MONITORING VEGETATION CHANGE IN THE NETHERLANDS

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Abstract - The Dutch national vegetation monitoring scheme collects sample-based surveillance data at a national scale. The objectives are (i) to assess if changes in eutrophication, acidification and desiccation lead to changes in the vegetation of natural habitats and (ii) to assess changes in botanical quality of natural habitats and farmland and (iii) to assess botanical changes in verges of traffic highways. The first results demonstrated that the national monitoring scheme is sensitive enough to track relevant changes in the vegetation. Examples are the increasing coverage of shrubs in natural areas and the signs of recovery of the vegetation of wet dune valleys in areas with hydrological measures.

Key words: monitoring, permanent plot, vegetation change.

Introduction

In the last century the flora of the Netherlands has changed considerably (Tamis, 2005). Common species have increased at the expense of many characteristic and rare species, leading to a greater uniformity of the vegetation, a process called biotic homogenization (McKinney & Lockwood, 1999). This process is mainly driven by changes in agriculture, land use, hydrology and by environmental pollution. These factors have not only led to changes in flora and vegetation, but have also affected butterflies and many other species groups. (For examples see Van Duuren *et al*. 2003).

To halt the loss of biodiversity in the Netherlands, environmental and nature policy plans have been adopted. Many environmental measures were taken to reduce acidifying and nutrient depositions and to restore the former hydrological situation. In addition, management of natural areas was adapted in order to reduce the effect of eutrophication and desiccation. This includes measures as the removal of trees, bushes and shrubs, low density grazing and locally the removal of nutrient-rich upper layers of soil.

To be able to evaluate the overall effectiveness of the policy measures, monitoring of the vegetation is required. There is a long tradition in the Netherlands to study changes in flora and vegetation. The raw data of many research projects have been stored in two separate databases: (i) "Florbase" (Tamis, 2005; Tamis *et al*., 2005) and (ii) the National Vegetation Database (Schaminée & Westhoff, 1992). Florbase contains data of plant species collected in 1 by 1 km squares and is useful to compile distributional maps of plant species. The National Vegetation Database contains data collected in relevés and was used for the Atlas of Plant Communities (Van Duuren *et al.,* 1998). Both databases are not sufficiently sensitive to measure short-term changes. Therefore, a new national vegetation monitoring scheme was started, based on recording the abundance of plant species in permanent plots. The scheme is a collaborative program of the provinces, the Netherlands Environmental Assessment Agency (MNP) and Statistics Netherlands (SN).

The objectives of the monitoring scheme are (i) to assess if changes in eutrophication, acidification and desiccation lead to changes in botanical composition of the vegetation of natural habitats, (ii) to assess changes in botanical quality of natural habitats and farmland and (iii) to assess botanical changes in verges of traffic highways. All together, the scheme may be considered as a general-purpose instrument to monitor large-scale botanical changes in the Netherlands.

As a first exploration of the possibilities of detecting changes with the data collected, we searched for major changes in botanical composition on a national scale on the one hand and examined changes in the vegetation due to hydrological measures in one region (dunes) on the other. Here we present some results of the first analyses.

Methods

Design of the scheme

11.945 fixed plots (permanent quadrates) were selected using a stratified random sampling strategy. Within each stratum 300 plots were selected randomly, but distances between plots of the same habitat type were at least 1 km. This distance was taken into account to minimize spatial autocorrelation between plots. Each plot is recorded once every four years, so each year data is being collected from about 2.500 plots. The scheme started in 1999, but because not all provinces joined the national scheme from the beginning, data collection in some areas has started in later years.

Fifty different strata were applied, based on combinations of habitat type, physical geographical region and environmental conditions (Alkemade *et al.,* 1999). We stratified according to six major habitat types in natural areas: (1) coniferous wood, (2) deciduous wood, (3) coastal open dunes, (4) heathland, (5) unimproved grassland and (6) marshland. For farmland we used the following landscape elements as strata: (1) ditches and drainage trenches, (2) ditch banks, (3) hedges, (4) road verges and (5) dikes.

All together these habitat types cover the natural terrestrial areas in the Netherlands as well as the botanical most-valued parts of farmland. Waterbodies, urban areas, arable fields and improved grasslands were excluded.

