatus* and *Anthoxanthum odoratum*.

Some consensus has been reached about the use of several criteria, especially about diversity and rarity (Margules & Usher, 1981). However, no general agreement exists about many other criteria and about how to translate criteria into indices. Therefore, it seems best to use several evaluation criteria to complement each other, each emphasizing other aspects (see also Götmark et al., 1986).

In this study the number of species was used, as well as two evaluation parameters that had been developed for the same areas as my study locations: the number of quality-indicating species by Drijver & Melman (1983) and the nature-value index by Clausman & Van Wijngaarden (1984). In the appendix a synopsis is given of all plant species involved in this study, valued according to both evaluation systems.

The species number depends on the size of the sample area (Mueller-Dombois & Ellenberg, 1974); therefore, the size of the sample plots was held constant in this study.

Since the indices of floristic richness give limited insight into the floristic differences, it seemed useful to assess the effects of agricultural factors on individual plant species too. Therefore, I developed a simple method that enabled the effects on individual plant species (including rare species) to be assessed (see Chapter 7).

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Extensification of dairy farming and floristic richness of peat grassland

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Abstract

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

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

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

Introduction

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

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

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

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

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

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

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

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

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

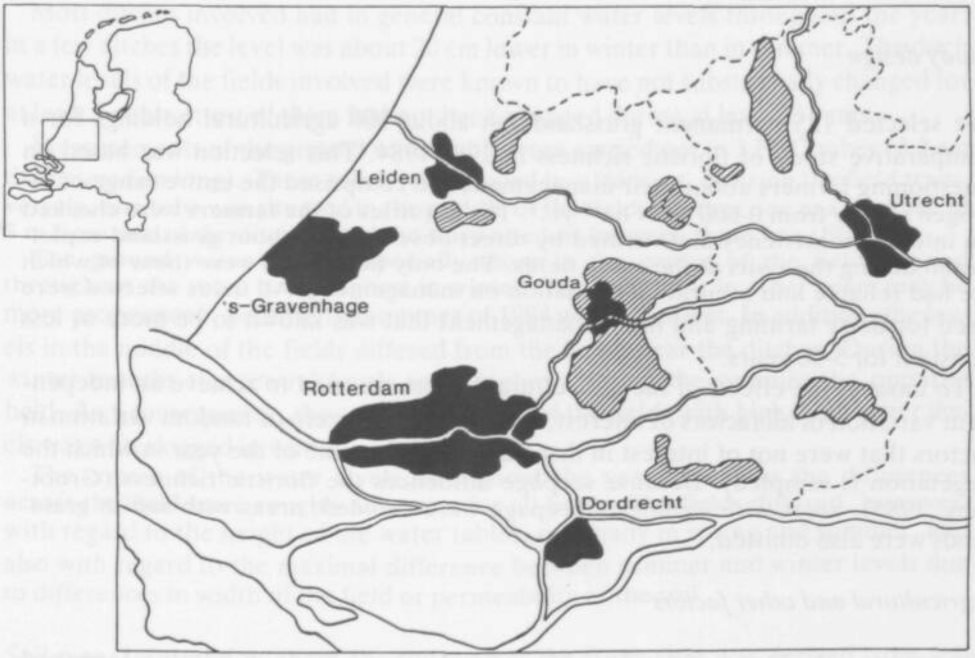

Fig. 1. Location of the study sites.

Study area

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

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

Material and methods

Study design

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

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

Agricultural and other factors

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

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

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

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

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

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

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

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

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

- mesotrophic peat,
- eutrophic peat,
- mesotrophic peat covered with clay, and
- eutrophic peat covered with clay.

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

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

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

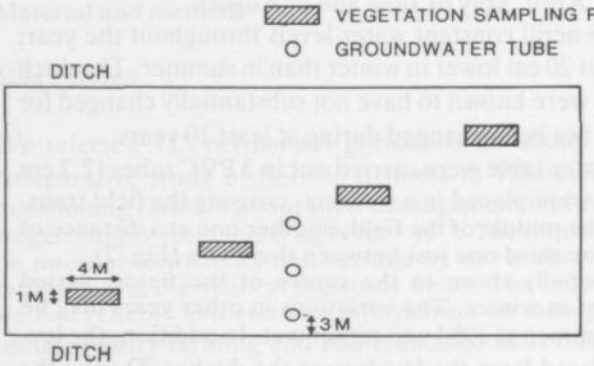

Fig. 2. Diagram (not to scale) showing the location of the vegetation sampling plots and the ground water tubes on a field.

Vegetation sampling

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

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

Parameters of floristic richness

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

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

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

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

Statistics

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

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

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

Results

Mutual independence of factors

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

Vegetation differences within the fields

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

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

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

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

* $P \leq 0.05$.

Vegetation differences between the fields

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

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

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

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

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

* $P \leq 0.05$.
** $P \leq 0.01$.

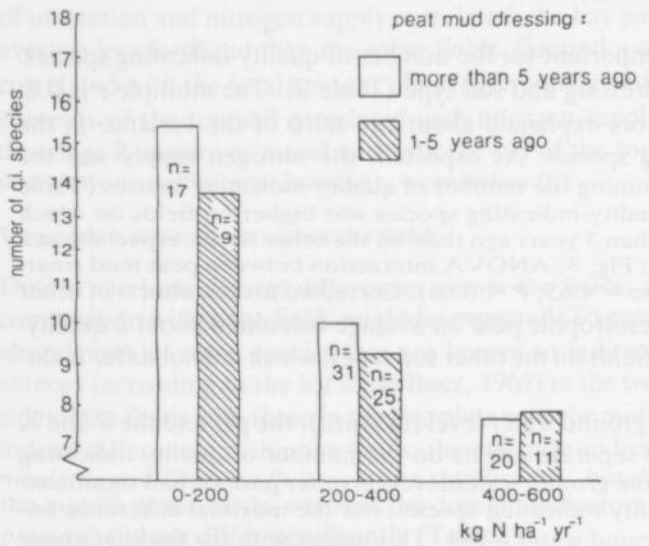

Fig. 3. Average number of quality-indicating species (see text) with different nitrogen supply at different periods after peat mud dressing. Corrected for soil type by means of ANOVA. *n* = number of fields.

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

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

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

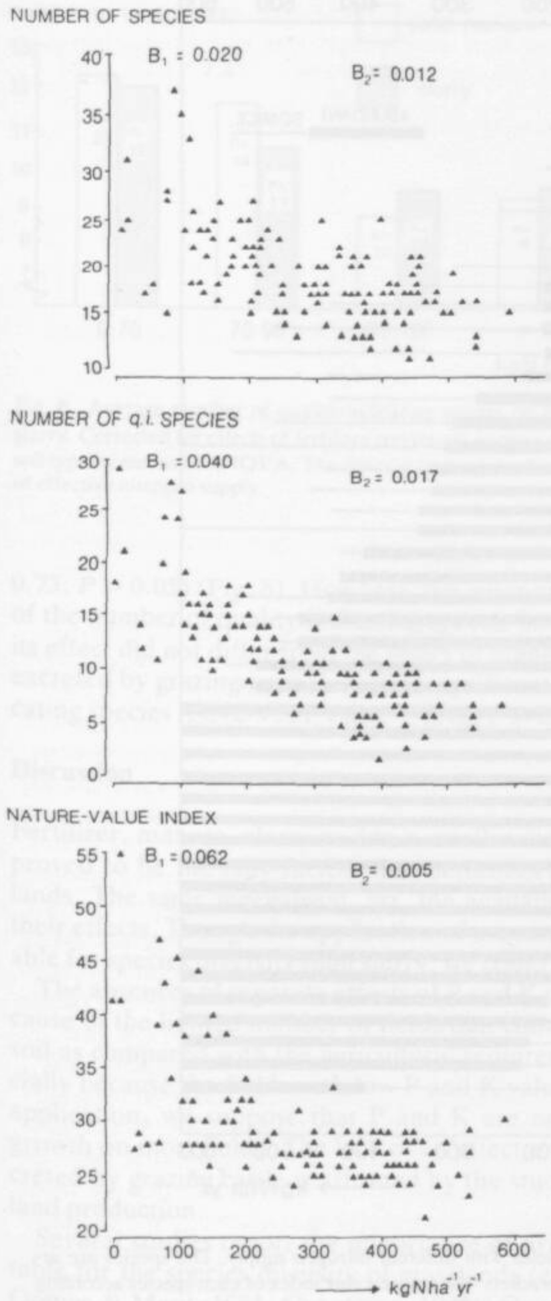

Fig. 4. Relations between three parameters of floristic richness (number of species and of quality-indicating species and nature-value index) and nitrogen supply. B_1: slope of the relation between 0 to 200 kg N ha^{-1} yr^{-1}. B_2: slope of the relation between 200 to 600 kg N ha^{-1} yr^{-1}.

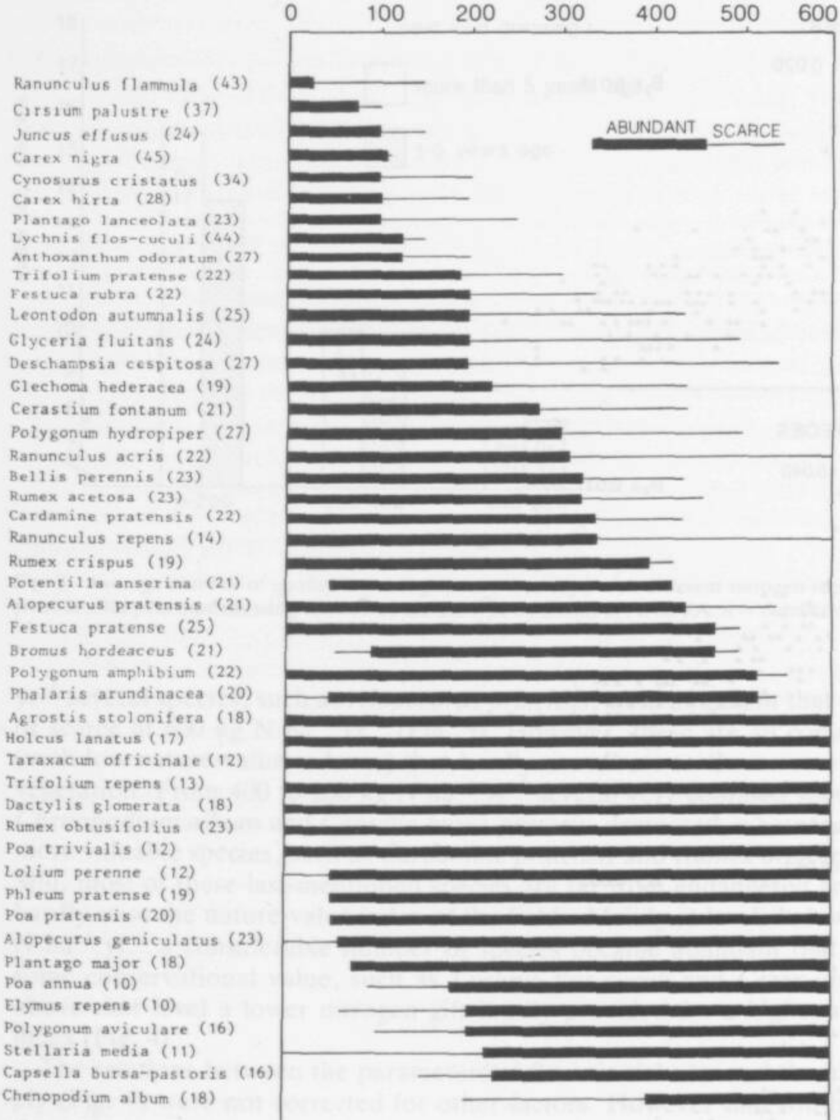

Fig. 5. Occurrence of grassland species on 125 fields with different nitrogen supply. The species are arranged according to response to nitrogen gift. In brackets: the nature-value index of each species according to Clausman & van Wijngaarden (see van Strien, in prep.). The mean cover of species indicated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

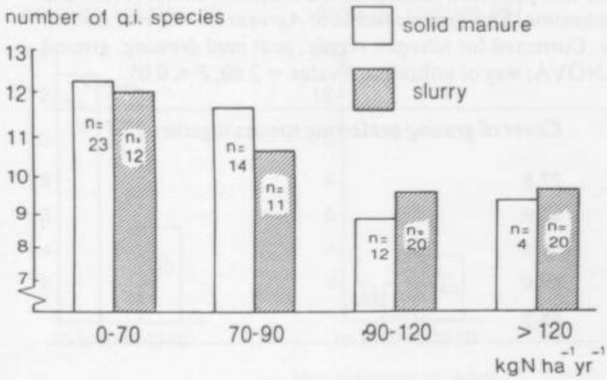

Fig. 6. Average number of quality-indicating species on fields treated with different doses of manure or slurry. Corrected for effects of fertilizer treatment, excreta deposited during grazing, peat mud dressing and soil type by means of ANOVA. The doses of both types of animal manure have been converted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

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

Discussion

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

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

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

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

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

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

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

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

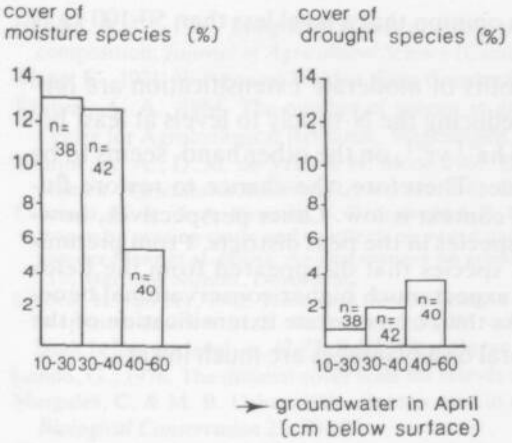

Fig. 7. Mean cover of moisture-indicating species (cover of *Alopecurus geniculatus* and *Glyceria fluitans* added) and drought-indicating species (cover of *Dactylis glomerata* and *Poa pratensis* added) with different ground water levels in April. Corrected for nitrogen supply, way of utilization,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

Significance for nature conservation

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

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

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

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

Acknowledgements

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4

FACTORS AFFECTING THE VEGETATION OF DITCH BANKS IN PEAT AREAS IN THE WESTERN NETHERLANDS

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SUMMARY

(1) The effects of a number of environmental factors on the ditch bank vegetation in peat areas in the western Netherlands were studied to find the best management strategy for conserving the flora of ditch banks.

(2) The effects of these factors on three different indices of floristic richness and on individual plant species were assessed by spatial comparisons of sampling plots using analysis of variance and matched pairs analysis.

(3) The floristic richness of the banks was higher on south-facing than on north-facing banks, and on steep south-facing than on gentle south-facing banks. Higher soil pH, high ditch water table (especially at north-facing banks), low grazing intensity and a low nitrogen supply on the adjacent fields (especially at fertilization rates of less than 200 kg nitrogen ha^{-1} $year^{-1}$) also favoured floristic richness.

(4) Type of peat soil, amount of manure and slurry applied to the fields, and phosphorus and potassium contents of the bank soil had no significant effects on the floristic richness of the banks.

(5) To maintain the species richness of the vegetation, it is recommended that (i) ditch banks are kept free of fertilizer and are protected from grazing by livestock, (ii) ditch water levels are kept high, (iii) that acidification is prevented and (iv) south-facing banks are kept steep.

INTRODUCTION

The floristic richness of grasslands on peat soils in the western Netherlands has decreased considerably in recent decades because of the intensification of dairy farming (de Boer 1982). The possibilities for restoring the floristic richness of these agricultural grasslands are limited. They are only of conservation value if the nitrogen supply is low, not exceeding 200 kg N ha^{-1} $year^{-1}$ (van Strien, Melman & de Heiden 1988). Such low levels are unusual in current Dutch agricultural practice. They can only be attained by establishing nature reserves or management agreements with farmers, although these are not easy to realize on a large scale. However, in areas with intensive dairy farming, there are some possibilities for nature conservation in ditches and on ditch banks. In the Dutch peat areas the long and narrow fields are separated by shallow ditches. These ditches and ditch banks together offer an extensive potential refuge for plant and animal species. Indeed, individual ditch banks can contain many herbaceous plant species, including several endangered grassland species. Even banks beside intensively managed fields frequently support a species-rich vegetation (Melman, Clausman & van Strien 1988).

Recent observations show, however, that the vegetation of the ditch banks is also becoming impoverished (Melman, Udo de Haes & van Strien 1986). There is therefore an urgent need to manage this vegetation to maintain and increase species diversity. Since the productivity of ditch banks is of limited economic value to the farmers, it should be relatively easy to reduce their exploitation. This strategy of restoring the floristic richness of field edges has been proposed before (Ruthsatz & Haber 1981; Gäbler 1985; Kuntze 1985) and has been carried out in certain arable regions in West Germany with positive results (Wolff-Straub 1985).

To find the best management for ditch banks, the factors that govern their vegetation must be known. Because a ditch bank lies between grassland and the ditch, the management of both is of interest. Several factors that might influence the bank vegetation are the nitrogen supplied to the fields, the ditch water table, the slope of the ditch bank and the ditch maintenance (de Boer 1977; van Dijk 1978; Anon. 1985). However, few quantitative studies have been done on the effects of these factors. In this paper we give data on the soil type, pH and the phosphorus and potassium contents of the bank soil, the gradient and aspect of the bank slope, the ditch water table, and the use of and the nitrogen supply to the adjacent fields.

MATERIAL AND METHODS

Study sites and study design

The study sites were in polders in Zuid-Holland and the western part of Utrecht province, with peat or clay-on-peat soils over clay deposits (Bijlsma 1982). Saline soils were avoided. The reclamation of these polders has been described by van der Linden (1982).

We investigated 220 ditch banks on 100 agricultural holdings; their selection was based on questioning farmers about their management of fields and ditches, backed up by field reconnaissance. Most ditches were 2–6 m wide and 0·3–0·6 m deep. All banks used in the study were known to have had a more or less constant management of adjacent fields and ditches for the previous 5–10 years.

Vegetation sampling

The ditch bank vegetation was examined by several observers between the end of June and mid September 1983–85, always before the ditches were cleaned. A relevé was made of the central 50-m length of each longitudinal ditch bank (i.e. two per field; Fig. 1), using the cover scale of Clausman & van Wijngaarden (1984). Each strip ran only 0·7 m up the bank from the water's edge, as this was the most species-rich part of the ditch bank vegetation and always contained almost all bank species.

Most banks were examined once, but twenty-five were surveyed in the three successive years to trace any systematic differences in floristic richness between years. However, because no differences between years were detected, these data were combined in the analyses.

Indices of floristic richness

Both the effects on the individual plant species as well as the effects on the floristic richness were examined. Three indices of floristic richness were used, differing in the weighting given to the conservation value of the species:

Number of species.

Number of quality-indicating species ('q.i. species') (Drijver & Melman 1983). This number includes all species except very common species characteristic of very intensive

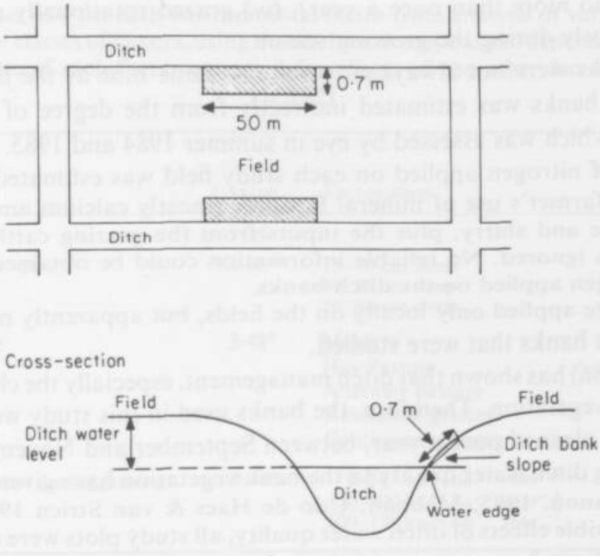

FIG. 1. Diagram (not to scale) showing the location of the relevés (hatched) on a field, and explaining several of the terms used.

exploitation and overexploitation (e.g. *Poa annua* and *Stellaria media*; nomenclature follows van der Meijden *et al.* 1983), and species that only occasionally occur in grasslands and on ditch banks, but that occur frequently in other habitats (e.g. *Lamium purpureum*).

Nature-value index. Clausman & van Wijngaarden (1984) determined a nature-value index of species from estimates of their local (Zuid-Holland), national and world rarity and their rate of decline. The nature-value index of a relevé was calculated by summing the nature-values of the species involved, taking into account their cover values.