All terrestrial physical geographical regions of the Netherlands were used as strata: (1) hilly area, (2) coastal area, (3) sandy area, (4) marine sea clay area, (5) river clay area, (6) peat area and (7) former estuarine area. To increase the opportunities to connect botanical changes to environmental policy measures, we stratified according to environmental areas. These areas were based on combinations of the amount of deposition in 1995 and the predicted deposition in 2020 (Alkemade *et al*., 1999).

Data collection and processing

To reach maximum standardisation of the data recording, guidelines for selection of plot location, plot size, sampling period, abundance scale etc. were prescribed (Statistics Netherlands, 2001). Professional field workers selected the plots and sampled the data, coordinated by the provinces. Vascular plants were recorded using the cover scale of Braun-Blanquet or equivalent scales. Additional data were collected on coverage and height of vegetation layers, inclination of the plot, management, land ownership and disturbances of the soil or vegetation. For each plot a detailed distinction of habitat type was made in the field.

Statistical analysis

Since the start of the monitoring in 1999 data are available for nearly two four-year rounds of investigations (Fig. 1). This provides the opportunity to examine changes between the two periods 1999-2002 and 2003-2006.

Changes in frequency and mean abundance of individual species were calculated. To analyse the effects of changes due to eutrophication, acidification and desiccation, we assessed for each plot per round the average Ellenberg values for nitrogen, moisture and acidity as well as for temperature, without taking into account abundances of species (Ellenberg *et al*., 1992). In addition, we calculated the sum of the abundance of selected species group, e.g. tall herbs, grasses, shrubs, trees and pioneer species, species of nutrient-rich or nutrient-poor soils (i.e. species with Ellenberg indicator value for nitrogen >6 and <6 respectively) and thermophilic and thermophobic species, (i.e. species with Ellenberg indicator value for temperature >6 and <5 respectively).

Furthermore, to examine the changes in botanical quality of natural habitats and farmland, we assessed species richness for each plot. Changes in the abundance of individual species were tested by Wilcoxon matched pairs signed ranks tests and changes in frequency of species by Chi-square tests. All other changes were tested by paired t-tests.

Results

Changes in botanical composition on a national scale

The most striking result of the first analysis was the increased coverage of shrub species in natural habitat types (table 1). *Rubus fruticosus*, *Prunus spinosa*, *Ilex aquifolium* and *Hippophae rhamnoides* were among the most conspicuous growers. The proportion of shrubs has increased significantly in dry dunes, dry grassland, wet grassland, dry deciduous woodland and coniferous woodland (Fig. 2). Also tall herbs have increased, e.g. *Cirsium arvense* and *Juncus effusus*. These herbs increased their

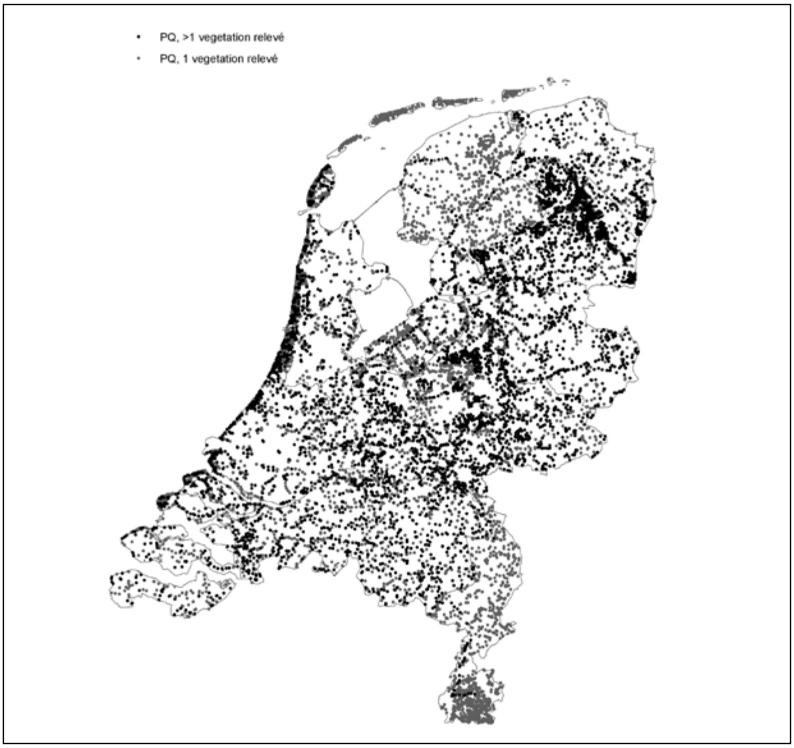

FIGURE 1 - Locations of study plots surveyed once and twice.

coverage in dry grassland, wet grassland en marshland. Pioneer species have declined in coverage (table 1), especially in dry dunes, wet dunes, wet grassland and dry deciduous woodland. A reduced coverage was also found for grasses in wet dunes, dry grassland, dry heathland, and in dry and wet deciduous woodland.