Physical factors

The soils at each field were noted from 1 : 50 000 soil maps (Anon. 1982). They were all mesotrophic or eutrophic peats, some with thin coverings of clay <40 cm thick.

Twenty samples of the top 10 cm of soil on the banks were collected from the strips in autumn 1983 and 1984. For each sample, the pH in water was determined and the contents of acetic acid-extractable phosphorus and potassium (Allen 1974) were estimated, measured colorimetrically with molybdate and by flame absorption photometry, respectively.

The mean aspect and gradient of the slope of each ditch bank sampled were determined and the level of the ditch water table below the field surface (Fig. 1). Ditch water tables were measured six times throughout 1 year. The water levels of the ditches involved in this study were known to have not changed substantially for at least 5–10 years.

Management

The fields were assigned to one of the following use categories: (i) meadow (cut for hay or silage more than once a year, with the first cut or grazing period before June); (ii) hay pasture (cut in June and subsequently only grazed); (iii) alternate pasture (grazed and cut alternately; cut no more than once a year); (iv) grazed rotationally and never cut; (v) grazed continuously during the growing season.

The ditch banks were not always mown at the same time as the fields. The grazing pressure on the banks was estimated indirectly from the degree of trampling of the sampling plots, which was assessed by eye in summer 1984 and 1985.

The amount of nitrogen applied on each study field was estimated following Pelser (1984) from the farmer's use of mineral fertilizer (mostly calcium ammonium nitrate), farmyard manure and slurry, plus the inputs from the grazing cattle. Nitrogen from precipitation was ignored. No reliable information could be obtained about the exact amount of nitrogen applied on the ditch banks.

Herbicides were applied only locally on the fields, but apparently never on the lower parts of the ditch banks that were studied.

Van Strien (1986) has shown that ditch management, especially the cleaning frequency, affects the bank vegetation. Therefore, the banks used in this study were selected along ditches that were cleaned once a year, between September and November.

Studies relating ditch water quality to the bank vegetation have given equivocal results (de Boer 1977; Anon. 1985; Melman, Udo de Haes & van Strien 1986). However, to minimize the possible effects of ditch water quality, all study plots were chosen more than 250 m from the farm houses to avoid the influence of waste water. Pumping-stations discharging nutrient-rich river water into the polders were also avoided. Because seepage may affect the vegetation (Grootjans 1985), areas with significant seepage were avoided.

Statistics

Two statistical approaches were used. Analysis of variance (ANOVA; Nie *et al.* 1975) was used to assess the separate effects of the factors simultaneously on the indices of floristic richness. Because the ANOVA could not handle more than five non-metric factors in one run, the metric factors were used as covariates in most runs. Effects of factors were assessed before interaction effects and were adjusted for the effects of all other non-metric factors and covariates involved, except for slope gradient, but including as factors the observer and week of sampling which can influence results (Kirby *et al.* 1986). Because the slope gradient or the chemical soil factors might be determined partly by several of the other factors, it would be invalid to correct the effects of the latter in the ANOVA for the former. To examine the dependence of slope and chemical soil factors on the other factors, several ANOVA runs were done, using slope gradient, pH, P and K as dependent variables. Slope gradient did prove to be strongly related to other factors, especially to ditch water table (Table 1). Additional slope factors were type of use and nitrogen input during grazing. Slope gradient was therefore not included in most analyses. Only a few analyses investigated the separate effect of slope, because bank inclination could be manipulated directly. In contrast, pH and the P and K contents could be treated as independent variables because other factors proved to be largely unrelated to them.

Selected pairs of relevés were compared by matched pairs analysis, to test the effects on individual plant species (A. J. van Strien & E. Meelis, unpublished). The plots were divided into two groups according to the value of one environmental factor (the 'dose factor'). Pairs of plots, one from each group, were selected, with all variables held constant except for slope gradient. Plots without an analogue in the other group were discarded. In this way, two subsets of matched plots were obtained for each dose factor. Differences in the occurrence of species between the two subsets of matched plots were examined by χ^2 testing; differences in cover by means of a sign test. Mutual dependence of

TABLE 1. Values of F for each environmental factor from analysis of variance and of mean slope for classes of factors, using the ditch bank slope as the dependent variable, with the effects of each factor corrected for effects of the other factors (Multiple $r=0{\cdot}62$)

Factor	F-value	Factor class	Mean slope (degrees)
Soil type	1·38		
Ditch water table	55·63**	15–40 cm deep	10·7
		40–50 cm deep	14·7
		50–80 cm deep	19·4
Type of use	3·48*	Meadow	13·9
		Hay Pasture	17·4
		Alternate pasture	13·1
		Rotational grazing	13·7
		Continuous grazing	13·2
Nitrogen input during grazing	3·41*	0–50 kg N ha^{-1} year^{-1}	15·5
		50–100 kg N ha^{-1} year^{-1}	14·1
		100–150 kg N ha^{-1} year^{-1}	13·6

* $P \leqslant 0{\cdot}05$; ** $P \leqslant 0{\cdot}01$.

the test results was ignored, because at each dose factor a limited and varying part of the entire data set was used (A. J. van Strien & E. Meelis unpublished).

RESULTS

The three indices of floristic richness were highly correlated: number of species and number of q.i. species, Pearson's $r=0{\cdot}87$ ($P<0{\cdot}01$); number of species and nature-value index, $r=0{\cdot}73$ ($P<0{\cdot}01$). Therefore, many of the results quoted use only one index, the number of q.i. species.

Observer and sampling period

Some observers found significantly more species and q.i. species than others (Table 2). Also, the number of species and q.i. species found increased slightly during summer (Table 2; Fig. 2). No significant differences in nature-value index due to observer and sampling period were found.

Soil type and pH

No differences in floristic richness were found on banks in areas with different peat soil types (Table 2). Ditch banks with a high pH carried more species and q.i. species than banks with a low pH. In contrast, the nature-value index did not depend on pH (Table 2; Fig. 2) because most species stimulated by a high pH (e.g. *Trifolium repens, Lolium perenne*) are common and have a low nature-value index (Table 3). At low pH there was a higher cover of several pioneer species of wet, nutrient-rich conditions (e.g. *Polygonum hydropiper, Bidens* spp.).

TABLE 2. Values of F from analyses of variance of environmental factors using three indices of floristic richness as dependent variables; values are corrected for effects of the other factors, except for ditch bank slope

Factors	Number of species	Number of q.i. species	Nature-value index
1. Observer	7·42**	4·28**	0·18
2. Sampling period	4·70*	3·49*	0·46
3. Soil type	2·46	2·07	1·15
4. pH	22·29**	13·64**	0·26
5. Slope aspect	3·88*	3·39*	4·96**
6. Ditch water table	19·00**	15·82**	9·88**
7. Type of use	1·93	3·00*	2·51*
8. Phosphorus content	0·73	1·81	0·00
9. Potassium content	0·73	1·68	2·00
10. Nitrogen supply	15·17**	28·94**	14·79**
Multiple r	0·67	0·67	0·54
r^2	0·45	0·45	0·30

* $P \leq 0{\cdot}05$; ** $P \leq 0{\cdot}01$.

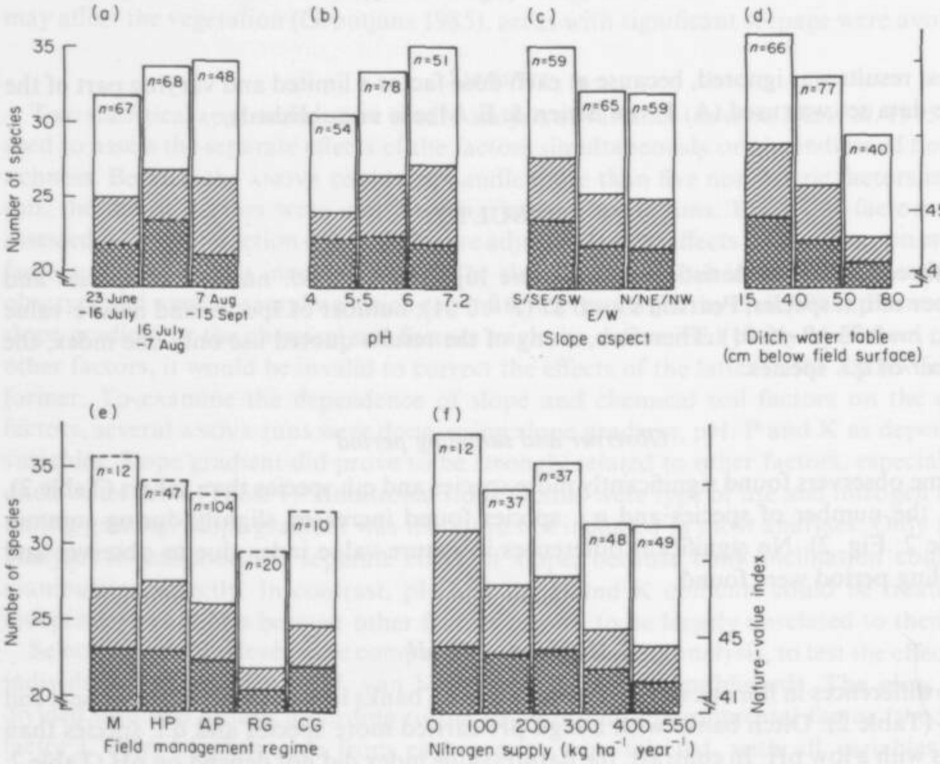

FIG. 2. Mean number of species (□), quality-indicating species(▨) and nature-value index (▩) of banks in relation to (a) sampling period, (b) pH, (c) slope aspect, (d) ditch water table, (e) type of use, and (f) nitrogen supply on the adjacent fields. Corrected for all factors mentioned in Table 1. M, meadow; H P, hay pasture; A P, alternate pasture; R G, rotational grazing; C G, continuous grazing; ----, differences between columns not significant.

TABLE 3. Species (with their native-value indices in parentheses) showing significant differences in frequency of cover between ditch banks with low and high pH, corrected for other factors by matched pairs comparison ($n=32$ in all columns)

	Number of cases in which species is present†		Mean % cover‡	
	pH 4–5·5	pH 5·5–7·2	pH 4–5·5	pH 5·5–7·2
More at low pH				
Agrostis stolonifera (18)	31	31	16·76	14·53*
Berula erecta (30)	13	5*	0·23	0·08*
Bidens cernua (31)	22	12*	0·60	0·47
Bidens tripartita (31)	13	5*	0·19	0·18
Glyceria maxima (22)	29	24	10·71	2·62**
Juncus effusus (24)	17	10	0·97	0·39*
Myosotis palustris (29)	28	27	1·37	0·69*
Polygonum hydropiper (27)	27	21	3·74	0·78**
Ranunculus flammula (43)	20	11*	0·78	0·18*
Ranunculus sceleratus (27)	20	14	0·40	0·24*
Rorippa amphibia (32)	22	7**	0·67	0·07**
More at high pH				
Cerastium fontanum (21)	13	24*	0·37	1·02**
Eleocharis palustris (29)	7	14	0·63	0·86**
Festuca rubra (22)	8	16	1·83	2·93**
Lolium perenne (12)	7	21**	0·27	1·00**
Lysimachia nummularia (36)	9	20*	0·25	0·65**
Plantago major (18)	1	8*	0·01	0·11*
Poa pratensis (20)	13	17	0·50	0·98*
Potentilla anserina (21)	4	9	0·06	0·19*
Rumex crispus (19)	0	6*	0·00	0·07*
Sagina procumbens (23)	11	21*	0·62	1·94**
Trifolium repens (13)	25	32*	1·77	2·87*
Triglochin palustris (37)	7	20**	0·35	1·58**

* $P \leq 0·05$, ** $P \leq 0·01$, by † χ^2 test, ‡ sign test.

TABLE 4. Differences in the number of quality-indicating species on banks on both sides of the fields on opposite slope aspects

			Number of pairs of banks with the highest number of q.i. species in:		Sign test
A		B	A	B	*T* value
South-east	:	north-west	9	3	6
South	:	north	17	3	14**
South-west	:	north-east	20	9	11*
West	:	east	13	11	2

* $P \leq 0·05$; ** $P \leq 0·01$.

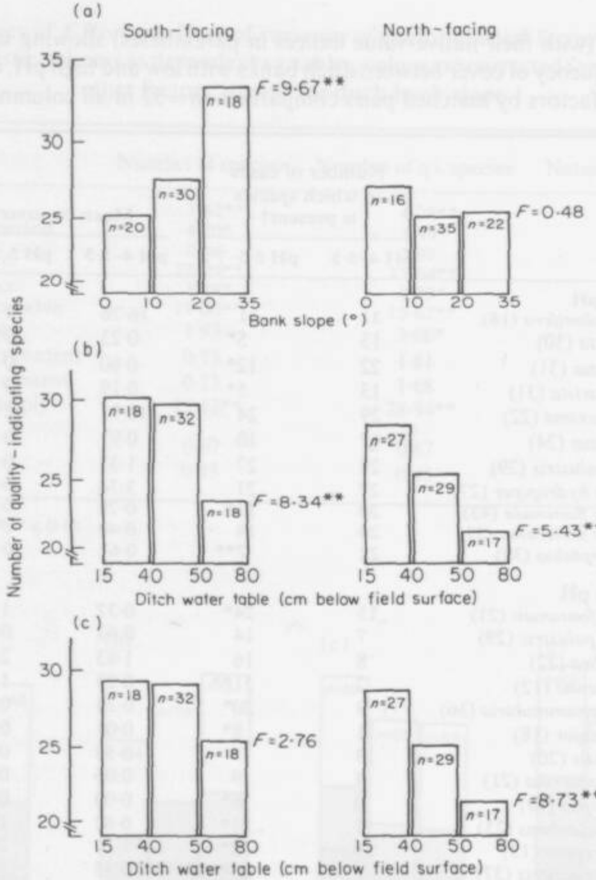

FIG. 3. Effects of ditch bank slope and ditch water table on the number of quality-indicating species on south- and north-facing slopes: (a) effects of ditch bank slope; (b) effects of ditch water table; (c) overall effects of ditch water table. All corrected for other factors, except (c) was not corrected for ditch bank slope (** $P<0{\cdot}01$).

Slope aspect and gradient

Significantly more q.i. species were found on south and south-west banks than on north and north-east banks (Table 4). Also, south-east banks appeared to be somewhat richer in species than north-west banks. To reduce the number of aspect classes, these were aggregated into the analyses: (i) S, SW and SE; (ii) N, NE, and NW; and (iii) E and W. There was also a significantly higher species-richness and nature-value index on south-facing banks (Table 2; Fig. 2).

Slope aspect was strongly related to the number of q.i. species on steeper slopes ($P<0{\cdot}01$) (Fig. 3a). Therefore, the botanical differences between south and north aspects on steep (> 15°) slope gradients were examined. Table 5 shows that a number of species of conservation value were more abundant on south banks, whereas only two common grassland species had a higher cover on north banks. The effects of slope gradient

TABLE 5. Species (with their nature-value indices in parentheses) showing significant differences in frequency or cover between south-facing (S, SW, SE) and north-facing (N, NW, NE) slopes steeper than 15° ($n=28$ in all columns)

	Number of cases in which species is present†		Mean % cover‡	
	South aspect	North aspect	South aspect	North aspect
More on south-facing banks				
Carex acuta (34)	10	3	0·79	0·11*
Carex disticha (43)	14	4	0·87	0·07**
Carex nigra (45)	11	5	0·47	0·07*
Eleocharis palustris (29)	11	7	0·69	0·38*
Juncus articulatus (30)	23	10**	1·30	0·52*
Lotus uliginosus (40)	15	8	1·10	0·48*
Lychnis flos-cuculi (44)	15	8	0·58	0·08*
Polygonum amphibium (22)	17	8*	0·36	0·34
Rumex hydrolapathum (36)	10	4	0·13	0·04**
Scutellaria galericulata (34)	16	7*	0·61	0·09*
More on north-facing banks				
Alopecurus pratensis (23)	15	17	0·98	1·60*
Stellaria media (11)	11	17	0·30	0·52*

* $P \leq 0{\cdot}05$, ** $P \leq 0{\cdot}01$, by † χ^2 test, ‡ sign test.

depended on the aspect; there were more q.i. species on steeper south-facing slopes, but the numbers on north-facing slopes were similar, regardless of gradient (Fig. 3a).

Ditch water table

Most ditches had a constant water level, with variations of less than 10 cm; in a few the level was 20 cm lower in winter than in summer. The summer measurements were used in the analyses.

At a permanently lower ditch water level, there were significantly fewer species and q.i. species and a lower nature-value index (Table 2; Fig. 2). Species associated with a high ditch water level tended to have higher nature-value indices than those associated with low water levels (Table 6).

These negative effects of lower ditch water levels cannot be caused by the steeper slopes that accompany such levels (Table 1), since steeper slopes were associated with a greater species diversity, at least for south-facing banks. Therefore, we conclude that ditch water-table effects are composed of two opposite effects: (i) a positive effect with south-facing banks, because the banks of ditches with lower water levels are steeper (Table 1; Fig. 3a); (ii) a negative effect of the ditch water table itself. Correcting for slope, fewer q.i. species on the banks of ditches with lower water table were found, regardless of slope aspect (Fig. 3b).

It appears that on south-facing banks the negative effect of the ditch water table itself overrules the positive effect of the slope (Fig. 3c). The aggregate effect of ditch water table (in Fig. 3c) is more conspicuous on north-facing banks than on south-facing banks because of the absence of a slope effect on north banks.

TABLE 6. Species (with their nature-value indices in parentheses) showing significant differences in frequency or cover between ditch banks with high and low water level ($n = 58$ in all columns)

	Number of cases in which species is present†		Mean % cover‡	
Depth of ditch water table (cm)	15–45	45–80	15–45	45–80
More at high ditch level				
Acorus calamus (33)	14	5*	0·57	1·12
Carex acuta (34)	15	11	0·38	0·14*
Juncus articulatus (30)	44	35	1·38	0·93*
Myosotis palustris (29)	50	50	0·96	0·50*
Oenanthe fistulosa (37)	44	35	1·82	0·83**
Potentilla anserina (21)	18	9	0·16	0·06**
Ranunculus flammula (43)	33	22	0·40	0·21*
Sagina procumbens (23)	36	24*	1·60	0·73*
Trifolum repens (13)	52	46	2·39	1·71*
More at low ditch level				
Dactylis glomerata (18)	1	8*	0·01	0·16*
Festuca rubra (22)	20	26	2·12	3·33*
Poa pratensis (20)	23	30	0·57	0·97*
Vicia cracca (25)	1	10*	0·01	0·09*

* $P \leqslant 0{\cdot}05$, ** $P \leqslant 0{\cdot}01$, by † χ^2 test, ‡ sign test.

Type of use of fields

Banks bordering meadows and hay pastures had more q.i. species and higher nature-values than those bordering fields with the other uses. The fewest q.i. species and lowest nature-values occurred on banks by rotationally and continuously grazed fields (Table 2; Fig. 2). Table 7 gives the difference in botanical composition between banks by meadow and hay pastures and by alternate pastures and rotationally and continuously grazed fields. A number of species that preferred meadows/hay pastures had high nature-value indices (> 40), whereas those of species preferring other uses were all < 40.

The banks of hay pastures were much steeper than those of the other fields (Table 1). This was because the lower grazing pressure on hay pastures resulted in less trampling of the banks ($P < 0{\cdot}01$).

Soil P and K contents and N supply

The P and K contents of the bank soil had no effects on floristic richness (Table 2). However, a higher nitrogen application on the fields lowered the floristic richness of the banks significantly (Table 2; Fig. 2). The effects of different nitrogen sources (Fig. 4) were as follows. (i) Fields with higher amounts of N fertilizer had fewer q.i. species on the banks. This was due entirely to the low numbers of q.i. species with more than 200 kg N ha^{-1} year^{-1}; there was no detectable effect of 0–200 kg N ha^{-1} year^{-1}. (ii) Neither manure nor slurry (alone or together) significantly affected the number of q.i. species. (iii) Higher estimated amounts of excreted nitrogen from grazing cattle were associated with fewer q.i. species. This may be related to the grazing activity itself, which was correlated with slope (Table 1) and trampling ($P < 0{\cdot}01$).

Table 8 gives the difference in botanical composition of banks bordering fields with low

TABLE 7. Species (with their nature-value indices in parentheses) showing significant differences in frequency or cover between ditch banks bordering (1) meadows or hay pastures and (2) alternate pastures, rotationally or continuously grazed fields ($n = 50$ in all columns)

	Number of cases in which species is present†		Mean % cover‡	
	1	2	1	2
More in meadows/hay pastures				
Anthoxanthum odoratum (27)	25	11**	1·68	0·46*
Bromus hordeaceus (21)	11	1**	0·12	0·01*
Caltha palustris (36)	8	0**	0·03	0·00*
Carex nigra (45)	23	9**	1·50	0·15*
Cerastium fontanum (21)	37	23**	0·55	0·37*
Iris pseudacorus (40)	9	0**	0·05	0·00**
Lychnis flos-cuculi (44)	22	9**	0·29	0·05*
Lysimachia nummularia (36)	24	12*	0·30	0·15*
Lysimachia thyrsiflora (45)	10	1*	0·08	0·01*
Mentha aquatica (31)	21	8**	0·29	0·06**
Polygnonum amphibium (22)	23	12*	0·44	0·12*
Rumex acetosa (23)	46	15**	1·64	0·33**
Trifolium pratense (22)	18	1**	0·27	0·00**
Vicia cracca (25)	14	1**	0·13	0·00**
More in pastures				
Bidens cernua (31)	18	26	0·16	0·33*
Glyceria fluitans (24)	40	49*	1·98	4·82**
Juncus articulatus (30)	30	34	0·76	1·33**
Lolium perenne (12)	19	28	0·30	0·78*
Oenanthe fistulosa (37)	35	38	0·99	2·21*
Polygonum hydropiper (27)	30	46**	2·09	1·73
Sagina procumbens (23)	22	27	0·43	1·65**

* $P \leq 0{\cdot}05$, ** $P \leq 0{\cdot}01$, by † χ^2 test, ‡ sign test.

and high amounts of nitrogen applied as fertilizer, manure and slurry. (To exclude possible effects due to type of use, the N load from grazing cattle was held constant between these nitrogen classes in the matched pairs analysis.) Many species with a high nature-value index were found more often with a low N supply than with high N. This underlines the negative effects of N supply on species-richness.

DISCUSSION

Soil type and pH

The analyses concerned the soil type of the areas in which the ditches were situated. The bank soils probably differ from the adjacent field soils because sludge dredged up during the annual ditch-cleaning is dumped on the banks, which therefore tend to become more similar in terms of soil composition and structure. This may explain why the field soil type was not related to the floristic richness of the banks.

A lower species diversity at pH levels < 5·5 has been noticed for grasslands elsewhere (Grime 1973; Silvertown 1980). The differences we found in botanical composition with varying pH correspond reasonably with those in other Dutch grasslands (Kruijne, de Vries & Mooi 1967).

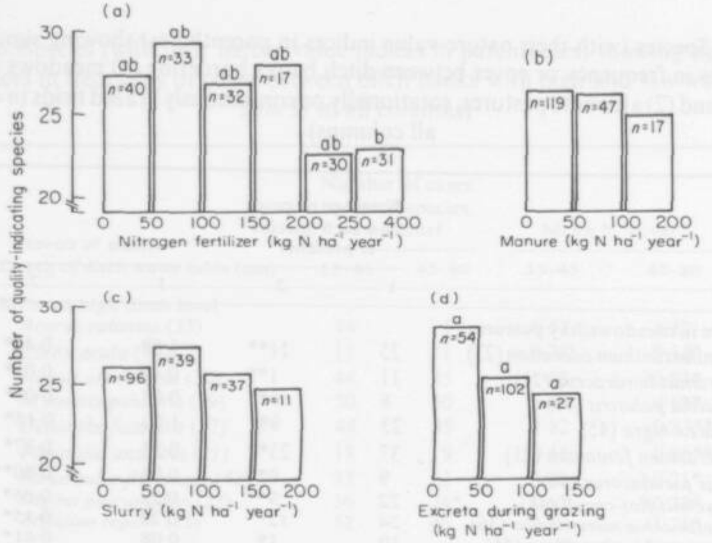

Fig. 4. Effects of nitrogen inputs in (a) fertilizer, (b) manure, (c) slurry, and (d) excretion during grazing on the number of quality-indicating species on banks (corrected for other factors, including the other types of N-application). Columns headed by the same letters within a treatment indicate ranges with significant F values ($P < 0.01$).

Slope aspect

Floristic richness was highest on south-facing banks, presumably because of the higher insolation (Geiger 1961).

All the species associated preferentially with south-facing banks were those of marshland or wet hayfields, and included several *Carex* spp. A preference of particular species for south-facing slopes, especially south-west slopes has been found before (Perring 1959; Lakhani & Davis 1982; Sykora & Liebrand 1986). However, in these studies the differences between aspects were more extreme because of the desiccation of the southerly slopes in summer. On chalk grasslands, for instance, the desiccation of south-facing slopes even led to the occurrence of xerophytic species (Perring 1959). Ditch banks do not dry out completely in summer, and therefore the differences in bank vegetation are less conspicuous than in chalk grasslands.

Because of the water surplus in winter and spring, the soil near the ditches remains wet and cold until late spring, and the vegetation develops slowly as a result. The higher floristic richness of south-facing banks may therefore be attributable to the more favourable conditions for development of the bank vegetation in spring and early summer. A higher temperature in spring will especially favour the germination of sedges and other marsh plants (Grime *et al.* 1981). Higher insolation may also promote vegetative growth and flowering (Geiger 1961; Rorison & Sutton 1975; Watts 1975).

Slope gradient

Steep south-facing banks receive more insolation in winter and spring than gentle southern slopes (and banks with a gradient of 0–30° also receive more insolation in summer) (Perring 1959; Geiger 1961). This probably explains the higher species-richness

TABLE 8. Species (with their nature-value indices in parentheses) showing significant differences in frequency or cover between banks bordering fields with low and high supply of nitrogen as fertilizer, farmyard manure and slurry (0–250 and 250–500 kg N ha^{-1} year^{-1}, respectively) ($n = 61$ in all columns)

	Number of cases in which species is present†		Mean % cover‡	
	Low N	High N	Low N	High N
More at low nitrogen supply				
Anthoxanthum odoratum (27)	32	12**	1·63	0·47**
Berula erecta (30)	24	15	0·29	0·07**
Cardamine pratensis (22)	57	52	1·41	0·96*
Carex acuta (34)	23	5**	0·29	0·07**
Carex disticha (43)	23	7**	0·61	0·03**
Carex nigra (45)	24	15	1·01	0·31*
Cirsium palustre (37)	22	8**	0·08	0·06**
Epilobium palustre (47)	10	2*	0·03	0·01*
Equisetum palustre (25)	6	0*	0·14	0·00*
Festuca pratensis (25)	20	7**	0·37	0·26**
Juncus effusus (24)	34	19**	1·19	0·37**
Lotus uliginosus (40)	39	24*	1·09	0·51**
Lychnis flos-cuculi (44)	25	10**	0·29	0·14**
Lysimachia nummularia (36)	32	16**	0·50	0·33*
Lythrum salicaria (31)	12	1**	0·08	0·00**
Rumex hydrolapathum (36)	21	8*	0·07	0·02**
Scutellaria galericulata (34)	23	13	0·33	0·14*
Trifolium pratense (22)	15	2**	0·31	0·02**
More at high nitrogen supply				
Butomus umbellatus (42)	5	15*	0·02	0·16**
Elymus repens (10)	15	36**	0·50	1·87**
Glechoma hederacea (19)	47	49	1·24	1·88*
Phalaris arundinacea (20)	27	30	0·65	3·28*
Poa pratensis (20)	33	37	0·79	1·10*
Polygonum aviculare (16)	5	17**	0·02	0·10**
Polygonum hydropiper (27)	39	56**	0·79	3·73**
Ranunculus sceleratus (27)	26	42**	0·17	0·65**
Stellaria media (11)	19	37**	0·14	0·42**

* $P \leq 0.05$, ** $P \leq 0.01$, by † χ^2 test, ‡ sign test.

of south-facing slopes with gradients of up to 35°. Steeper north-facing banks always receive less radiation than gentle slopes (Geiger 1961), and in our study did not carry more species than gentle slopes.

It is often recommended (e.g. Gäbler 1985) that the slopes of ditch banks and other water courses should be gentle rather than steep, to promote floristic richness. That may be valid where a marked soil-water gradient could develop, which might enhance species diversity. However, on banks adjacent to agriculturally-exploited grasslands, species-rich vegetation is usually confined to a narrow strip along the ditches. Here, steeper slopes appear to be preferable for south-facing banks, and no special inclination can be recommended for north-facing banks.

Ditch water table

The separate effects of water table and slope gradient on botanical composition could not be examined because there were too few samples for the matched pairs comparison.

The mechanism of the negative effect of ditch water table is unknown. Steeper slopes are frequently mentioned as causing negative water-table effects on species richness, but we did not find this. Possibly an improved mineralization of the peat soil is involved (de Boer 1977; Grootjans 1985), though we have no evidence about this.

Type of use

Grazing might either increase or decrease species-richness, depending on its intensity (Huston 1979). In current dairy farming, however, the grazing intensity is usually too high to favour greater floristic richness: on fields that are predominantly grazed, the floristic richness of the banks was lower than that by fields with lower grazing pressures (Fig. 2).

The lower species-richness might be due to the less steep slopes caused by the higher grazing pressure. But, on average, the effects of type of use and grazing intensity on the slope gradient seem to be too small to explain the effects on the floristic richness (Table 1); also, a more gentle slope was disadvantageous only for southern banks. Trampling and defoliation are probably more important for the bank vegetation. Trampling physically disturbs vegetation and soil, thereby impoverishing the species-richness (van der Maarel 1971; van Dijk 1978). It led to a greater abundance of the pioneer species *Bidens cernua* and *Polygonum hydropiper* on banks of more grazed fields (Table 7). Defoliation lowers the chance of species flowering and producing ripe seeds and stimulates the tillering of grasses such as *Lolium perenne*.

Soil P and K contents and nitrogren supply

The P and K values of the banks are high, presumably due to the yearly treatment with ditch sludge rich in P and, to a lower extent, K; the values frequently exceeded those of the adjacent fields (A. J. van Strien unpublished). But we suppose that the lack of any correlations with P and K was because neither limit growth of the bank vegetation.

The effect of the annual nitrogen supply on the richness and composition of the bank vegetation corresponds with the known effects of nutrient additions to grasslands (Rorison 1971; Elberse, van den Bergh & Dirven 1983; van Strien, Melman & de Heiden 1988). Effects of the nitrogen input from grazing on the number of q.i. species could be demonstrated within a range of 0-150 kg N ha^{-1} $year^{-1}$, though no effects of fertilizer, manure or slurry were found at that range (Fig. 4). These grazing effects were probably caused not by the nutrient addition, but by the effects of the grazing itself.

It is striking that no difference in floristic richness of banks was found when these organic dressings were applied at rates of 0–200 kg N ha^{-1} $year^{-1}$. This probably reflected variations in the degree to which the banks were manured by different farmers. It may also explain why no differences in floristic richness on banks were found between fields dressed with either manure or slurry, though such a difference is sometimes expected (van Gelder 1986). The same large variation in fertilizer dressing of the banks might be expected. Indeed, a lower floristic richness was found only if the fertilizer application exceeded 200 kg N ha^{-1} $year^{-1}$. That does not imply that low nitrogen loads do not affect the bank vegetation, but that the average amount of nitrogen supplied to the banks was only higher when there was a high nitrogen load on the fields.

Implications for ditch vegetation management

The nitrogen supply is not the only important factor for the bank vegetation. It is therefore possible that species-rich banks and species of conservation value occur beside highly fertilized fields. The potential conservation value thus seem to be considerably higher for ditch banks than for grasslands (van Strien, Melman & de Heiden 1988). On the other hand, a more intensive grassland exploitation negatively affects the bank vegetation, because of the high nitrogen supply, the higher grazing intensity, and also the lower ditch water table that often accompanies the more intensive exploitation.

The richness of banks might decline in future, not only because of possible further intensification, but also because of a possible delayed reaction by the bank vegetation to the actual management (Anon. 1985). For this study, we selected ditch banks that had been managed in a more or less constant way for 5–10 years. However, a delayed adaptation may last longer (Elberse, van den Bergh & Dirven 1983), so our findings overestimate the conservation possibilities of ditch banks.

Nevertheless, it is clear that the negative effects of intensive grassland exploitation on ditch banks can be reduced by special management. Keeping the banks free from fertilizer and presumably also from manure and slurry, and protecting them from grazing will be beneficial. It will also be worthwhile to keep a high ditch water table, to prevent acidification of banks and to prevent south-facing banks from becoming less steep.

Several of these measures will not seriously hamper the agricultural exploitation of the grasslands, so the prospects of maintaining botanically-rich ditch banks beside agricultural fields may be good.

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5

EFFECTS OF MECHANICAL DITCH MANAGEMENT ON THE VEGETATION OF DITCH BANKS IN DUTCH PEAT AREAS

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Summary

(1) The effects of three aspects of mechanical ditch management (cleaning frequency, cleaning method and dredging) on the ditch bank vegetation in Dutch peat areas were studied.

(2) An optimum relationship between species richness and cleaning frequency was assessed; the greatest species richness was found when cleaning was once every 2-3 years.

(3) 38 species benefited more from ditch cleaning every 2-3 years than from yearly ditch cleaning; they included species that are endangered in the peat district. Only 5 common species had more cover when ditch cleaning was yearly. The botanical differences between ditch cleaning once every 2-3 years and less frequent ditch cleaning were somewhat small.

(4) The results suggest the following reasons for the floristic richness being poorer with yearly ditch cleaning than with less frequent ditch cleaning: the larger supply of nutrient-rich sludge, the vegetation being suffocated by sludge and the physical damage caused to the plants. Soil acidification resulting from sludge dumping is not important.

(5) The somewhat poorer species richness of banks along ditches cleaned less frequently than every three years is presumably associated with the ongoing succession.

(6) The cleaning method appeared to be irrelevant to the floristic richness of the banks, probably because of the variation in how the farmers use the cleaning machinery.

(7) No botanical differences were found between banks of ditches that had been dredged 1-5 years previously and those of ditches that had been dredged more than 5 years previously, presumably because the dredged mud was spread over the fields and not over the banks.

(8) A ditch-cleaning frequency of once every 2 or 3 years is recommended, provided this is compatible with proper water management. In all management practices the strip of the bank immediately above the water level should be kept free from ditch sludge.

Introduction

Many grasslands in the peat polders in the western Netherlands used to be rich in plant species (Westhoff et al., 1971; De Boer, 1982). The intensification of dairy farming, including the increased use of nutrients, has led to species-rich plant communities being nowadays largely confined to the banks of the ditches bordering the fields. Because the low-lying parts of these ditch banks are of only minor agricultural value, they might become a focal point for nature conservation in the cultivated parts of the peat areas (Melman et al., 1988).

According to Van Strien et al. (1989) banks should be excluded from fertilizing and manuring and protected from intensive trampling by the cattle in order to maintain or restore their floristic value. Furthermore, a high level of the ditch water, a high pH of the soil and, for south-facing banks, a steep slope will favour the species richness.

In addition, changes in the management of ditches by the farmers might raise the species diversity of banks. A regular management is prescribed by regional water boards in the Netherlands in order to maintain a proper discharge of water from the peat polders (Van der Linden, 1982). All the plants in and near the ditches must be removed frequently, to prevent the eutrophic ditches from becoming clogged. The plant material and mud removed when the ditches are cleaned are dumped on the banks, thereby restoring their slopes, which cattle and the terrestrialization process have degraded. The water boards often prescribe cleaning once a year, before the winter. They also specify the depth and the profile of the ditches. Many ditches are dredged once every 5-10 years, to meet these specifications. The large volume of mud removed from the ditch bottoms is usually spread over the adjacent fields, but may also be dumped on the banks.

Farmers may choose the method of ditch cleaning. Formerly, they cleaned the ditches manually, but nowadays most ditches are cleaned mechanically; in the peat district water plants are only rarely controlled by chemicals. The mechanization of the ditch management has frequently been assumed to threaten the species diversity on the banks, especially because most of the big machines used are expected to deposit large amounts of sludge. Therefore, to maintain species richness, farmers are advised to clean ditches manually or with a mowing-basket, which is thought to deposit a small amount of sludge; other methods are discouraged (Rijksinstituut voor Natuurbeheer, 1979). Sometimes a less frequent cleaning is suggested to benefit the bank flora.

Few studies have been done to support these recommendations about ditch management. Beltman (1984) compared the banks of ditches cleaned by mowing-basket with those cleaned by ditch-scoop in a peat polder in the province of Utrecht. Though he found no differences in species number, his study suggests that species with a relatively high conservation value occur more along ditches cleaned with the mowing-basket than along ditches cleaned with the ditch-scoop. In an experimental study Geerts (1988) found that mechanical cleaning led to a greater decrease of species worth conserving than manual cleaning. The management regimes of both studies was constant over a period of 3 and 5 years respectively.

In our study we compared the effects of five cleaning methods and several cleaning frequencies. In addition, we studied whether the dredging of the ditches affects the bank vegetation.

Material and methods

Study sites and study design

The study sites were in the peat areas of Zuid-Holland and the western part of Utrecht (see Van Strien et al., 1988). These boggy areas were drained and reclaimed from about 1100 AD. At that time, many parallel ditches were dug to drain the peat so that the area could be farmed. This resulted in a polder landscape with long, narrow fields separated by ditches (Van der Linden, 1982). Most ditches were 3 - 6 m wide and contained 0.3 - 0.6 m water and a 0.2 - 0.5 m thick layer of sapropelium.

The effects of ditch management were studied by means of spatial comparison of the vegetation of 320 banks at different management regimes. The management of the ditches and the adjacent fields of grass was known to have been constant for 5-10 years preceding our study. To study the effects of low cleaning frequencies we chose banks along ditches that had been cleaned at least three times by the same method.

Apart from this, 47 banks were observed in three consecutive years (1984-1986) after they had been cleaned, to monitor the temporal changes in the vegetation after cleaning.

Vegetation sampling

The ditch bank vegetation was sampled in 1983-1986 between the end of June and mid-September, always before the cleaning. The banks monitored in the three consecutive years were always examined in the same months. On each bank a 50 m long relevé was made, using the cover scale of Clausman & Van Wijngaarden (1984). Each relevé ran 0.7 m up the bank from the water's edge, as this strip always contained almost all bank species. The vegetation in the water of the ditches was not recorded.

Indices of floristic richness

We used three indices of floristic richness of the sampling plots:

(1) number of species;

(2) number of quality-indicating species ("q.i. species") (see Drijver & Melman, 1983). This number includes all species except very common species favoured by intensive exploitation and overexploitation (e.g. *Stellaria media*; nomenclature follows Van der Meijden et al., 1983) and species that occur only occasionally in grasslands and on ditch banks in the Netherlands, but which are common in other habitats (e.g. *Lamium purpureum*);

(3) nature-value index. Clausman & Van Wijngaarden (1984) determined what they call the "nature-value index" of species from estimates of their regional (Zuid-Holland), national and world rarity and their rate of decline. Furthermore, they distinguish the nature-value index of a plot, which they calculated by summing the nature-values of all species present, taking into account their cover percentages.

Ditch management

Information about ditch management and grassland exploitation was obtained from 150 farmers involved in this study and from field observations.

We distinguished the following four classes of cleaning frequency: (1) yearly, henceforth referred to as high frequency (2) once every two years, (3) once every three years, together referred to as medium frequency and (4) less frequently, referred to as low frequency.

All the current methods of cleaning ditches in Dutch peat areas were represented:

(1) manual cleaning. This method involves cutting into the edge of the ditch bank at a distance of about 10-20 cm from the water line and then using a hook to pull the water plants, some sapropelium and soil material onto the banks;

(2) mowing-basket. This machine has a basket with a cutter bar in front of it. The cutter bar mows the water plants and renews the edge of the ditch bank. Some of the water plants and the material from the ditch and the bank falls back into the ditch through the bars of the basket; the remainder is dumped onto the banks;

(3) ditch-scoop. This equipment has no cutter bar. As with manual cleaning, the ditch bank edge is cut loose, and water plants, some of the sapropelium and material from the edge of the ditch bank is dumped onto the banks. The gaps in the scoop are usually smaller than those of the mowing-basket and therefore more ditch material is thought to fall on the banks;

(4) other types of specialized cleaning machinery, mainly the bottom auger. This machinery loosens water plants, the ditch bottom and the edge of the ditch bank; the material is transported and pulverized and a mixture of water-rich sludge is squirted over the banks;

(5) any two of the above methods, used alternately.

We did not study the timing of the ditch cleaning. In fact, almost all the farmers cleaned their ditches between September and November, and they generally dumped the sludge on the banks within 1.5 m of the water's edge.

Most of the ditches were dredged once every 5-10 years. We distinguished two classes: ditches that had been dredged 1-5 years before our study and those that had been dredged more than 5 years before our study.