No changes were found for average Ellenberg indicator values for nitrogen, nor for abundance of species of nutrient-rich or nutrient-poor soils (table 1). Cold-loving species decreased significantly, but no change was found in thermophilic species and in average Ellenberg values for temperature.

Effects of hydrological measures in wet dunes

For many years, the vegetation in the coastal dunes has suffered desiccation due to the extraction of drinking-water leading to lower ground water tables. Recently, recovery measures were carried out to restore the former hydrological situation in some areas. Changes in botanical composition were compared between areas with and without recovery measures in former wet dunes. In areas with such measures, species richness increased significantly, whereas changes in species richness were not significant in areas without measures (Fig. 3). Changes in abundance of individual species indicated the recovery of wet dune vegetation (table 2). Examples of increasing species are *Hydrocotyle vulgaris* and *Mentha aquatica*. Both species are able to respond rapidly to wetter circumstances. Although the wet weather of the last few years may have contributed to their recovery, the increase of typical wet dune species was stronger in areas where hydrological restoration measures were taken (Fig. 3).

TABLE 1 - Changes in natural habitat types on a national level between 1999-2002 and 2003-2006 (n=5156). * p<0.05, ** P<0.01.

	Change (%)	Significance
Change in coverage of plant groups		
Trees	0,0	
Shrubs	9,7	**
Tall herbs	4,8	**
Pioneers	-5,9	**
Grasses	-2,6	**
Changes related to eutrophication		
Average Ellenberg indicator value for nitrogen	0,0	
Sum of coverage of species of nutrient-poor soils	0,0	
Sum of coverage of species of nutrient-rich soils	0,6	
Changes related to climatic change		
Average Ellenberg indicator value for temperature	-0,1	
Sum of coverage of thermophobic species	-6,4	*
Sum of coverage of thermophilic species	-2,9	

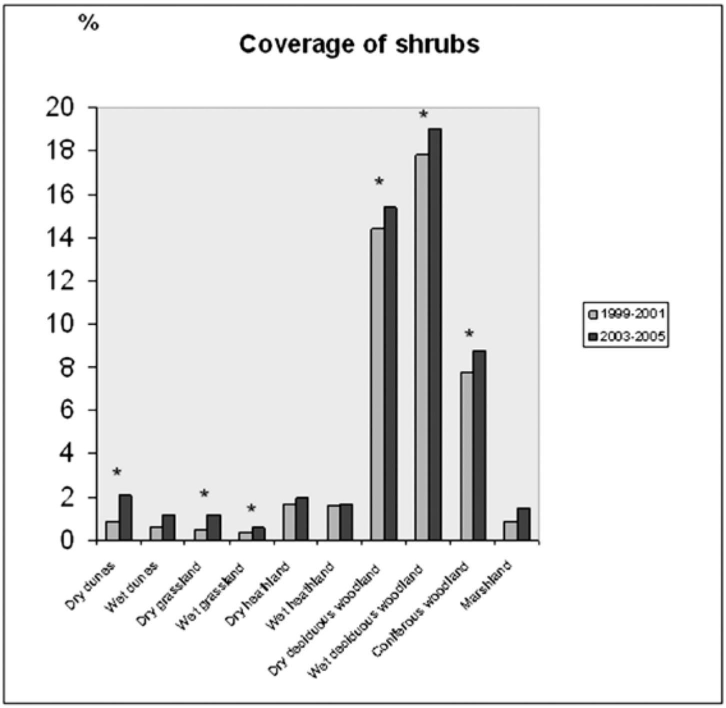

FIGURE 2 - Mean abundance of shrubs per plot in 1999-2001 and 2003-2005. * P<0.05.

Table 2 - Changes of species in wet dunes (% average coverage). Only species were listed with frequency > 10% and change in coverage > 1% (n=70). * P<0.05.