Physical factors and field management

Soil samples were collected once in the autumn, a few months after the ditches had been cleaned. The 0-10 cm layer of the banks within 70 cm from the ditch water line was sampled. In addition, the peat mud in the ditches was sampled. After extraction in acetic acid, the P contents were measured colorimetrically with molybdate and the K contents were measured by flame absorption photometry (Allen, 1974); the pH was determined in water; Total N was measured by the Kjeldahl method; Total C by measuring the weight loss on ignition at 450°C (Allen, 1974).

The bank gradient was determined at 70 cm from the water's edge. For a description of how we measured other factors that may influence the bank vegetation, see Van Strien et al. (1989). We distinguished the following ranges or classes:

- soil type: (1) mesotrophic peat; (2) eutrophic peat; (3) mesotrophic clay-on-peat; (4) eutrophic clay-on-peat. Coverings of clay were < 40 cm thick;
- slope aspect: (1) facing south, south-east and south-west; (2) facing north, north-east and north-west; (3) facing east and west;
- ditch water table: range of 15 - 80 cm below the grassland surface;
- type of land use: (1) meadow (cut frequently); (2) hay pasture (cut in June, subsequently only grazed); (3) alternate pasture (grazed and cut alternately); (4) grazed rotationally (and never cut); (5) continuously grazed during the growing season;
- nitrogen applied on the adjacent fields: range of 0 - 550 kg N ha^{-1} yr^{-1}, consisting of mineral fertilizer, farmyard manure, slurry and droppings from grazing cattle.

Statistical analysis

The effects of ditch cleaning on botanical parameters were adjusted statistically for all factors that were found to be important (see Van Strien et al., 1989): observer, sampling period, soil type, pH of the topsoil, slope aspect, water table, type of land use and nitrogen supply. No correction for bank gradient was made in the analyses, since a change of bank profile might be part of the mechanism of the effects of ditch management. Two statistical methods were used:

(1) Analysis of variance (ANOVA; Nie et al., 1975). ANOVA was used to assess the individual effects of the factors on floristic richness or on groups of plant species. The ANOVA calculated the means of the dependent variables per factor class, corrected for the effects of all other factors involved. Metric factors were both used as covariates and as factors divided into several classes in the ANOVA runs. Each factor was adjusted for all other factors involved in the ANOVA (see Van Strien et al., 1988).

(2) Comparison of matched pairs. ANOVA was not suitable for assessing the effects on individual plant species, because many zero cover values were recorded. Therefore, we tested the effects on individual plant species by comparing matched sets of sampling plots.

For each test the plots were divided into two groups according to the value of the factor studied. The pairs of relevés were selected in such a way that the only factor that differed between the pairs was the one being studied. Differences in the occurrences of species between the matched pairs were tested with a chi-square test; differences in cover were tested with a sign test. Mutual dependence of test results was ignored, because at each dose factor a limited and varying part of the entire data set was used (Van Strien & Meelis, 1990).

Results

All factors together explained about half of the variance in floristic richness of ditch banks (multiple $r = 0.72$ for e.g. the number of species). Corrected for other factors, the cleaning frequency proved to be significantly related to all three indices of floristic richness (Fig. 1; F value = 21.04; $P < 0.01$ for e.g. the number of species). No differences in floristic richness could be ascribed to the method of ditch cleaning and to the time elapsed since ditch dredging (F value = 0.16; $P > 0.05$ and F value = 1.44; $P > 0.05$ respectively for the number of species); the same held when only the ditches cleaned yearly were tested.

The number of species, quality-indicating species and the nature-value index was lowest on banks with a high cleaning frequency. Furthermore, the number of species and quality-indicating species was somewhat lower on banks with a low cleaning frequency than along ditches with a medium cleaning frequency (Fig. 1).

Because of the optimum-like relationship in Fig. 1, we compared the botanical composition of banks of ditches that were cleaned at medium frequency with those of ditches cleaned at high frequency and with those of ditches cleaned at low frequency. We found that 38 species were more abundant on banks of ditches cleaned at medium frequency than on those of ditches cleaned at high frequency (Table 1). Many of these species have a high nature-value index (≥ 40) and are endangered in the peat district, e.g. *Epilobium palustre* and *Lysimachia thyrsiflora*. Only 5 species, all of them common, had greater cover on banks of ditches cleaned at high frequency. The botanical differences between banks of ditches cleaned with medium frequency and those of ditches cleaned with low frequency seem to be much smaller (Table 2); this may be because of the smal-

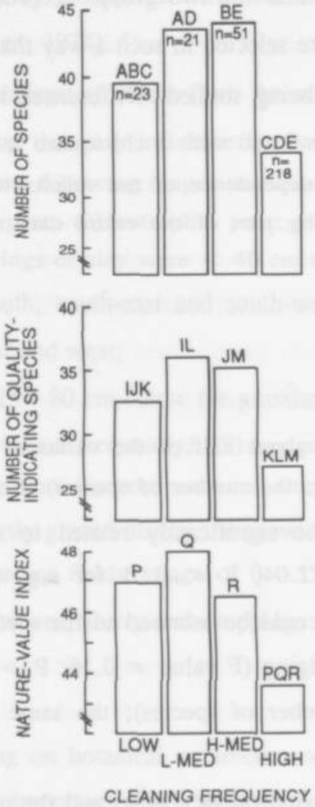

Fig. 1. Mean number of species, quality-indicating species and nature-value index of banks in relation to cleaning frequency. Columns headed by the same letters differed significantly (ANOVA; P ≤ 0.05). Low: cleaning less often than once every three years; L-med: cleaning once every three years; H-med: cleaning once every two years; High: yearly cleaning. All periods after the last cleaning were combined.

ler differences in species richness (see Fig. 1), but also because a limited number of matched pairs was involved.

Several pioneer species (*Polygonum hydropiper*, *Ranunculus sceleratus*) were found more at a higher frequency of ditch cleaning, whereas several species that are often part of land-forming plant communities did better on banks of ditches with lower cleaning frequency, such as *Phragmites australis* and *Acorus calamus* (Table 1; Table 2).

The botanical differences between classes of ditch-cleaning method and between dredging classes were only slight and not straightforward.

To view the changes in time after a cleaning, we examined banks in consecutive years.

Table 1. Species (with their nature-value indices in parentheses) showing significant differences in presence or cover between banks of ditches with medium and high cleaning frequency, corrected for other factors by means of matched pairs comparison (n = 68 in all columns).

Cleaning frequency	Number of cases in which species is present 1) *medium*	*high*	Mean cover (%) 2) *medium*	*high*
More abundant with medium frequency:				
Agrostis stolonifera (18)	68	67	21.20	15.62 **
Alisma plantago-aquatica (29)	16	4 **	0.06	0.01 *
Anthoxanthum odoratum (27)	52	20 **	2.57	1.15 **
Berula erecta (30)	49	20 **	0.47	0.20 **
Caltha palustris (36)	15	2 **	0.07	0.01 *
Carex disticha (43)	31	21	0.75	0.57 *
Carex hirta (28)	46	29 **	0.69	0.43 *
Carex nigra (45)	51	22 **	0.77	0.76 **
Cerastium fontanum (21)	59	48 **	0.66	0.67
Cicuta virosa (45)	29	5 **	0.11	0.01 **
Deschampsia cespitosa (27)	20	6 **	0.46	0.04 **
Eleocharis palustris (29)	49	25 **	1.64	0.74 **
Epilobium palustre (47)	24	5 **	0.16	0.03 **
Festuca rubra (22)	53	27 **	5.29	2.25 **
Galium palustre (35)	66	58 *	1.69	1.04
Hydrocotyle vulgare (40)	18	5 **	0.29	0.10 *
Iris pseudacorus (40)	18	4 **	0.08	0.01 **
Juncus articulatus (30)	63	52 *	1.61	1.41
Juncus effusus (24)	41	24 **	0.46	0.95 *
Leontodon autumnalis (25)	10	1 *	0.05	0.00 *
Leontodon saxatilis (40)	6	0 *	0.03	0.00 *
Lotus uliginosus (40)	52	39 *	0.84	0.74
Lychnis flos-cuculi (44)	40	18 **	0.81	0.17 **
Lycopus europeus (29)	21	7 **	0.08	0.02 **
Lysimachia thyrsiflora (45)	33	9 **	0.15	0.05 **
Mentha aquatica (31)	49	22 **	0.55	0.16 **
Myosotis palustris (29)	65	57 *	0.89	0.90
Nasturtium microphyllum (29)	33	18 *	0.36	0.09 *
Oenanthe fistulosa (37)	63	50 **	1.43	2.05
Phragmites australis (18)	13	4 *	0.07	0.02 *
Potentilla anserina (21)	32	21	0.26	0.19 *
Prunella vulgaris (31)	21	6 **	0.20	0.03 **
Rumex acetosa (23)	59	44 **	1.12	1.22
Rumex hydrolapathum (36)	52	21 **	0.23	0.05 **
Sagina procumbens (23)	50	36 *	1.49	1.14 *
Stellaria palustris (48)	17	5 *	0.08	0.03 *
Trifolium pratense (22)	29	7 **	0.24	0.13 **
Triglochin palustris (37)	53	35 **	1.60	1.50 *
More abundant with high frequency:				
Holcus lanatus (17)	66	66	9.05	12.92 *
Lolium perenne (12)	36	39	0.26	0.74 *
Phalaris arundinacea (20)	23	33	0.29	2.01 **
Polygonum hydropiper (27)	56	54	1.09	2.32 *
Ranunculus sceleratus (27)	26	38	0.12	0.56 *

* $P \leq 0.05$; ** $P \leq 0.01$ by [1] X^2-test, [2] sign test

Table 2. Species (with their nature-value indices in parentheses) showing significant differences in presence or cover between banks of ditches with low and medium cleaning frequency (n=18 in all columns).

	Number of cases in which species is present 1)		Mean cover (%) 2)	
Cleaning frequency	*low*	*medium*	*low*	*medium*
More abundant with low frequency:				
Acorus calamus (33)	8	6	5.30	0.26 *
Holcus lanatus (17)	18	17	12.32	7.31 *
Iris pseudacorus (40)	9	3	0.17	0.10 *
Trifolium repens (13)	17	13	2.29	1.42 *
More abundant with medium frequency:				
Glyceria fluitans (24)	15	17	1.89	7.19 *
Polygonum hydropiper (27)	12	15	0.29	2.08 *
Potentilla anserina (21)	2	9 *	0.03	0.20 **
Nasturtium microphyllum (29)	7	11	0.12	0.64 *

* $P \leq 0.05$; ** $P \leq 0.01$ by [1] X^2-test, [2] sign test

We found no differences in the number of species and in the nature-value index one and two years after ditch cleaning (A in Table 3) and no such differences for the 15 banks that remained uncleaned for three years (B in Table 3). No autonomous changes in floristic richness occurred during these years; this could be demonstrated on 19 banks along ditches cleaned yearly (Table 3). One and two years after the cleaning we found no systematic changes in the 38 species (Table 1) that preferred banks along ditches at a medium frequency of ditch cleaning to a high frequency; 13 species had higher cover 1 year after cleaning and 16 species had higher cover 2 years after cleaning (sign test on cover values p= 0.31; n= 38).

A group of common pioneer species, consisting of *Bidens cernua*, *Bidens tripartita*, *Juncus bufonius*, *Polygonum hydropiper* and *Ranunculus sceleratus*, was compared over more than two years by means of ANOVA. This group had the highest cover at high frequency of ditch cleaning; at lower cleaning frequency the cover was the highest in the first year after ditch cleaning and then decreased with time (Fig. 2A).

The differences in bank gradient were also traced by means of ANOVA. After 1-2 years had lapsed since the cleaning, the bank gradients at low/medium frequency of ditch cleaning did not differ from those of banks of ditches cleaned at high frequency (Fig.

Table 3. Mean number of species and nature-value index on banks of ditches with different cleaning frequencies and with different periods elapsed since cleaning. 28 banks were involved with ditch cleaning once every two years or less frequently (A); 15 of those had been cleaned once every three years or less frequently (B). 19 banks were involved along ditches that were cleaned yearly. All banks were three times examined, in the summers of 1984, 1985 and 1986.

Cleaning frequency	No. of yrs after cleaning	Mean number of species		Mean nature-value index	
Once every two years or less frequently					
		A (n=28)	B (n=15)	A (n=28)	B (n=15)
	1	46.0	46.6	48.3	49.7
	2	46.5	47.8	48.5	49.6
	3		45.4		49.4
		0.75[1]	0.93[2]	1.16[1]	3.10[2]
Yearly					
		(n=19)		(n=19)	
(1984)	1	37.0		42.1	
(1985)	1	39.1		42.3	
(1986)	1	39.0		42.5	
		1.76[2]		0.32[2]	

* P ≤ 0.05 by [1] Matched pairs t-test (t-value) [2] Friedman test (X^2)

2B). This is because the ditch cleaning interrupts the process of terrestrialization and restores the bank profile. Only after more than two years did the bank gradients become more gentle.

Differences in the amount and frequency of sludge dumping are expected to be reflected in the chemical parameters of the soil. Indeed, the P content was higher in samples from banks cleaned frequently than in samples from banks cleaned less frequently (Table 4). However, no differences in P were found for different ditch cleaning methods and for periods of different length after dredging. Frequency of cleaning, cleaning methods and time elapsed since dredging had no effect on the pH and K contents (Table 4).

The pH and P content of the sapropelium were higher than those of the adjacent banks (Table 5). The K contents did not differ significantly. The average C/N ratio and the C/N range of the bank soil were smaller than those of the sapropelium, probably because of the decomposition of the organic material dumped on the banks (Table 5).

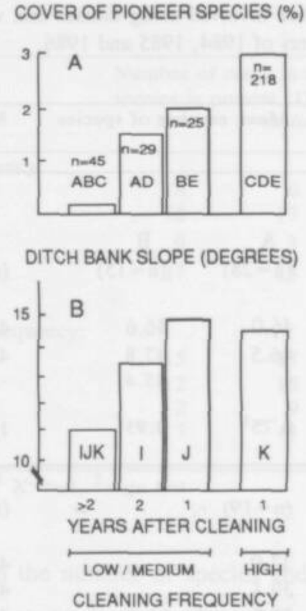

Fig. 2. Mean cover of pioneer species (A) and mean slope gradient in summer (B) in relation to the number of years after the ditch was cleaned and cleaning frequency. Columns with the same letters differed significantly (ANOVA; $P \leq 0.05$). Low and medium frequencies were combined.

Discussion

The results indicate that on present-day dairy farms in the peat district of the western Netherlands modifications to the ditch management may promote the floristic richness of the ditch banks. A considerable number of species would benefit from such changes of the management, including species with relatively high nature-value indices, such as *Lysimachia thyrsiflora*, *Lychnis flos-cuculi* and *Carex disticha*. The potential advantages of changing the management strategy are at least as great as the effects of reducing the supply of fertilizer and manure (Van Strien et al., 1989).

Since the effects of the frequency of ditch cleaning appear to be most important for the floristic richness of ditch banks, we will discuss the possible mechanisms underlying them more thoroughly.

Table 4. Values of $pH\text{-}H_2O$, P and K of the topsoil of banks of ditches with different cleaning frequencies, methods of cleaning and periods that had elapsed since the ditches had been dredged. Corrected for other factors by means of matched pairs comparison. The P and K contents are expressed as mg per 100 g dry soil.

Factor	pH		P		K	
	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.
Frequency of ditch cleaning (n=22)						
High	6.01	0.52	3.22	3.65	20.4	18.4
Medium/Low	5.81	0.43	1.65	1.97	17.4	10.8
			*			
Method of ditch cleaning (n=42)						
Hand/Mowing-basket	5.89	0.56	2.62	2.17	23.4	16.9
Ditch-scoop/Bottom auger	5.81	0.55	3.13	2.51	27.3	20.9
Period after ditch dredging (n=39)						
1-5 years before	5.75	0.42	2.80	2.74	22.9	15.1
More than 5 years before	5.90	0.56	2.32	2.12	20.2	9.8

* $P \leq 0.05$ by sign test

Table 5. Selected chemical properties of 28 ditch bank topsoils and sapropelium of adjacent ditches, sampled in the autumn of 1986. P and K values are expressed in mg per 100 g dry soil.

	pH		P		K		C/N		C/N
	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.	range
Bank soil	6.31	0.53	5.09	5.00	34.8	22.9	16.2	1.5	13-19
Sapropelium	6.83	0.31	8.78	9.06	35.1	15.5	21.9	9.5	11-47
	**		*				**		

* $P \leq 0.05$; ** $P \leq 0.01$ by sign test

Frequency of ditch cleaning

The greater occurrence of *Polygonum hydropiper* and other pioneer species at higher frequencies of ditch cleaning points to sludge dumping as a factor determining the botanical composition of banks. These annual species prefer wet and nutrient-rich habitats and germinate rapidly on bare spots in the sward (Westhoff & Den Held, 1969). When much sludge is dumped on the banks the vegetation under it suffocates, but annuals can germinate on the bare sludge. If there is no further dumping of sludge these pioneers will disappear within several years (Fig. 2A). Yet, our results suggest that the suffocation effects are not severe. The cover of the pioneer species in general remained low after the ditches had been cleaned. Furthermore, no decline of floristic richness was detected after the cleaning (Table 3), nor were substantial changes recorded in the botanical composition.

The sludge is dumped in the autumn, when the above-ground parts of many plant species are starting to die off. The sludge dries out and weathers in winter, and only small remnants remain in the spring; these apparently do not seriously hamper plant development. This suggests that the effect of suffocation is limited, provided that the banks have not been completely covered with a very thick layer of sludge. The sludge might also cause acidification of the bank soil, if any FeS_2 present in the ditch mud oxidizes (Breeuwsma et al., 1985). However, the pH of the banks was only slightly lower than the pH of the sapropelium. Also the relatively high pH (about 6) of bank soils of ditches that are cleaned yearly suggests that no appreciable acidification is caused by ditch cleaning.

Because the sludge in eutrophic waters is usually rich in P and N (Table 5; Brock et al., 1983), it may increase the nutrient availability on the banks, thereby adversely affecting species richness. The higher amount of P at yearly cleaning than at medium cleaning frequency points to the role of ditch cleaning as a source of nutrients. This explains that a considerable number of the species that benefit from medium rather than high frequency of ditch cleaning in fact are species that prefer less fertile conditions e.g. *Anthoxanthum odoratum* and *Leontodon autumnalis* (see Van Strien et al., 1988). Nutrients from the dumped sludge are not directly available for plant growth, because the mineralization of the sludge may be delayed as a result of the high C/N ratio of the peaty mud of ditches. Many ditches contained sapropelium with C/N ratios above 20-25, up to 47; such high levels temporarily immobilize the nitrogen instead of increasing nitrogen availability (Parnas, 1975). Therefore, the process of species dying out because more nutrients are available from yearly ditch cleaning will last several years; in addition most of the plant species involved are perennials, which do not disappear rapidly (Elberse et al., 1983). This would explain why no decline of floristic richness was detected after the cleaning.

Physical damage to the plants when the edge of the bank is being removed may be important also. Several of the species that prefer a medium frequency of ditch cleaning to a high frequency are perennials with large rhizomes e.g. *Cicuta virosa* and *Rumex hydrolapathum* (Westhoff & Den Held, 1969). These species will benefit from a lower frequency of ditch cleaning, because their rhizomes are less often damaged or removed by the ditch cleaning. Even so, the botanical composition hardly changes the first 2-3 years after a cleaning. Apparently, the succession proceeds slowly.

When the succession is allowed to proceed undisturbed, species richness will eventually decline. Helophytes with rhizomes, such as *Acorus calamus*, may become more abundant. Tall species will become dominant and species richness will decline, because plant growth is more difficult under the dense canopy (Oomes & Mooi, 1981; Wheeler & Giller, 1982). We therefore tentatively conclude that the disturbance caused by ditch cleaning probably prevents a dominance of tall marsh plants and benefits other species.

The changes of bank slope over time are too small to contribute to the poorer bank species richness that occurs with low cleaning frequency (Van Strien et al., 1989). Another possible explanation might be that ditches cleaned infrequently are scoured very drastically when they are cleaned, and much sludge is removed from the ditch bottoms and dumped on the banks, thereby suffocating the bank vegetation. But immediately after cleaning we found no indication of such suffocation at these cleaning frequencies; the few banks with a low frequency of ditch cleaning showed no clear difference in species richness in the first three years after the cleaning.

Thus, more than one mechanism seems to underlie the optimum relationship between species richness and cleaning frequency. At high frequent cleaning, a larger supply of nutrients will contribute to fewer species, whereas at low frequent cleaning the ongoing succession might be responsible for the poorer species richness; in both cases the end result is a greater shoot biomass, which is thought to reduce the species richness (Al-Mufti, 1977; Grime, 1978, 1979; Vermeer & Berendse, 1983). Other mechanisms such as suffocation and removing of rhizomes may also play a role.

In his experimental study Geerts (1988) found that the vegetation of ditch banks of ditches cleaned once every two years and cleaned yearly did not differ. However, he compared banks of ditches that were cleaned manually and relatively small amounts of sludge were dumped on the banks. Therefore, the lack of a frequency effect in his study might be due to small differences in the cleaning.

Cleaning method and time elapsed since dredging

We found no differences in floristic value of banks between methods of ditch cleaning; the botanical composition hardly differed between the methods. Even the supposed extremes in cleaning method, hand and bottom auger, did not result in banks of different floristic richness. The fact that sludge dumping appeared to be important for the bank vegetation suggests that in current cleaning practice the machinery used does not generally differ in the amount of sludge dumped; this is confirmed by the lack of a difference in P contents of the bank soil (Table 4). Probably, the lack of a machinery effect is the result of the great variation in the way farmers do the cleaning. Both the amount of the dumped material and its composition can vary considerably within each method, e.g. in terms of the amount of sapropelium.

Beltman (1984) and Geerts (1988) found greater botanical differences than we did between banks along ditches cleaned by different machinery. In their studies less than ten farmers were involved and the different machinery used was most probably intentionally accompanied by actual differences in the management and the amounts of sludge dumped. Our data on the way ditches are cleaned on 150 dairy farms suggest that in practice the type of cleaning machinery alone does not say much about the real management intervention and the amounts of sludge dumped.

The lack of differences in bank vegetation and chemical composition of bank soil as a result of the time elapsed since dredging agrees with the reports of the farmers that the sludge is spread over the fields and that banks are kept free from the dredged mud. The floristic richness and chemical composition of the soil of grasslands did indeed differ depending on the time elapsed since dredging (Van Strien et al., 1988; Van Strien & Ter Keurs, 1988).

Some suggestions for ditch management

Reducing the frequency of the ditch cleaning to once every two or three years is floristically beneficial. Less frequent cleaning seems to be less desirable; it may bring about a somewhat lower species richness.

A reduced cleaning frequency, if compatible with a proper water management of the polders, might be attractive to farmers, because it saves time and money. If less frequent ditch cleaning is not feasible, other measures that reduce the dumping of sludge on the banks and protect the rooting zone can be used to improve floristic richness. It seems to be unnecessary to lime to prevent the banks from possible acidification due to sludge dumping.

Our results on cleaning method do not agree with the general opinion that manual cleaning and cleaning with a mowing-basket have less negative effects on the bank vegetation than other methods. Recommending a particular sort of cleaning machinery does not guarantee that great floristic richness will be achieved. It is more important to do the cleaning properly. Large amounts of sludge, especially large quantities of the nutrient-rich sapropelium, should not be dumped on the banks anyway. Furthermore, it is floristically undesirable to dump the sludge on the lowest and most species-rich part of the banks. It is better to spread it over the adjacent fields, which are usually already species-poor.

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DISTRIBUTIONS OF WEEDS IN RELATION TO FLORISTIC RICHNESS OF DITCH BANK VEGETATION AND DAIRY FARMING PRACTICE

A.J. van Strien, M.A.W. Noordervliet & T. van der Meij

Summary

Dairy farmers in the peat areas of the western Netherlands expect weed problems to increase if they manage ditch banks with the aim of maintaining botanical diversity. Therefore, distribution patterns of twelve weeds on fields of grass and ditch banks were studied to find out whether ditch banks contribute to weed problems and whether these problems are greater if the banks support a floristically rich vegetation. Floristic richness was expressed as the nature-value index.

Weed species varied considerably for particular distances from the ditch; the most noxious weeds (e.g. *Cirsium arvense*) rarely occurred on banks or preferred the upper parts (e.g. *Elymus repens*).

A higher nature-value index of the vegetation of the lowest part of the bank slopes was accompanied by fewer weeds and fewer of the most noxious species on that spot.

The cover of weeds on the field appeared to be related to nitrogen supply and other agricultural factors, but no relation with the bank cover was found, except for *Taraxacum officinale*.

It is concluded that managing the vegetation on the lower parts of the banks for diversity should not enhance weed problems, but should reduce them.

Introduction

The intensification of dairy farming in the grassland areas on peat soil in the western Netherlands has caused many plant species to decline in recent decades (De Boer, 1982). Many species once common on these grasslands now occur only on the ditch banks bordering the pastures, especially on the part near to the water (Melman et al., 1988).

The floristic richness of the banks can be maintained by specific measures, such as keeping the banks free from fertilizer or preventing the cattle from trampling the banks (Van Strien et al., 1989). Therefore, the ditch banks offer opportunities for conserving many plant species, provided that dairy farmers do not perceive floristically rich banks as disadvantageous.

Compared with agriculturally exploited banks, floristically rich banks have two potential disadvantages to farmers: a lower yield and a possible increase of weed problems. Lower yields will hardly be a loss; most farmers do not regard the lowest part of the banks as production units, because the banks are difficult to exploit as a result of the wetness of the soil and their slope (Melman et al., 1988). Consequently, the nutrient status is relatively poor closest to the ditch water.

The agriculturally undesirable plant species pose a potentially more serious problem. Various weeds are common nowadays in the pastures in the western peat areas of the Netherlands. They include *Elymus repens, Poa annua, Stellaria media* and *Cirsium arvense*. Farmers commonly regard field margins as a source of weeds (Marshall, 1988) and expect weeds to increase if the management of ditch banks is aimed at a floristically rich vegetation. Though seed dispersal is limited for many species, the strip of bank nearest the water's edge is sufficiently close to the fields to allow seeds from weeds to be dispersed on the fields (Hill, 1977; Marshall, 1989). In addition, some of these weeds might spread vegetatively from the ditch banks. It has been stated that weeds do not invade grass swards if the grasslands are properly managed and have a closed turf (Amor & Harris, 1975; Werkgroep Akkerdistel, 1978), but with intensive grassland exploitation a dense turf cannot always be maintained. Gaps in the sward frequently arise, as a result of heavy cuts followed by poor regrowth, by grazing cattle (poaching and urine scorching) and by heavy or uneven distribution of slurry. Such gaps provide opportunities for weeds to establish (Van Burg et al., 1980; Ennik et al., 1980).

Hardly any information appears to be available on weed spread from ditch banks into grass swards. We examined whether the vegetation of the lowest part of the banks contributes to weed problems on the adjacent fields and whether this influence is greater for banks supporting a species-rich vegetation.

Material and methods

Outline of the study

The habitat characteristics of the weeds might provide indications about the potential risks of weed problems. Therefore, we examined the distribution of weeds over the slope of the banks from ditch water line to the field.

More directly, we assessed the relation between the floristic richness of the banks and the cover of each weed on the fields, by examining the relation between the floristic richness and the weed occurrence on the banks and then by examining the relation between weed cover on the banks and on the fields. To assess the latter relation properly, we corrected for other environmental factors affecting the weed cover on the fields.

Environmental factors

The 125 dairy farms involved in the study are in the peat areas of the provinces of Zuid-Holland and Utrecht. All the fields and banks studied were known to have had a constant management regime during the preceding 5-10 years. Data on management regimes were obtained by questioning the farmers and by field observations (see also Van Strien et al., 1989). The main issues in the survey were nitrogen supply, grassland utilization, water table and weed control.

Nitrogen applications ranged from 0 - 600 kg N ha^{-1} $year^{-1}$. The grassland utilization was classified in five classes ranging from frequently cut to continuously grazed. Weeds appeared to be mainly controlled chemically; herbicides were mainly applied locally and selectively and the lowest parts of the banks were usually not sprayed. Those fields that were entirely treated with herbicides were dropped from the study. Of the remaining fields we distinguished between fields with chemical weed control and fields without. The soil types of the fields were derived from soil maps (scale 1:50000). Four soil classes were distinguished: eutrophic peat, eutrophic clay-on-peat, mesotrophic peat and mesotrophic clay-on-peat. Water tables were measured in 1984. The pH-KCl of the top 10 cm of soil on all fields was determined once. Field dressing with peat mud was assigned to two classes: dressed with sludge 1-5 years before our study and dressed more than 5 years before our study.

Vegetation sampling

The vegetation of 125 fields and 320 ditch banks was examined once between the end of June and mid-September 1983-85. All plant species were recorded. Four grassland plots (1 m x 4 m) were sampled per field, along a diagonal (Fig. 1); cover values from these

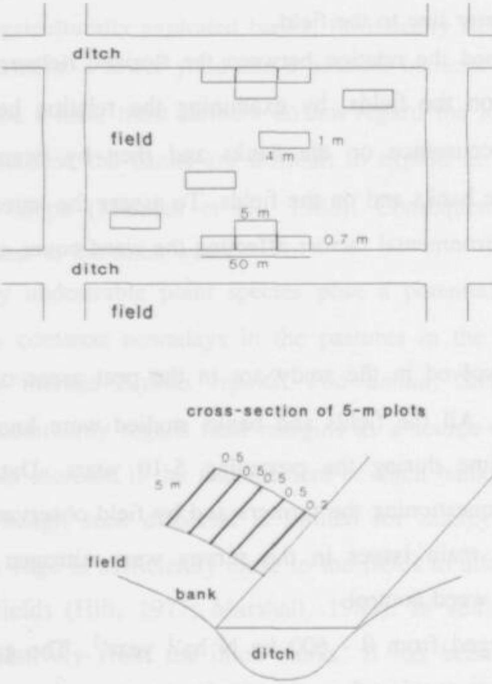

Fig. 1. Diagram (not to scale) showing the location of the vegetation sampling plots on the field and the ditch banks (hatched). Both the 50-m and the 5-m ditch bank plots are indicated; in a cross-section of the latter the distinguished strips are indicated.

four plots were averaged. For each field two more relevés (50 m x 0.7 m) were made of the central part of the longitudinal ditch banks (Fig. 1). The bank plots were sampled from the water's edge up to 0.7 m from the ditch; this strip comprised almost all bank species. In addition, in a number of cases, the entire bank slope was examined by means of separate relevés of 5 m x 0.5 m or, nearest to the ditch, 5 m x 0.2 m (Fig. 1).

Vegetation parameters

We analyzed the occurrence of the 12 most common weeds in the study area. Ten of these weeds are species that in large quantities reduce yield or quality of the herbage, though farmers are sometimes very annoyed if they find small quantities of them. These weeds are: *Cirsium arvense, Deschampsia cespitosa, Elymus repens, Poa annua, Ranunculus acris, Ranunculus repens, Rumex obtusifolius, Stellaria media, Taraxacum officinale (Sect. Vulgaria)* and *Urtica dioica* (Pelser, 1984). Two poisonous species were also found: *Cicuta virosa* and *Equisetum palustre* (Klapp et al., 1953; Dietl, 1982; Pelser, 1984).

The nature-value index of the bank vegetation was used as the parameter expressing the floristic richness of the banks. This index is strongly correlated with other floristic richness parameters, such as the number of species (Van Strien et al., 1989). The nature-value index of an individual plant species is based on an estimate of its rarity and its rate of decline (Clausman & Van Wijngaarden, 1984). The index of the entire sampling plot is calculated by summing the nature-values of the individual species, taking into account their cover values (see also Van Strien et al., 1989).

Analysis of data

The 5-m plots were used to examine the distribution of weeds over the entire slope. To prevent bias from interrelations between environmental factors, such as relations between ditch water table and length of slope, we selected banks with the same profile and length.

We used 320 50-m bank plots to assess the relations between nature-value index and cover of weed species on banks.

Analysis of variance (ANOVA) was applied to test the relation between the cover values of each weed on bank and field, adjusted for other factors that might affect weeds on the fields. Since ANOVA is not possible when the data comprise many zero cover values, we used only the 6 most common weeds on the 50-m plots in the ANOVA (*Elymus repens, Poa annua, Ranunculus acris, Ranunculus repens, Stellaria media* and *Taraxacum officinale*). Data of the two opposite 50-m bank plots were averaged. As well as bank cover the following factors were used in the ANOVA: nitrogen supply, type of grassland use, level of ground water in April, whether or not peat mud dressing had been applied, pH of the topsoil and presence or absence of chemical weed control of the species. Metric factors were both used as covariates and as factors divided into several classes in the ANOVA runs. Each factor was adjusted for all other factors involved in the ANOVA (see

Van Strien et al., 1988).

Results

About 75% of all farmers involved used chemical weed control on the fields, especially against *Cirsium arvense*; other frequently treated species were *Urtica dioica* and *Rumex obtusifolius* (Table 1). In addition, these three species were sometimes mechanically controlled. None of the farmers reported attempts to control *Elymus repens*. Farmers did not distinguish between *Ranunculus spp*. The most abundant species on the banks were *Elymus repens*, *Poa annua* and *Ranunculus repens*. *Elymus repens* attained particularly high cover percentages on the upper parts of the banks. *Cicuta virosa*, *Cirsium arvense* and *Urtica dioica* were the least abundant weeds.

Species differed strongly in their preference for particular distances from the ditch (Fig. 2). *Cicuta virosa* was found near the ditch water line only. *Ranunculus repens* and possibly *Deschampsia cespitosa* preferred the lowest part of the slope. Other species predomi-

Table 1. Percentages of farmers performing chemical control of the weeds (n = 125).

Weed species	Weed control
Cicuta virosa	0%
Cirsium arvense	66%
Deschampsia cespitosa	3%
Elymus repens	1%
Equisetum palustre	0%
Poa annua	0%
Ranunculus acris	9%
Ranunculus repens	9%
Rumex obtusifolius	18%
Taraxacum officinale	3%
Stellaria media	10%
Urtica dioica	18%

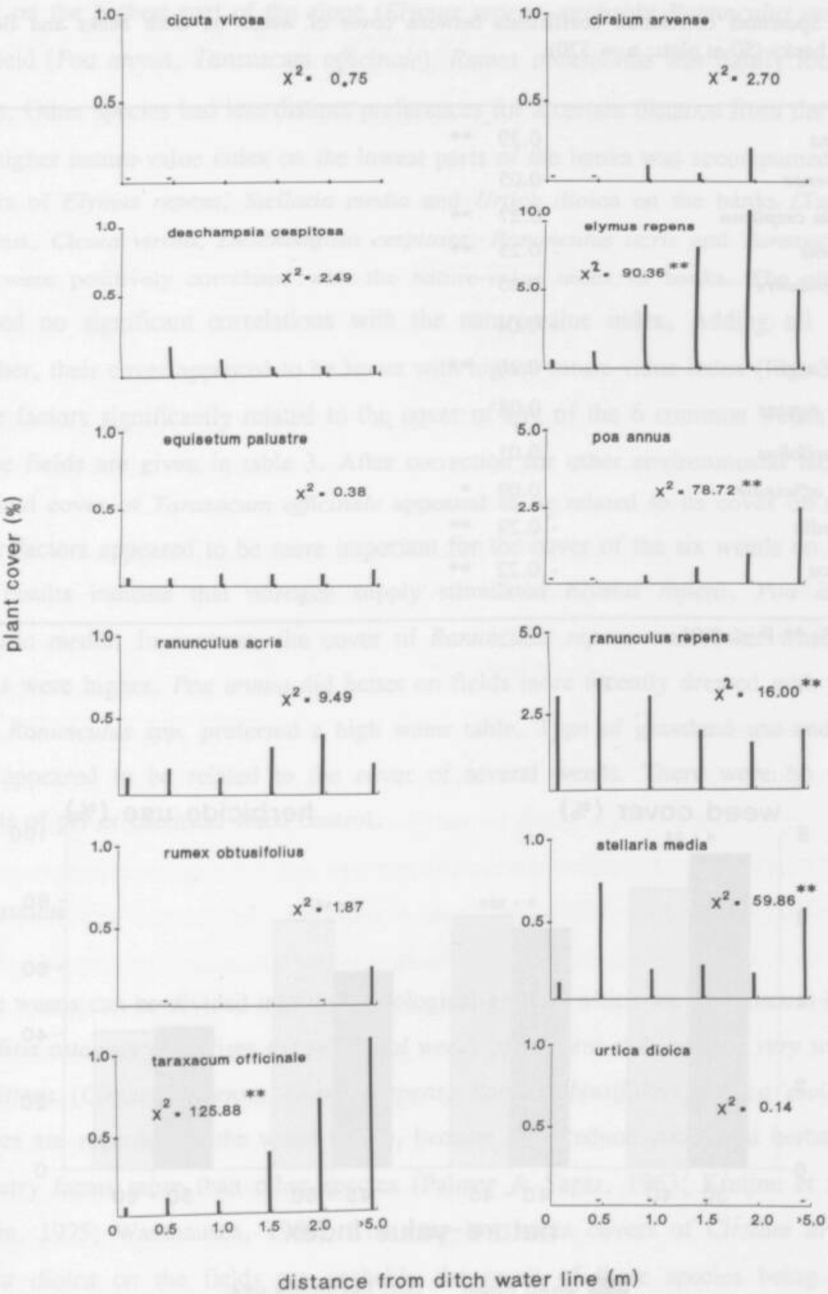

Fig. 2. Cover of weed species found at increasing distance from the ditch water line. >5 indicates the data of the plots of the adjacent grasslands. Data of the two opposite 5-m bank plots were averaged. Tested by means of Friedman test (* P ≤ 0.05; ** P ≤ 0.01; n=71). Notice the deviating scale of the cover of *Elymus repens*, *Poa annua* and *Ranunculus repens*.

Table 2. Spearman correlation coefficients between cover of weeds on ditch banks and floristic richness of banks (50-m plots; n = 320).

Cicuta virosa	0.39	**
Cirsium arvense	0.05	
Deschampsia cespitosa	0.27	**
Elymus repens	- 0.23	**
Equisetum palustre	0.05	
Poa annua	- 0.04	
Ranunculus acris	0.16	**
Ranunculus repens	- 0.08	
Rumex obtusifolius	0.01	
Taraxacum officinale	0.09	*
Stellaria media	- 0.29	**
Urtica dioica	- 0.22	**

* P ≤ 0.05; ** P ≤ 0.01

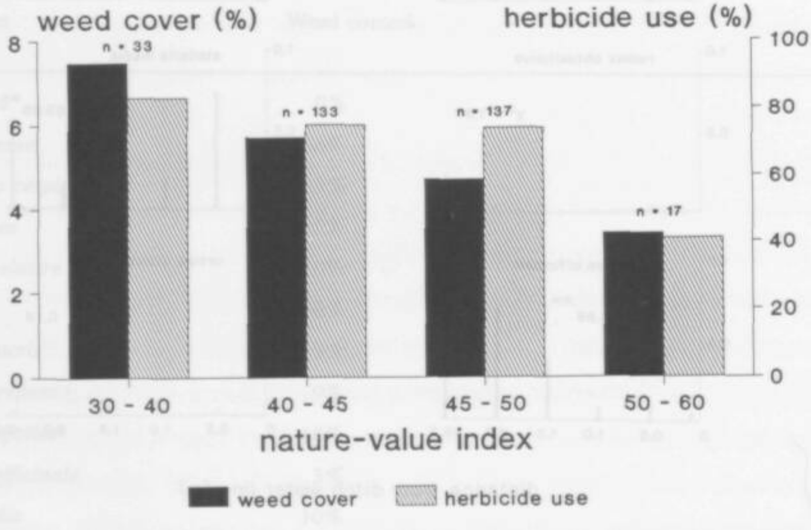

Fig. 3. The relation between the summed cover of 12 weed species on the ditch bank and the nature-value index of the bank vegetation (50-m plots; Spearman's r= - 0.20; p<0.01). In each nature-value class the percentage of farmers using herbicides is indicated (hatched).

nated on the highest part of the slope (*Elymus repens*, probably *Ranunculus acris*) or on the field (*Poa annua, Taraxacum officinale*). *Rumex obtusifolius* was hardly found on the banks. Other species had less distinct preferences for a certain distance from the ditch.

A higher nature-value index on the lowest parts of the banks was accompanied by lower covers of *Elymus repens*, *Stellaria media* and *Urtica dioica* on the banks (Table 2). In contrast, *Cicuta virosa*, *Deschampsia cespitosa*, *Ranunculus acris* and *Taraxacum officinale* were positively correlated with the nature-value index of banks. The other weeds showed no significant correlations with the nature-value index. Adding all 12 weeds together, their cover appeared to be lower with higher nature-value index (Fig. 3).