	1999-2001	2003-2005	Significance
Hydrocotyle vulgaris	3,7	7,8	*
Mentha aquatica	3,9	6,0	
Prunella vulgaris	1,6	3,3	*
Lotus pedunculatus	0,9	2,2	
Carex nigra	2,4	3,5	
Trifolium repens	2,3	3,3	
Euphrasia stricta	0,6	1,7	*
Agrostis capillaris	3,1	1,5	
Agrostis stolonifera	7,5	6,0	

Discussion

Changes in vegetation

The increase of shrubs and the decrease of grasses and pioneer species in nature areas all point to an ongoing succession of the vegetation. For Britain, Smart *et al.* (2003a) found similar changes in the vegetation. This phenomenon may be caused by management practices insufficient to prevent succession. It may also be due to eutrophication that accelerates natural succession, although we did not find any change in Ellenberg values for nitrogen. This is remarkable, because for decades eutrophication was regarded as one of the major factors driving the changes in botanical composition in the Netherlands (Tamis, 2005; Tamis *et al.*, 2005). Recent changes in Britain were still related to increased mean Ellenberg indicator values for nitrogen (Smart *et al.*, 2003b). This requires further investigation, taking into account recent discussions on the reliability of Ellenberg values (Wamelink *et al.*, 2005).

Tamis (2005) has noticed the increase of thermophilic species in the last decennia in the Netherlands. We found a decline of thermophobic species which points at the same direction of change. There are two possible explanations why we did not find an increase in thermophilic species. First, the study of Tamis (2005) is based of the occurrence of plant species in 1 by 1 km squares all over the country. Most of our data comes from natural habitats whereas no data at all was collected in urban areas. But the most apparent increases in thermophilic species probably occur in urban areas, because generally these areas are warmer. Second, many of the thermophilic species investigated by Tamis are rare species and not well covered by our scheme. We still may conclude from our data that apparently the share of thermophilic species in the vegetation of natural areas does not increase in the considered period.

The changes in wet dune vegetation suggest a positive effect of the measures taken. Rare and highly-valued species of wet dunes such as *Parnassia palustris* may also profit from the hydrological alterations, but changes in rare species are difficult to detect with this scheme.

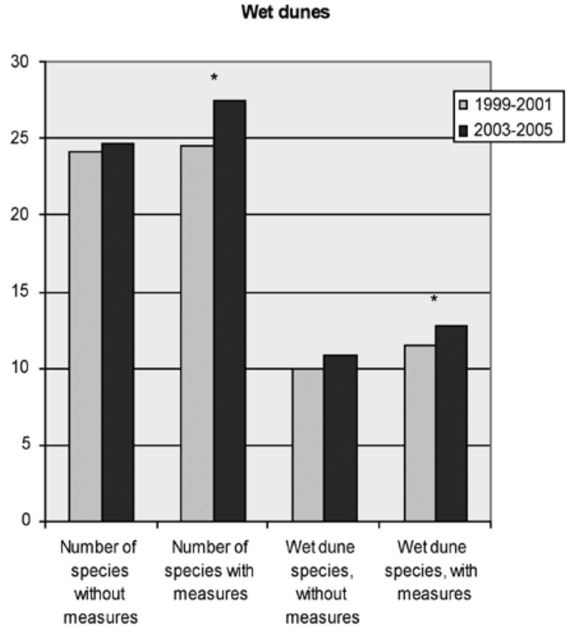

FIGURE 3. Changes in number of species and abundance of species typical for wet dunes in areas with and without hydrological measures. * P<0.05.

Performance of the monitoring scheme

The results demonstrated that the national monitoring scheme is sensitive enough to track relevant short-term changes in the vegetation. As the time series continues to grow, the opportunities to detect changes will increase. This makes the scheme a promising tool to survey policy-relevant changes in the vegetation of the Netherlands. But to detect such changes, a careful selection of indicators is required because changes in short time series are expected to be rather small.

Because each new round of data collection requires four years, new results are only available once every four years. To stimulate the use of the results of this scheme, we would rather publish new results every year, as is the case for most of the other national monitoring schemes in the Netherlands (see for examples of other schemes www.natuurcompendium.nl). Therefore, we will implement an imputation method to estimate missing yearly data. This will also reduce the difficulties due to the later start of several provinces whose data collection rounds are out of phase with the other provinces.

Unfortunately, inspection of the data revealed that some field workers have not selected their plots randomly and we have to take that into account in the analysis. Some habitat types appeared to be oversampled within strata, such a moist heathland where dry heathland was undersampled. We will develop weighting procedures to adjust for this, comparable to those applied in e.g. the national butterfly monitoring scheme (Van Swaay *et al*., 2002).

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