The factors significantly related to the cover of any of the 6 common weeds examined on the fields are given in table 3. After correction for other environmental factors, only the field cover of *Taraxacum officinale* appeared to be related to its cover on the banks. Other factors appeared to be more important for the cover of the six weeds on the fields. The results indicate that nitrogen supply stimulated *Elymus repens*, *Poa annua* and *Stellaria media*. In contrast, the cover of *Ranunculus repens* was lower when nitrogen inputs were higher. *Poa annua* did better on fields more recently dressed with peat mud. Both *Ranunculus spp.* preferred a high water table. Type of grassland use and soil type also appeared to be related to the cover of several weeds. There were no significant effects of pH or chemical weed control.

Discussion

The weeds can be divided into three ecological groups, which we will discuss in turn. The first category comprises the *perennial weeds of nutrient-rich and not very wet conditions* (*Cirsium arvense*, *Elymus repens*, *Rumex obtusifolius*, *Urtica dioica*); these species are regarded as the worst weeds, because they reduce yields and herbage quality on dairy farms more than other species (Palmer & Sagar, 1963; Kruijne et al., 1967; Moore, 1975; Wasshausen, 1987). The very low mean covers of *Cirsium arvense* and *Urtica dioica* on the fields are probably the result of these species being controlled regularly. *Elymus repens* attains much greater infestations; this grass species is difficult to regulate selectively. If the sward contains very much *Elymus repens*, the whole field is chemically treated and reseeded (Roozenboom, 1979).

Table 3. Results of analysis of variance of environmental factors using the cover of 6 abundant weeds on the fields as dependent variables; values are corrected for the effects of other factors. Only significant F values are indicated. Cl-pt means clay-on-peat soil.

Weed species	Multiple r	Factor	F value	State of factor preferred
Elymus repens	0.57	nitrogen supply	3.92 *	high
		type of use	8.37 **	meadow
		soil type	9.21 **	peat
Poa annua	0.43	nitrogen supply	7.21 **	high
		peat mud dressing	3.89 *	recently
Ranunculus acris	0.35	water table	4.03 *	high
Ranunculus repens	0.61	nitrogen supply	15.10 **	low
		water table	5.27 *	high
Stellaria media	0.30	nitrogen supply	3.90 *	high
Taraxacum officinale	0.43	soil type	4.57 *	cl-pt
		its bank cover	4.03 *	high

* $P \leq 0.05$; ** $P \leq 0.01$

The preference of this species group for nutrient-rich and dry conditions is confirmed by the ANOVA results for *Elymus repens* and by the fact that these species hardly occur on the lowest-lying parts where the nutrient status is relatively poor and the soil is wet. At a larger nature-value of the vegetation on the lowest part of the banks, the cover of *Elymus repens* and *Urtica dioica* is lower; *Cirsium arvense* and *Rumex obtusifolius* do not correlate with this index, but occur rarely on that location anyway, even though these sites were hardly sprayed. Thus, these species will most probably not increase with a floristically richer vegetation on the banks.

The second group consists of *annual weeds that rapidly germinate in bare areas on nutrient-rich soil* (*Poa annua, Stellaria media*). Since these species have limited competitive power, they do not persist in a closed canopy (Roozenboom, 1977). The ANOVA results confirmed their preferences for nutrient-rich conditions. The yield of organic matter may fall as a result of these species, though for *Poa annua* this is only true for major invasions (Wells & Haggar, 1974). The large cover of *Stellaria media* towards the bottom of the slope might be the result of bare spots caused by the dumping of sludge from the cleaning of ditches, though the nutrient status is relatively poor on that site; other annual species usually emerge on the dumped sludge, such as *Polygonum hydropiper* (Van Strien et al., in press). Just as with the first group, a higher nature-value index of the bank vegetation is accompanied by fewer numbers of the species from this group.

The remaining group (*Cicuta virosa, Deschampsia cespitosa, Equisetum palustre, Ranunculus acris, Ranunculus repens* and *Taraxacum officinale*) mainly comprises *perennial weeds preferring less nutrient-rich conditions* (Kruijne et al., 1967). This is reflected by the distribution of these species over the slope: several species preferred the site near the ditch, with the poorest nutrient status and the wettest soil. An exception is *Taraxacum officinale* which has no such a preference (Kirchner, 1955) and which tended to occur on the highest parts of the slope. For the *Ranunculus spp.* the ANOVA reveals a preference for a small nitrogen supply and for wet conditions. In contrast with the other groups, species of this group had higher cover values when the nature-values of the banks was higher, although some correlations are poor.

Most of the species of this last category cause only minor problems in current dairy farming. They occur in small quantities only, as in the case of *Equisetum palustre*, or will decrease if too much nitrogen is supplied to the fields, as in the case of *Ranunculus repens*. Some should not be perceived as serious field weeds, since they hardly affect yields, even when very abundant, as in the case of *Taraxacum officinale* (Kirchner, 1955). The poisonous *Cicuta virosa* is an exception; this species grows near the water only. *Cicuta virosa* might increase if ditch bank management implies less frequent cleaning of the ditches, and thus less frequent removal of its rhizomes (Van Strien et al., 1989). In such cases, some extra care might be required to prevent cattle from eating this plant. However, *Cicuta virosa* is scarce and limited to certain areas.

Thus, several species of the last-mentioned group might be stimulated by a management strategy aimed at nature conservation on the lowest parts of the banks. Nevertheless, the total number of weeds of all three groups near the water can be expected to be less if such management is applied, because this location is less suited for the species from the first two groups and this unsuitability increases with a higher nature-value of the bank vegetation. Moreover, the most noxious species will decline.

The ANOVA results suggest that dispersal of weeds from the lowest part of the banks into the fields is limited. A significant relation between bank and field locations was found only for *Taraxacum officinale*. This species is able to disperse over great distances (Kirchner, 1955) and might indeed invade from the banks into the pastures or vice versa. In his study on arable fields, Marshall (1989) also found that most species of the field edges did not spread into the fields. Other factors seem to be more important for infestations; for instance the surplus of seed already present in the seed bank of the grasslands, such as in the case of *Poa annua* (Roozenboom, 1977). Another more critical factor might be weed invasion from the upper parts of the banks. Several noxious weeds attain a high cover on the upper parts of the banks, especially *Elymus repens, Poa annua* and *Stellaria media*. The large numbers of these species are perhaps stimulated by the fraising of this part of the slope, leading to a damaged sward and to the spread of viable rhizomes of *Elymus repens*.

Our results confirm Marshall's (1988) expectation that a "species-rich habitat by its nature will contain only low populations of potential field weeds". Obviously, this is also valid for habitats that are not exceptionally nutrient-poor, such as ditch banks along exploited fields. A widening ecological gap between the low parts of ditch banks and the field, caused by their different management, apparently reduces the risk of weed problems. Therefore, the concern about weed problems need not constrain ditch bank management focused on promoting floristic richness.

Two shortcomings of the study should be noted. Several management factors that possibly affect weed cover on the fields, e.g. uneven application of slurry, were not taken into account in the ANOVA because of lack of information. We assumed that on average these factors did not differ between factor classes.

Another possible flaw of the study concerned weed control. The ANOVA results were adjusted for chemical weed control; furthermore, the species most controlled (*Cirsium arvense, Rumex obtusifolius* and *Urtica dioica*) were not subjected to the ANOVA because of their many zero values. However, the data on the distribution of the weeds over the entire bank were not adjusted for weed control, and nor were the relations between nature-value index and weeds on the banks. Probably, more herbicides were used on the upper parts of the banks; this implies that the weed cover might be higher there than indicated in fig. 2. The distribution patterns of the most controlled species might be the most misleading; presumably the relative unsuitability of the low parts of the banks for these species is even more pronounced. The relations between nature-value index and weed cover on the low strips will be less distorted by weed control, since these relations concerned sites where weeds are rarely controlled. Moreover, at a higher nature-value index even fewer farmers used herbicides regularly (Fig. 3), supporting the idea that weed problems decrease as the nature-value index of banks increases.

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A Matched Pairs Selection method for the analysis of abundance data with many zero values

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Abstract. A simple method is described to analyze plant species abundance data with many zero values. To investigate the impact of an environmental factor on rare species, two subsets of sampling plots are selected pairwise from the original data set. They differ in the value of the particular factor under consideration but are similar with respect to all other factors. Subsequently, the botanical composition of these subsets, including rare species, is compared using non-parametric tests. An example is given from a study on ditch bank vegetation. Some limitations, and a method for taking into account the dependence of the statistical tests, are discussed.

Keywords: Ditch bank vegetation; Rare species; Univariate analysis.

Introduction

Hypotheses about the separate effects of environmental factors on the level of the individual plant species can be tested either by especially designed experiments or by spatial comparison of vegetation sampling plots by means of (generalized) linear models, (multivariate) analysis of variance, or similar approaches (see e.g. Ward 1978; Mccullagh & Nelder 1985; Jongman, ter Braak & van Tongeren 1987).

However, these statistical techniques fail in case where interest is focused on rare species. The large fraction of zero values involved in data matrices with many rare species generally results in:

1. An 'over-parametrization'.
2. Numerical estimation problems, i.e. convergency problems.
3. Large variances of the estimates.

Moreover, the abundance data of rare species are far from normally distributed, hence methods based on the normality assumption, like (M)ANOVA cannot be applied (Sokal & Rohlf 1981). Sometimes it is possible to transform the data in such a way that they become more or less normally distributed with equal variances (see e.g. Meltzer & van Dijk 1986). More frequently the problem is circumvented by omitting the rare species from the analysis (e.g. Barendregt et al. 1986). However, this may weaken the significance of the conclusions, especially from a nature conservation point-of-view, where such species are often considered the most valuable ones.

In order to enable the analysis of this type of data, we developed a robust (univariate) method incorporating simple non-parametric tests based on as few assumptions as possible. In this method the sampling plots are selected pairwise from the original data set. We illustrate this approach with vegetation data from ditch banks.

The method

The Matched Pairs Selection method consists of two steps:

1. Composing two subsets of matched pairs of sampling plots.
2. Comparing the botanical composition of the subsets of matched plots.

Composing the subsets of matched plots

Values for each environmental factor are grouped into two (or more) classes. The sampling plots are divided into groups according to these classes for any one environmental factor (the 'dose' factor). Then, for each plot within a class-group a plot is selected from the other group in such a way that all observed environmental conditions for the plots are similar, except of course for the factor under consideration. Plots without a proper analogue in the other group are discarded. In this way two (or more, depending on the number of classes of the dose factor) subsets of matched plots can be created for each dose factor.

The number of matched plots will be small if several nuisance factors are divided into many classes or if the tolerated differences are small. On the one hand the ecological conditions must be as identical as possible; on the other hand the classes must be broad enough to provide a sufficiently large number of plots which can be matched. Clearly, we search for a compromise between what is possible and what is desirable. The same holds for the number of environmental factors one wishes to correct: adding a factor results in a reduction of the number of matched plots. Therefore, the analysis should be restricted to factors that are expected to be important.

Comparing the botanical composition of matched plots

Under the null hypothesis that a selected environmental factor does not influence the botanical composition, the abundance data of the groups will not differ. This can be tested by a chi-square test or any other suitable non-parametric test.

Because the effects of the environmental factors are examined with one and the same data set, the test results concerning the different dose factors may be dependent. This dependence must be taken into account, for instance by using Bonferroni probabilities. Usually a significance level of α/m is recommended, where m is the total number of tests (Feller 1968). However, Simes (1986) and Hochberg (1988) proposed more powerful Bonferroni procedures based on the ordered p-values of the individual tests.

We followed Hochberg's procedure:

- Order the p-values of the tests in ascending order:
$P(1), P(2), \ldots, P(m-1), P(m)$
- Consider the largest p-value $P(m)$
- If $P(m) \leq \alpha$ all individual hypotheses H are rejected. If not, then H (m), the null hypothesis associated with the (m)-th test, cannot be rejected and one examines $P(m-1)$
- If $P(m-1) \leq \alpha/2$ then all hypotheses $H(i)$ $(i = m-1, \ldots, 1)$ are rejected. If not, then H $(m-1)$ cannot be rejected and one continues with $P(m-2)$
- If $P(m-2) \leq \alpha/3$ all hypotheses $H(i)$ $(i = m-2, \ldots, 1)$ are rejected. If not, then $H(m-2)$ cannot be rejected and one proceeds with $(m-3)$, etc.

Example

The example is taken from a study on ditch bank vegetation in agriculturally-exploited peat areas in the Netherlands (van Strien et al. in press). The original data set consisted of relevés of ditch banks with different pH, slope aspect, ditch water table, type of use and nitrogen supply of the adjacent grasslands, cleaning frequencies of the bordering ditches, etc.

To examine the separate effects of e.g. cleaning frequency, type of grassland use and pH of the bank top soil, on the botanical composition of the banks, each of these three factors was divided into two classes. Three matching procedures were carried out, whereby all factors except the dose factor were held similar. Examples of the criteria used in these selection procedures were:
- Slope aspect: the plots had to belong to the same class. The three classes were: 1) facing north, north-east and north-west; 2) south, south-east and south-west; 3) east

Table 1 . Examples of species showing significant differences between classes of one or more of three factors under consideration tested by means of matched pairs comparison. Both results for presence (with chi-square test) and mean cover (with sign test) are presented. Percentage figure following species name: presence % in the entire data set of 320 relevés.

Classes of cleaning frequency (n = 68):
- once every 2-3 years (1)
- yearly (2)

Classes of type of use (n = 50):
- meadows and hay pastures (1)
- alternate and pure pastures (2)

Classes of pH-H_2O of bank soil (n = 32):
- 4.0 - 5.5 (1)
- 5.5 - 7.2 (2)

	Presence			Mean cover (%)		
	1	2	P	1	2	P
Berula erecta (43%)						
Clean. fr.	49	20	≤0.01	0.47	0.20	≤0.01
Use	19	19	>0.05	0.24	0.19	>0.05
pH	13	5	0.05	0.23	0.08	0.04
Cicuta virosa (17%)						
Clean. fr.	29	5	≤0.01	0.11	0.01	≤0.01
Use	3	2	>0.05	0.01	0.02	>0.05
pH	0	0	-	-	-	-
Lychnis flos-cuculi (41%)						
Clean. fr.	40	18	≤0.01	0.81	0.17	≤0.01
Use	22	9	≤0.01	0.29	0.05	0.01
pH	8	13	>0.05	0.04	0.19	>0.05
Lysimachia thyrsiflora (23%)						
Clean. fr.	33	9	≤0.01	0.15	0.05	≤0.01
Use	10	1	0.01	0.08	0.01	0.02
pH	0	0	-	-	-	-
Prunella vulgaris (12%)						
Clean. fr.	21	6	≤0.01	0.20	0.03	≤0.01
Use	03	1	>0.05	0.07	0.01	>0.05
pH	0	0	-	-	-	-

underlined: significant

and west;
- Ditch water table: the tolerated difference between the plots was less than 15 cm;
- Amount of fertilizer applied to the adjacent fields: the tolerated difference between the plots was smaller than 75 kg N ha^{-1} yr^{-1}.

In the same way criteria were formulated with respect to type of grassland use, amount of manure and slurry applied to the fields, amount of excreted nitrogen by grazing cattle, cleaning frequency, cleaning method and sampling period.

The original data set contained 320 relevés. Three pairwise selection procedures and subsequent testing were performed by means of an APL computer program. For cleaning frequency the selection resulted in two subsets each of 68 relevés, the remaining 184 were discarded. For 'type of grassland use' 50 pairs were found and for pH 32 pairs of plots. Subsequently, differences in presence and cover of all individual plant species between the subsets were tested by means of a chi-square and a sign test respectively. Then the test results of the three dose factors were combined according to Hochberg (1988). An example may illustrate Hochberg's procedure. The highest p-value of the three tests with respect to the cover of *Berula erecta* concerns the factor type of use ($P > 0.05$), so the associated null hypothesis cannot be rejected at a level of significance $\alpha = 0.05$ (Table 1). The second highest p-value, 0.04, is still higher than $\alpha/2$, which means that no effect of pH has been proven. The third highest p-value, < 0.01, is smaller than $\alpha/3$, which implies a significant effect of cleaning frequency.

It could be demonstrated that, apart from relatively abundant species such as *Lychnis flos-cuculi* (present in 41 % of the 320 plots), also rare species such as *Cicuta virosa* and *Prunella vulgaris* (present in only 17 % and 12 % of the plots respectively) differed significantly in presence and cover between the classes of one or more of the factors (Table 1). Repeating the matching procedure showed that differences in results were negligible.

Discussion

The example shows that the Matched Pairs analysis can be an effective statistical tool to trace separate effects of environmental factors on the occurrence of rare plant species. Many ditch bank species concerned in the field study could not be examined by means of (M)ANOVA or GLM techniques, since about only 15 % of the species occurred in more than 50 % of the plots.

Applications of this method need not to be limited to vegetation science; in fact the method can be helpful to interpret all data sets with many zero values of the dependent variables.

The statistical adjustment to meet the dependence of the test results will be the more necessary if the overlap of cases used in the comparisons is greater. When almost different but representative parts of the entire data set are involved in the different tests, the Bonferroni procedures can of course be omitted.

Different parts of the original data set can be involved with each dose factor, which might be not representative of the entire data set. One should be aware of (and apply preliminary tests or visual scanning methods) detecting possible relevant deviations, because they may bias the conclusions of the study.

A limitation of the method is that only main effects, and no interactions between effects can be detected. Therefore it should be checked that no substantial interactions exist concerning the rare species; this might be verified to a certain degree by examining interactions by appropriate methods like (M)ANOVA or GLM, using more abundant species, or vegetation parameters that are ecologically related to the rare species.

It might be neccessary to verify whether the resulting subsets as a whole unintentionally differ in other factors than the dose factor, which may be expected when the tolerated differences at the selection were great. Therefore the differences between the subsets should be tested for all factors and if relevant differences appear to occur, the selection procedure must be redone with smaller tolerated differences.

The use of the sign test in testing the covers is not completely straightforward. Many pairs will be excluded in the sign tests because of equal zero values. However, this will not affect the reliability of these sign tests, assuming that such pairs mainly concern ecological conditions unsuitable for the species involved.

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8

SUMMARY AND PROSPECTS

Introduction

In the western peat district of the Netherlands the plant species diversity of grasslands and ditch banks is rapidly declining because of intensive dairy farming. Many plant species that until recently were very common in the peat areas, such as *Lychnis flos-cuculi, Caltha palustris* and *Anthoxanthum odoratum* are becoming scarce.

Establishing reserves to protect valuable areas will not help to stop the overall decline. Therefore, this study aimed to find opportunities for plant species to survive on modern dairy farms. In order to be able to design management regimes directed at maintaining or restoring species diversity on grasslands and ditch banks, the factors governing their vegetation were studied.

Dairy farmers in the peat areas expect weed problems to increase when the management of ditch banks is focused on maintaining botanical diversity. Therefore, it was examined whether banks supporting a species-rich vegetation might contribute to weed problems.

Study design and analysis

A multifactor, transverse study design was used to assess the individual effects of the agricultural factors. This approach implied the spatial comparison of a great number of plots on grasslands and ditch banks, differing in management regime. 150 dairy farms on peat soil in the Dutch provinces of Zuid-Holland and Utrecht were involved.

Data on grassland exploitation, ditch management and properties of the banks were obtained from the farmers and from field observations. Only steady-state situations were selected; all grasslands and ditch banks used in this study were known to have had a more or less constant management for the previous 5-10 years. On each grassland 16 m^2 was sampled. Ditch bank plots were 50 m x 0.7 m; each plot ran 0.7 m up the bank from the water's edge.

The study plots were carefully selected, to yield a data set with an almost independent variation of the factors studied. All factors studied are mentioned in table 1 and 2.

The effects of the agricultural and other factors on three parameters of floristic richness were examined: the number of species, the number of quality-indicating species, and the "nature-value index". The number of quality-indicating species means the number of species characteristic of normal to moist grassland (see Drijver & Melman, 1983). The nature-value index of a plant species includes two aspects: the rarity of the species on different spatial scales and its rate of decline. The nature-value index of a sample plot is calculated by summing the nature-values of all species present, taking into account their cover percentages (see Clausman & Van Wijngaarden (1984) and the Appendix).

In addition, the effects on individual plant species were assessed.

"Matched pairs analysis" (chapter 7)

Analysis of variance was used to assess the effects of the factors, corrected for the influences of other factors. However, this method could not be used to test the effects on individual species, due to the large fraction of zero values involved in the data matrices with many species, especially with many rarer species. Therefore, a simple, robust method was developed that enabled the analysis of data with many zero values, the "matched pairs analysis".

Results of the study

Grasslands (chapter 3)

Most variation in the floristic richness of the grasslands studied was brought about by differences in nitrogen supplied as fertilizer, manure and slurry (Table 1). Solid farmyard manure and liquid slurry did not differ in their effects on floristic richness. Most fields supported about 15-20 common species. The grasslands only had more than 25 plant species, among which less common species as *Lychnis flos-cuculi* and *Cynosurus cristatus*, when the nitrogen supply was low, not exceeding 100 - 200 kg N ha^{-1} yr^{-1}.

Furthermore, the number of quality-indicating species was somewhat lower on fields recently dressed with peat mud and grasslands on mesotrophic peat had a few more species than on eutrophic peat and on clay-on-peat. The type of use, the level of the water in the ditches, the pH and the P and K content of the grassland topsoil were found to have

Table 1. The influence of a number of factors on the number of quality-indicating species of the vegetation of grasslands. These results corresponded very well with those concerning the other parameters of floristic richness (see chapter 3).

At increasing factor:
-- decrease ; $p \leq 0.01$
- decrease ; $p \leq 0.05$
ns not significant
+ increase ; $p \leq 0.05$
++ increase ; $p \leq 0.01$

Factor (+ range)	Number of quality-indicating species
Nitrogen supply on field (0 - 600 kg N ha^{-1} yr^{-1})	--
Type of animal manure (solid manure - slurry)	ns
Type of use (meadow - pasture)	ns
Level of ground water (April) (10 - 60 cm below surface)	ns
Peat mud dressing (less - more than 5 yrs ago)	+
Soil type (mesotrophic peat - eutrophic peat - mes. clay-on-peat - eutr. clay-on-peat)	-
pH of topsoil (pH-KCl 3.7-5.7)	ns
P and K content of topsoil	ns

no significant effects on the floristic richness of grasslands.

Ditch banks (chapter 4)

The species diversity of the ditch banks ranged from about 20-25 species, with common species as *Glyceria maxima* and *Holcus lanatus*, to 60-70 species, including relatively rare species as *Potentilla palustris* and *Carex panicea*. The results with all three parameters of floristic richness corresponded very well with each other (Table 2).

A small amount of nitrogen applied on the grassland parcels adjacent to the ditch bank

Table 2. The influence of a number of factors on three parameters of floristic richness of the ditch bank vegetation.

At increasing factor:		
	--	decrease ; $p \leq 0.01$
	-	decrease ; $p \leq 0.05$
	ns	not significant
	+	increase ; $p \leq 0.05$
	++	increase ; $p \leq 0.01$

Factor (+ range)	Number of species	Number of q.i. species	Nature-value
Nitrogen supply (0 - 550 kg N ha^{-1} yr^{-1})	--	--	--
Type of animal manure (solid manure - slurry)	ns	ns	ns
Type of use (meadow - pasture)	ns	-	-
Level of ditch water (15 - 80 cm below surface)	--	--	--
Slope aspect (S - W - E - N)	-1)	-1)	--1)
Slope angle (0 - 35 degrees)	++1)	++1)	ns
Soil type (mesotrophic peat - eutrophic peat - mes. clay-on-peat - eutr. clay-on-peat)	ns	ns	ns
pH of topsoil ($pH-H_2O$ 4.0 - 7.2)	++	++	ns
P and K content of topsoil	ns	ns	ns
Cleaning frequency (once every year - less than once every 3 yrs)	++2)	++2)	++2)
Cleaning method (hand - mowing-basket - ditch-scoop - auger)	ns	ns	ns
Peat mud dressing (less - more than 5 yrs ago)	ns	ns	ns

1) Effects depend on slope angle and slope aspect respectively
2) Optimum relationship

and a high level of water in the ditch favoured the floristic richness of the ditch banks (Table 2). The effects of nitrogen supply appeared mainly to result from the amounts of N fertilizer applied. The type of animal manure was not important. The number of quality-indicating species and the nature-value index were lower at a higher grazing intensity.

The floristic richness was higher on south-facing banks than on north-facing banks, and higher on steep (up to 35°) south-facing banks than on gentle south-facing banks.

The number of species and the number of quality-indicating species were higher at a high pH of the bank soil. Type of peat soil and the P and K contents of the bank soil had no significant effects on the floristic richness of the banks.

Ditch banks and ditch management (chapter 5)

The ditch management proved to be important for the ditch bank vegetation. Regional waterboards require the farmers to manage their ditches in order to maintain a proper discharge of water from the peat polders. Almost all ditches are cleaned mechanically once a year, often in the autumn. Plants in and near the ditches are removed and dumped on the banks, together with mud from the ditch bottom.

The floristic richness of banks was higher along ditches that were cleaned once every 2-3 years than on banks along ditches cleaned yearly (Table 2), probably because of the less frequent supply of nutrient-rich sludge, less frequent suffocation and less frequent damage to the vegetation. The number of species and the number of quality-indicating species was somewhat lower on banks along ditches cleaned less frequently than once every 3 years than on banks cleaned once every 2-3 years.

No differences were found in floristic richness of banks that could be attributed to methods of ditch cleaning. That might be because of the variation within cleaning methods in terms of the amount and composition of the sludge dumped on the banks. Neither did the dredging of the ditches have any detectable effects on ditch bank vegetation.

Noxious weeds (chapter 6)

The most noxious weeds hardly occurred on banks or preferred the high-lying parts. A higher nature-value index of the vegetation of the low-lying part of the bank slopes was accompanied by lower amounts of weeds. No relation could be detected between the cover of weeds on the fields and the bank cover, except for *Taraxacum officinale*. It is concluded that management of the vegetation on the low-lying parts of the banks for diversity should not raise weed problems, but should reduce them.

Compatibility of vegetation maintenance measures and current farming practice

The dose-effect relationships assessed can be used to formulate measures for the maintenance of species-rich plant communities on dairy farms in the western peat areas in the Netherlands. The most promising measures are those that are technically and financially compatible with farming.

Grasslands

The possibilities for increasing the floristic richness of grasslands on modern dairy farms in the peat areas are very limited. The grassland vegetation has some floristic richness only when the nitrogen supply is below 100-200 kg N^{-1} ha^{-1}; such low levels are scarcely attainable in current dairy farming. This is why this study focused on the management of ditch banks.

Ditch banks

Farmers are far more likely to be persuaded to practice measures to maintain species diversity on ditch banks than on their fields, because ditch banks are of minor importance as production units. The compatibility of various of such measures with dairy farming practice was estimated (see also Kruk et al., 1988; Van Strien & Ter Keurs, 1988; Melman, 1990; Parmentier, 1990; Van der Ploeg & Roep, 1990).

Kruk et al. (1988) noticed that some farmers were willing not to dress the banks near the ditches with manure and fertilizer, because they consider the ditch banks as having little agricultural value. Under certain circumstances it pays to keep the banks free from fertilizer (Melman & Van der Linden, 1988). Thus, reducing the amounts of manure and fertilizer applied to the banks seems to be compatible with dairy farming practice. However, ditch banks often receive nitrogen doses unintentionally when the fields are fertilized and manured. Therefore, it would be useful to modify the machines that spread the fertilizer and the manure, to prevent this. Furthermore, instead of spreading the animal manure over the fields and the banks, it can be injected into the topsoil of the fields. The Dutch government may prescribe that manure be injected in order to reduce the amount of ammonia emitted from livestock farms. Injected manure would not reach the banks directly, and this would benefit the bank flora. But the prescription of the injection of manure might harm meadow birds considerably (Kruk & Ter Keurs, 1990).

Intensive grazing and trampling of the bank vegetation can be prevented by fencing off the ditch banks. Fencing may have certain advantages for the farmers too, but it also has disadvantages (it costs money and requires time for maintenance). Thus, this measure to prevent trampling probably do not fit easily into farming practice. Another possibility is not to heavily graze the fields with species-rich ditch banks.

A higher level of water in the ditches would favour the bank vegetation. When water is higher in the ditches, however, the fields remain wetter for a longer period in spring and this hampers the exploitation of the grasslands. Therefore, many farmers prefer a low level of water in the ditches. But recent research has shown that the financial results of farms that maintain high levels do not differ greatly from those of farms with low levels of water in their ditches (Van Eck & Prins, 1990). This suggests that high levels of water in the ditches do not necessarily reduce the profitability of dairy farming considerably.

On average, banks with a high acidity support less species than banks with a low acidity, though their nature-value index did not differ much. Severe acidification of banks might be prevented by liming, but it is uncertain whether liming is useful and necessary.

Both a fairly steep slope angle and a very gentle slope can be favourable for the bank vegetation. Steep (up to about 35°), south-facing banks benefit from the more intensive sun radiation. Very gentle slopes have a broad, moisty zone which is difficult for farmers to exploit; they receive little nitrogen supply and are not intensively grazed, leading to conditions beneficial for the wild flora (see Melman, 1990). However, very gentle banks are difficult to maintain; they are very susceptible to poaching. Steeper banks require less maintenance and are preferred in dairy farming. Very gentle bank slopes are probably only practicable in areas designated for "nature development".

Furthermore, a ditch cleaning frequency of less than once a year will benefit the bank flora, provided that the frequency is not less than once every three years. Several Dutch farmers are willing to clean their ditches less often than once a year, since this might save time and money (Kruk et al., 1988). Many ditches in the peat area are oversized and will keep their draining function even when they are not totally free from plant growth (see Pitlo, 1989). Other researchers (Twisk & Ter Keurs, 1990) study under which conditions a less frequent cleaning is compatible with the water management.

The method of the ditch management requires also attention. Switching to other types of machinery does not guarantee a higher floristic richness on the banks. It is more important to clean the ditches properly; dumping of large amounts of sludge on the banks and damage to the ditch bank vegetation should be avoided. Other modifications to ditch management may also be recommended, such as dumping the sludge on only one side of the ditch, preferably the north-facing bank (see Van Strien & Ter Keurs, 1988).

Possible obstacles to the implementation of ditch bank management in dairy farming practice

Several measures to maintain or increase the floristic richness of the ditch banks appear to be more or less compatible with the dairy farming practice. Some of these measures may even be profitable agriculturally. But the prospects of the ditch bank vegetation do not depend solely on how compatible the measures are with farming. There are also psychological and socio-cultural obstacles to vegetation management.

On the whole, Dutch farmers are not very interested in the maintenance of species-rich plant communities (Katteler & Kropman; 1983; Volker, 1984; Van Strien & Ter Keurs, 1988). Many Dutch dairy farmers associate vegetation management with poorly productive grasslands, with neglect and with an increase of noxious weeds, such as *Cirsium arvense*. However, mainly these opinions arise because farmers are unfamiliar with ditch bank management. Poorly productive ditch banks are not a serious agricultural loss, the management of ditch banks should not be neglected and management regimes for ditch banks that are aimed at increasing vegetation diversity do not appear to raise weed problems, but rather to reduce them.

Information on vegetation management, and the setting up of demonstration fields may improve the acceptance of vegetation management regimes by dairy farmers. It is easier to introduce vegetation management if grants are given for the purchase of appropriate machinery. In addition, ditch bank management would be more attractive if farmers were rewarded financially for the "production" of species-rich banks on their farms ("nature production payment", see Van Strien et al., 1988).

Ditch banks will be an extensive refuge for many endangered plant species if farmers pay more attention to the management of ditch banks. Present-day dairy farming in the western peat areas of the Netherlands will then contribute to the maintenance of wild plant species.

9

SAMENVATTING EN PERSPECTIEVEN

Inleiding

In het Hollands-Utrechtse veenweidegebied gaat de botanische rijkdom van de graslanden en slootkanten sterk achteruit onder invloed van de intensieve melkveehouderij. Veel plantesoorten die tot voor kort nog algemeen waren, worden schaars, zoals *Echte koekoeksbloem, Dotterbloem* en *Reukgras*.

Het instellen van natuurreservaten om de waardevolle terreinen te beschermen kan de algemene achteruitgang niet stoppen. Daarom is deze studie gericht op het verkennen van de mogelijkheden om plantesoorten te behouden op moderne landbouwbedrijven. Daartoe is onderzocht welke factoren van belang zijn voor de botanische rijkdom van graslanden en slootkanten.

Boeren verwachten dat lastige onkruiden gaan toenemen als het beheer van de slootkanten zou worden gericht op het behoud of herstel van een soortenrijke vegetatie. Daarom is ook nagegaan of soortenrijke slootkanten onkruidproblemen zouden kunnen vergroten.

Onderzoeksopzet en analyse van gegevens

Om de afzonderlijke effecten van landbouwfactoren te kunnen vaststellen is gekozen voor een zogenaamde beschrijvend-analytische onderzoeksopzet (transversaal onderzoek): een ruimtelijke vergelijking tussen een groot aantal graslanden en slootkanten die verschillen in inrichting en beheer. In totaal zijn 150 melkveebedrijven op veengrond in Zuid-Holland en het westelijke gedeelte van Utrecht bij het onderzoek betrokken.

Informatie over graslandgebruik, slootbeheer en slootkanteigenschappen werd verkregen van de boeren en door metingen in het veld. Alleen die graslanden en slootkanten zijn meegenomen waarvan bekend was dat inrichting en beheer tenminste vijf jaar min of meer gelijk waren gebleven. Op elk grasland is 16 m^2 onderzocht. Op elke slootkant is een opname gemaakt van 50 meter lang (parallel aan de sloot) en 70 cm breed (vanaf de waterlijn).

De onderzoekslokaties zijn zodanig gekozen dat een min of meer onafhankelijke variatie tussen een aantal onderzochte factoren werd verkregen. De in het onderzoek betrokken factoren zijn vermeld in tabel 1 en 2.

De effecten zijn onderzocht op drie maten die de floristische rijkdom van de vegetatie kunnen weergeven: het aantal soorten, het aantal kwaliteitsindicerende soorten en de zogenaamde natuurwaarde-index. Bij het aantal kwaliteitsindicerende soorten gaat het om die soorten die karakteristiek zijn voor vochtige tot normaal-vochtige graslanden (zie Drijver & Melman, 1983). De natuurwaarde-index van elke soort is opgebouwd uit de zeldzaamheid van elke soort op verschillende ruimtelijke schalen en de mate van achteruitgang. De natuurwaarde-index van een vegetatie-opname is berekend door de indexen van de soorten te sommeren en daarbij rekening te houden met de abundantie van elke soort (zie Clausman & Van Wijngaarden (1984) en zie de Appendix). Omdat de drie waarderingsmaten beperkt inzicht geven in de botanische verschillen, zijn ook de effecten op afzonderlijke soorten onderzocht.

"Matched pairs analysis" (hoofdstuk 7)

Met behulp van variantie-analyse zijn de afzonderlijke effecten van factoren vastgesteld. Deze methode kon echter niet worden gebruikt bij het vaststellen van de effecten op afzonderlijke soorten, vanwege het grote aantal nulwaarden van veel soorten, vooral van de relatief zeldzame soorten. Daarom is een eenvoudige, robuuste statistische techniek ontwikkeld, de "matched pairs analysis" die het mogelijk maakt om ook effecten op de relatief zeldzame soorten na te gaan.

Resultaten van het onderzoek

Graslanden (hoofdstuk 3)

Verreweg de meeste variatie in de floristische rijkdom van graslanden bleek toe te schrijven aan de hoeveelheid toegediende stikstof afkomstig van kunstmest en dierlijke mest (Tabel 1). Stalmest en drijfmest hadden dezelfde effecten op de floristische rijkdom van de graslanden. De meeste graslanden waren vrij soortenarm met ca. 15-20 algemene plantesoorten. Alleen bij een stikstofgift lager dan 100 à 200 N ha^{-1} $jaar^{-1}$ kwamen gras-

Tabel 1. De zelfstandige invloed van een aantal factoren op het aantal kwaliteitsindicerende soorten van graslanden. De resultaten met de andere floristische rijkdom parameters kwamen hiermee sterk overeen (zie hoofdstuk 3).

Als factor toeneemt:	--	afname ; $p \leq 0.01$
	-	afname ; $p \leq 0.05$
	ns	niet significant
	+	toename ; $p \leq 0.05$
	++	toename ; $p \leq 0.01$

Factor (+ traject)	Aantal kwaliteits-indicerende soorten
Mestgift op perceel (0 - 600 kg N ha^{-1} jr^{-1})	--
Type dierlijke mest (stalmest - drijfmest)	ns
Gebruikswijze (maailand - weiland)	ns
Grondwaterpeil (april) (10 - 60 cm onder maaiveld)	ns
Opbrengen bagger (minder - meer dan 5 jaar geleden)	+
Veensoort (mesotroof veen - eutroof veen - mes. veen met kleidek - eutr. veen met kleidek)	-
Zuurgraad bodem (pH-KCl 3.7-5.7)	ns
P en K gehalte van bodem	ns

landen voor met meer dan 25 soorten, waaronder minder algemene soorten als *Echte koekoeksbloem* en *Kamgras*.

Daarnaast bleken bij recent opgebrachte slootbagger iets minder kwaliteitsindicerende soorten voor te komen en bleken op mesotrofe veengrond iets meer kwaliteitsindicerende soorten voor te komen dan op andere bodemsoorten. Er werden geen effecten aangetoond van het graslandgebruik, het grondwaterpeil, de zuurgraad en de hoeveelheid fosfor en kalium in de bodem op de floristische rijkdom van de graslandvegetatie.

Tabel 2. De zelfstandige invloed van een aantal factoren op drie floristische rijkdom parameters van de vegetatie van slootkanten.

Als factor toeneemt:
- -- afname ; $p \leq 0.01$
- \- afname ; $p \leq 0.05$
- ns niet significant
- \+ toename ; $p \leq 0.05$
- \+ + toename ; $p \leq 0.01$

Factor (+ traject)	Aantal soorten	Aantal kwalit. soorten	Natuur-waarde
Mestgift op perceel (0 - 550 kg N ha^{-1} jr^{-1})	--	--	--
Type dierlijke mest (stalmest - drijfmest)	ns	ns	ns
Gebruikswijze (maailand - weiland)	ns	-	-
Slootwaterpeil (15 - 80 cm onder maaiveld)	--	--	--
Expositie (Z - W - O - N)	-[1]	-[1]	--[1]
Helling onderaan talud (0 - 35 graden)	+ +[1]	+ +[1]	ns
Veensoort (mesotroof veen - eutroof veen - mes. veen met kleidek - eutr. veen met kleidek)	ns	ns	ns
Zuurgraad bodem ($pH-H_2O$ 4.0 - 7.2)	+ +	+ +	ns
P en K gehalte bodem	ns	ns	ns
Slootschoningsfrequentie (elk jaar tot minder vaak dan eens per drie jaar)	+ +[2]	+ +[2]	+ +[2]
Slootschoningsmethode (hand - maaikorf - slootbak - vijzel)	ns	ns	ns
Opbrengen bagger (minder - meer dan 5 jaar geleden)	ns	ns	ns

1) Effecten afhankelijk van respectievelijk helling en expositie
2) Optimumverband

Slootkanten (hoofdstuk 4)

De soortenrijkdom van de slootkanten liep uiteen van 20-25 soorten, met algemene soorten als *Liesgras* en *Echte witbol*, tot 60-70 soorten, met betrekkelijk zeldzame soorten als *Wateraardbei* en *Blauwe zegge*. De resultaten met de verschillende floristische rijkdom parameters kwamen sterk met elkaar overeen (Tabel 2).

Hoe lager de mestgift op de percelen en hoe hoger het water in de sloot, des te hoger waren de drie floristische rijkdom parameters. Het bemestingseffect bleek vooral toe te schrijven aan de kunstmestgift. Het type dierlijke mest was niet van belang. Bij meer beweiding waren het aantal kwaliteitsindicerende soorten en de natuurwaarde-index lager.

Op slootkanten met een zuid-expositie was de floristische rijkdom groter dan op naar het noorden gerichte oevers. De taludhelling was alleen van belang bij op het zuiden gerichte slootkanten; de meeste soorten en kwaliteitsindicerende soorten waren daar te vinden op de steilere hellingen (tot 35°).

Bij een hogere zuurgraad van de bodem waren het aantal soorten en het aantal kwaliteitsindicerende soorten hoger, maar de natuurwaarde-index niet. Bodemsoort en de hoeveelheid fosfor en kalium in de bodem hadden geen aantoonbare relatie met de floristische rijkdom van slootkanten.

Slootkanten en slootonderhoud (hoofdstuk 5)

Ook het slootonderhoud bleek van belang voor de slootkantvegetatie. Waterschappen schrijven de boeren voor om hun sloten te schonen, zodat het waterpeil in de polders goed kan worden gehandhaafd. Bijna alle boeresloten worden eens per jaar mechanisch geschoond, vaak in de herfst. Alle plantengroei in en vlakbij de sloten wordt dan verwijderd en op de slootkanten gedeponeerd, samen met slootbagger.

Minder vaak dan jaarlijks schonen ging samen met een hogere floristische rijkdom (Tabel 2). Dat komt waarschijnlijk doordat bedekking met nutrientrijke bagger, verstikking van de vegetatie door bagger en beschadiging van de vegetatie door het slootonderhoud minder vaak optreden. Bij minder dan eens per drie jaar slootschonen is het aantal soorten en kwaliteitsindicerende soorten enigszins lager dan eens per twee of drie jaar schonen.

Tussen methoden van slootschoning onderling zijn nauwelijks verschillen in slootkantvegetatie gevonden, vermoedelijk vanwege de grote variatie in de hoeveelheid en samenstelling van het slootvuil bij elke methode. Ook is geen effect gevonden van het uitbaggeren van sloten.

Lastige onkruiden (hoofdstuk 6)

De schadelijkste onkruiden kwamen nauwelijks op de slootkanten voor of prefereerden het hoogste gedeelte van de slootkant, tegen de graslandrand aan. Een hogere floristische rijkdom op het onderste deel van de slootkant, gemeten als natuurwaarde-index, ging gepaard met lagere aantallen lastige onkruiden. Er werd geen relatie gevonden tussen de bedekking van onkruiden op het grasland en die in de slootkant, behalve bij *Paardebloem*. Uit deze gegevens is geconcludeerd dat een slootkantbeheer dat is gericht op behoud of herstel van soortenrijke vegetaties op het onderste gedeelte van de slootkant onkruidproblemen eerder zal verminderen dan zal vergroten.

Inpasbaarheid van maatregelen in de landbouwpraktijk

Op grond van het effecten-onderzoek zijn maatregelen te formuleren die van belang zijn voor het behoud of het herstel van soortenrijke vegetaties. Het meestbelovend zijn maatregelen die technisch en financieel goed inpasbaar zijn in de landbouwbedrijfsvoering.

Graslanden

De mogelijkheden voor het herstel van de floristische rijkdom van graslanden op gangbare melkveebedrijven in het westelijke veenweidegebied lijken beperkt. Alleen bij een lagere bemesting dan 100 à 200 kg N ha^{-1} $jaar^{-1}$ hebben graslanden enige floristische rijkdom, maar dergelijke mestgiften lijken landbouwkundig gezien nauwelijks op enige schaal te verwachten. Daarom richtten wij ons verder vooral op het beheer van slootkanten.

Slootkanten

Voor slootkanten zijn de vooruitzichten in principe veel beter, omdat deze voor de landbouwbedrijfsvoering van veel minder belang zijn. Van een aantal maatregelen is de inpasbaarheid geschat (zie ook o.a. Kruk et al., 1988; Van Strien & Ter Keurs, 1988; Melman, 1990; Parmentier, 1990; Van der Ploeg & Roep, 1990).

Een aantal boeren bleek bereid om de slootkanten over een strook van 1 tot 2 meter vanaf de sloot niet mee te bemesten met kunstmest en dierlijke mest, omdat ze de slootkantvegetatie van ondergeschikt belang vinden voor het bedrijfsresultaat (Kruk et al., 1988). Onder bepaalde omstandigheden is het zelfs goedkoper om de kanten niet mee te mesten met kunstmest (Melman & Van der Linden, 1988). Vermindering van het meemesten lijkt dus een inpasbare maatregel. Slootkanten worden echter vaak onbedoeld meebemest. Technische aanpassingen op mestverspreiders zouden dit kunnen verminderen. Een andere mogelijkheid is het injecteren van dierlijke mest in de graszode. Mogelijk wordt een dergelijke injectie van mest verplicht in het kader van het mestbeleid om de hoeveelheid ammoniak die uit mest vrijkomt te verminderen. Slootkanten kunnen daarvan profiteren, omdat er dan geen dierlijke mest meer in de kant terecht komt. Overigens zouden weidevogels juist sterk kunnen worden geschaad door de verplichting van het injecteren van dierlijke mest (Kruk & Ter Keurs, 1990).

Intensieve beweiding en vertrapping van slootkanten kan worden voorkomen door de slootkanten af te rasteren. Dat kan weliswaar ook bedrijfsvoordelen met zich meebrengen, maar afrasteren brengt ook kosten en onderhoud met zich mee. Deze maatregel lijkt dus minder gemakkelijk inpasbaar. Een andere mogelijkheid zou zijn om de percelen met de soortenrijkste slootkanten niet zwaar te beweiden.

Een hoger slootpeil is gunstig voor de slootkantflora, maar bij een hoger slootpeil zijn de percelen langer nat in het voorjaar, waardoor de exploitatie moeilijker is. Daarom kiezen veel boeren eerder voor een laag peil. Recent onderzoek laat echter zien dat het financiële resultaat van landbouwbedrijven bij hoge slootpeilen niet veel minder is dan die met lage slootpeilen (Van Eck & Prins, 1990). Dit suggereert dat hoge peilen de bedrijfsvoering niet perse aanzienlijk schaden.

Zure slootkanten hebben gemiddeld minder soorten dan minder zure kanten, maar de zuurgraad bleek geen belangrijke factor voor de natuurwaarde-index te zijn. Sterke verzuring van de slootkanten zou kunnen worden tegengegaan door bij het bekalken van percelen de slootkanten mee te nemen, maar het is de vraag of dat zinvol en nodig is.

Er is zowel iets te zeggen voor een vrij steile taludhelling als voor een erg flauwe slootkant. Steile (tot ca. 35°), op het zuiden gerichte kanten profiteren van de extra zoninstraling. Zeer flauwe kanten vormen een brede vochtige zone waarvan de exploitatie moeilijk is. Zulke slootkanten vallen dan als het ware min of meer buiten de bedrijfsvoering, zodat een gunstig milieu kan ontstaan voor de wilde flora (zie Melman, 1990). Toch zijn zeer flauwe kanten moeilijk in bedrijfsverband te handhaven, omdat ze gevoelig zijn voor vertrapping. In de landbouwpraktijk geven boeren de voorkeur aan vrij steile kanten en hebben zeer flauwe taluds weinig kans. Deze kosten grond en er is extra onderhoud nodig om die flauwe taluds intact te houden. Zulke flauwe taluds lijken hooguit in het kader van natuurbouwprojecten, bijvoorbeeld bij landinrichting, mogelijk.

Een lagere slootschoningsfrequentie dan jaarlijks schonen is gunstig voor de flora van slootkanten, mits de frequentie niet lager is dan eens per 3 jaar. De bereidheid onder boeren om minder vaak dan eens per jaar te schonen is vrij aanzienlijk, omdat dat tijd en geld kan besparen (Kruk et al., 1988). Veel sloten in het veenweidegebied zijn overgedimensioneerd en zullen hun ontwateringsfunctie ook nog behouden als ze niet geheel ontdaan zijn van plantengroei (zie Pitlo, 1989). Onderzocht wordt onder welke omstandigheden deze maatregel inpasbaar is in het waterbeheer (Twisk & Ter Keurs, 1990).

Ook de slootschoningswijze vraagt aandacht. Het gebruik van andere apparatuur is nog geen garantie voor een floristisch rijkere slootkant. De wijze waarop met die apparatuur wordt omgegaan is minstens zo belangrijk. Voorkomen moet worden dat veel nutrientrijke slootbagger onder op de kanten komt en dat de slootkantvegetatie sterk wordt beschadigd. Ook andere aanpassingen van het slootonderhoud kunnen floristisch voordelig en agrarisch inpasbaar zijn, zoals het opbrengen van het slootvuil op één kant (de op het noorden gerichte kant heeft daarbij de voorkeur; zie verder Van Strien & Ter Keurs, 1988).

Mogelijke belemmeringen bij de invoering van slootkantbeheer in de landbouwpraktijk

Een aantal maatregelen die gunstig zijn voor de slootkantvegetatie lijken dus redelijk tot goed inpasbaar in de landbouwbedrijfsvoering. Sommige maatregelen zouden zelfs ook agrarisch gezien voordelig kunnen zijn. De perspectieven van slootkanten hangen echter niet uitsluitend af van de inpasbaarheid van maatregelen. Er zijn ook psychologische en sociaal-culturele belemmeringen om tot een ander slootkantbeheer te komen.

Boeren zijn slechts matig geïnteresseerd in het behoud van soortenrijke plantengemeenschappen (Katteler & Kropman; 1983; Volker, 1984; Van Strien & Ter Keurs, 1988). Bij veel boeren roept vegetatiebeheer namelijk een beeld op van laag produktieve graslanden, van verwaarloosd land en van een toename van lastige onkruiden, zoals *Akkerdistel*. Dat beeld klopt echter niet goed bij slootkantbeheer. Laag produktieve slootkanten zijn landbouwkundig gezien nauwelijks nadelig, slootkanten moeten niet worden verwaarloosd en een slootkantbeheer gericht op het verkrijgen van soortenrijke vegetaties vergroot de onkruidproblemen niet, maar vermindert deze eerder.

Voorlichting over vegetatiebeheer en de aanleg van demonstratie-slootkanten kunnen de acceptatie bij boeren vergroten. Een extra stimulans kan uitgaan van investeringspremies op apparatuur waarmee slootkanten beter kunnen worden beheerd. Verder kan slootkantbeheer extra aantrekkelijk worden gemaakt als boeren financieel zouden worden beloond voor het "produceren" van soortenrijke slootkanten op hun bedrijf ("natuurproduktiebetaling"; zie Van Strien et al., 1988).

Als de boeren de slootkanten meer aandacht en zorg geven kan de huidige landbouw in de westelijke veenweidegebieden nog aanzienlijke betekenis hebben voor de wilde flora. De slootkanten kunnen dan een toevluchtsoord vormen voor tal van bedreigde plantesoorten en de landschappelijke waarde van het polderlandschap aanzienlijk vergroten.

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APPENDIX

Nature-value index

Two indices of floristic richness used in this study are not well-known: the number of quality-indicating species (Drijver & Melman, 1983) and the nature-value index (Clausman & Van Wijngaarden, 1984).

The evaluation system of Drijver and Melman is not complicated; the number of quality-indicating species are all plant species that they considered as characteristic of normal to moist grasslands (see the list below).

The evaluation system of Clausman & Van Wijngaarden is more complicated and requires to be described in more detail. The central concept in their system is the degree in which wild plant species are threatened in their survival. This threat has been defined as the expected rarity of a plant species in the future and includes its present-day rarity of species and its rate of decline.

For each species Clausman & Van Wijngaarden determined the present-day rarity on different scales:

(1) the provincial (regional) rarity of the species, which was calculated from data of an extensive survey of the vegetation of all kinds of habitats in the province of Zuid-Holland. This rarity was defined as the quotient of the total number of spots of 100 m^2 in Zuid-Holland and the find-spots (in sample plots of about 100 m^2) of the species in this province. The cover of a plant in the sample plots was also weighted, leading to the following formula:

Provincial rarity of species I = (no. of spots in Zuid-Holland x (1 - $^{10}\log$ (mean cover of species I))) / (no. of find-spots of species I in Zuid-Holland).

(2) the national rarity of the species, which was calculated from national UFK ("uurhokfrequentieklassen") data about plant species (see also 2.4).

(3) the world rarity of the species, which was estimated from the area in which the species occurs and the rarity of the species within this area.

All three rarity figures were divided into rarity classes and were combined as follows: Integral rarity of species I = (provincial rarity + national rarity + world rarity) / 3.

The rate of decline of the species was estimated from:

(1) the changes in provincial rarity of the species in recent years.

(2) the changes in national rarity (UFK data) of the species between 1930 and 1980.

(3) the vulnerability of the species and its habitats.

All three estimations of the rate of decline were divided into classes and were combined as follows:

Integral rate of decline = 4 x ((change in provincial rarity + change in UFK + vulnerability) / 3).

The nature-value index of a species is an estimation of the rarity of the species in the future:

Nature-value index = integral present-day rarity - integral rate of decline.

The nature-value indices of individual plant species in my study range from 10 concerning *Elymus repens* and *Poa annua*, which are very common and increasing species, to more than 50 concerning rare and decreasing species such as *Calla palustris* and *Cirsium dissectum* (see the list below).

Furthermore, Clausman & Van Wijngaarden calculated the nature-value index of sample plots by summing the nature-values of all species present, taking into account their cover percentages. Some examples of the mean nature-value index of vegetation sample plots on different habitats in the province of Zuid-Holland are:

intensively exploited grassland	26
mean grassland	31
mean arable field	37
mean road verge	39
mean ditch bank along grassland	42
mean ditch	42
mean peat marshlands	53

Recently Clausman et al. changed the nature-value indices slightly. The old and new nature-value indices of vegetation sample plots of ditch banks were correlated highly (r = 0.98; n = 7500 sample plots of the survey of the province of Zuid-Holland).

Value of plant species in this study

Below the species involved in this study are given, valued according to the system of Drijver & Melman (1983) ("quality-indicating" species) and Clausman & van Wijngaarden (1984) ("nature-value index"). Nomenclature is according to Heukels & Van der Meijden (1983).

+ : quality-indicating species (q-i)
- : no quality-indicating species
? : unknown
n-v : nature-value index

	q-i	n-v
Achillea millefolium	+	22
Achillea ptarmica	+	42
Acorus calamus	+	33
Agrostis canina	+	42
Agrostis capillaris	+	29
Agrostis stolonifera	+	18
Ajuga reptans	+	46
Alchemilla gracilis	+	>50?
Alisma gramineum	+	50
Alisma plantago-aquatica	+	29
Alopecurus geniculatus	+	23
Alopecurus pratensis	+	21
Angelica sylvestris	+	29
Anthoxanthum odoratum	+	27
Anthriscus sylvestris	+	24
Apium nodiflorum	+	36
Arrhenatherum elatius	+	30
Atriplex prostrata	-	27
Bellis perennis	+	23
Berula erecta	+	30
Bidens cernua	-	31
Bidens tripartita	-	31
Brassica napus	-	?
Brassica rapa	-	?
Bromus hordeaceus	+	21
Butomus umbellatus	+	42
Calla palustris	+	63
Caltha palustris	+	36
Capsella bursa-pastoris	-	16
Cardamine hirsuta	-	34
Cardamine pratensis	+	22

	q-i	n-v
Carex acuta	+	34
Carex cuprina	+	38
Carex disticha	+	43
Carex echinata	+	53
Carex elata	+	51
Carex hirta	-	28
Carex nigra	+	45
Carex oederi	+	57
Carex ovalis	+	43
Carex panicea	+	50
Carex paniculata	+	44
Carex pseudocyperus	+	50
Carex riparia	+	36
Carex rostrata	+	44
Catabrosa aquatica	-	33
Cerastium fontanum	+	21
Chenopodium album	-	18
Chenopodium ficifolium	-	24
Cicuta virosa	+	45
Cirsium arvense	-	18
Cirsium dissectum	+	57
Cirsium palustre	+	37
Cirsium vulgare	-	21
Coronopus squamatus	-	35
Crepis capillaris	-	30
Cynosurus cristatus	+	34
Dactylis glomerata	+	18
Danthonia decumbens	+	48
Deschampsia cespitosa	+	27
Eleocharis palustris	+	29
Elymus repens	-	10

	q-i	n-v
Epilobium ciliatum	+	33
Epilobium hirsutum	+	23
Epilobium palustre	+	47
Epilobium parviflorum	+	27
Epilobium tetragonum	+	33
Equisetum arvense	+	17
Equisetum fluviatile	+	36
Equisetum palustre	+	25
Erigeron canadensis	-	30
Eriophorum angustifolium	+	45
Eupatorium cannabium	+	31
Festuca arundinacea	+	36
Festuca pratensis	+	25
Festuca rubra	+	22
Filipendula ulmaria	+	31
Galium palustre	+	35
Glechoma hederacea	+	19
Glyceria fluitans	+	24
Glyceria maxima	+	22
Gnaphalium uliginosum	-	37
Heracleum sphondylium	+	32
Holcus lanatus	+	17
Hydrocotyle vulgaris	+	40
Hypericum tetrapterum	+	48
Iris pseudacorus	+	40
Juncus articulatus	+	30
Juncus bufonius	+	30
Juncus bulbosus	+	44
Juncus conglomeratus	+	44
Juncus effusus	+	24
Juncus subnodulosus	+	45
Lamium album		20
Lamium purpureum	-	24
Lapsana communis	-	26
Lathyrus palustris	+	54
Lathyrus pratensis	+	32
Leontodon autumnalis	+	25
Leontodon saxatilis	+	40
Leucanthemum vulgare	+	39
Lolium multiflorum	-	?
Lolium perenne	-	12
Lotus uliginosus	+	40
Lychnis flos-cuculi	+	44
Lycopus europeus	+	29
Lysimachia nummularia	+	36
Lysimachia thyrsiflora	+	45
Lythrum salicaria	+	31
Matricaria discoidea	-	16
Mentha aquatica	+	31
Mentha arvensis	+	37
Menyanthes trifoliata	+	53
Myosotis arvensis	+	29
Myosotis palustris	+	28
Nasturtium microfyllum	+	29
Oenanthe aquatica	+	37
Oenanthe fistulosa	+	37
Peucedanum palustre	+	38
Phalaris arundinacea	+	20
Phleum pratense	-	19
Phragmites australis	+	18
Plantago lanceolata	+	23
Plantago major	-	18
Poa annua	-	10
Poa pratensis	+	20
Poa trivialis	-	12
Polygonum amphibium	-	22
Polygonum aviculare	-	16
Polygonum hydropiper	-	27
Polygonum lapathifolium	-	20
Polygonum mite	-	39
Polygonum persicaria	-	18
Potentilla anglica	+	58
Potentilla anserina	+	21
Potentilla palustris	+	41
Prunella vulgaris	+	31
Ranunculus acris	+	22
Ranunculus flammula	+	43
Ranunculus repens	+	14
Ranunculus sceleratus	-	27
Rorippa amphibia	+	32
Rorippa palustris	-	28
Rorippa sylvestris	-	30
Rumex acetosa	+	23
Rumex acetosella	+	25
Rumex conglomeratus	+	34
Rumex crispus	-	19
Rumex hydrolapathum	+	36
Rumex maritimus	+	40
Rumex obtusifolius	-	23
Sagina procumbens	+	23
Scirpus maritimus	+	34
Scirpus lacustris	+	43

	q-i	n-v		q-i	n-v
Scirpus setaceus	+	47	*Thalictrum flavum*	+	48
Scutellaria galericulata	+	34	*Trifolium dubium*	+	28
Senecio aquaticus	+	43	*Trifolium pratense*	+	22
Senecio vulgaris	-	17	*Trifolium repens*	+	13
Sium latifolium	+	36	*Triglochin palustris*	+	37
Solanum dulcamara	-	23	*Tussilago farfara*	+	19
Solanum nigrum	-	23	*Typha angustifolia*	+	32
Sonchus asper	-	23	*Typha latifolia*	+	27
Sonchus oleraceus	-	20	*Urtica dioica*	-	17
Sparganium erectum	+	28	*Valeriana officinalis*	+	30
Stachys palustris	+	30	*Veronica arvensis*	+	31
Stellaria graminea	+	34	*Veronica beccabunga*	+	39
Stellaria media	-	11	*Veronica serpyllifolia*	?	40
Stellaria palustris	+	48	*Vicia sativa*	?	32
Stellaria uliginosa	+	36	*Vicia cracca*	+	25
Symphytum officinale	+	31	*Viola palustris*	+	52
Taraxacum officinale	-	12			

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Curriculum vitae

Arco van Strien werd op 29 augustus 1953 geboren te Zierikzee. Hij deed in 1971 het eindexamen HBS-B aan de Christelijke Scholengemeenschap Johannes Calvijn te Rotterdam. In hetzelfde jaar begon hij met de studie biologie aan de Rijksuniversiteit te Leiden. In 1975 deed hij het kandidaatsexamen B3 (biologie met natuurkunde). Het doctoraalpakket bestond uit het hoofdvak Farmacologie en de bijvakken Medische Fysiologie en Diersystematiek. Het doctoraalexamen werd behaald in december 1978 met de vermelding "cum laude". Van 1979 - 1987 werkte hij onder leiding van drs. W.J. ter Keurs bij de onderzoeksgroep Milieubiologie van de Vakgroep Populatiebiologie van de Rijksuniversiteit te Leiden, waar hij zich vooral bezighield met onderzoek naar de relaties tussen landbouw en natuur en milieu. In 1988 - 1989 was hij werkzaam in de informatica. Momenteel is hij werkzaam op het Centraal Bureau voor de Statistiek, Hoofdafdeling Landbouwstatistieken, Afdeling Natuurlijk Milieu.