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Considerable environmental bottlenecks for species listed in the Habitats and Birds Directives in the Netherlands

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ABSTRACT

Many habitats and species have their existence threatened, especially in densely populated areas such as Western Europe. To stop the decline of biodiversity, the Natura 2000 network is being set-up. The ultimate objective is to get all habitat types (of Annex I of the Habitats Directive) and species (of Annexes II, III and IV of the Habitats Directive and Annex I of the Birds Directive) in a favourable conservation status. In the Netherlands a national ecological network has been set up for this purpose which includes the designated Natura 2000 sites. The current amount of atmospheric nitrogen deposition, acidification and desiccation were compared with limit values per habitat type for nitrogen deposition load, soil pH and spring groundwater table respectively and subsequently presented together in one map. Fragmentation was tested for 80 species.

For two-third of the examined natural surface the critical load for nitrogen deposition is exceeded, desiccation is present in over 90% of the area of groundwater dependent nature. Problems with acidification are less pronounced. Fragmentation is present causing regional problems for up to six species. When the four pressures are combined, about two third of the areas suffer from at least one pressure. Many areas suffer from a combination of nitrogen deposition and desiccation.

We conclude that environmental and spatial conditions are insufficient to meet the biodiversity target set by the European Union for the Natura 2000 network, habitat types and species.

1. Introduction

Biodiversity is declining, both on the global and the European level (Butchart et al., 2010; Chapin et al., 1998; Dobson, 2005; Smith et al., 2000; Swift et al., 1998). One of the most important actions to preserve and restore Europe's biodiversity is the creation of a Europe-wide ecological network of nature conservation areas – called the Natura 2000 Network (HD issued in 1992, CD 92/43/EEC). This network, established under the Habitats Directive (92/43/EEG) and Birds Directive (2009/147/EG), will accommodate threatened and valuable habitats and species in all EU member states. Conservation measures should be taken to appropriately manage Special Areas of Conservation (SAC's) and Special Protection Areas (SPA's). Natura 2000 sites should be big enough or connected to other suitable sites within and between member states in order to sustain healthy (meta-) populations of the protected species. The ultimate objective of the European Union is to get all habitat types (of Annex I of the Habitats Directive) and species (of Annexes II, III and IV of the Habitats Directive and Annex I of the Birds Directive) in a favourable conservation status; the Habitats and Birds Directives are intended to prevent the decline of the population size of any of these listed species and the deterioration of any habitat type.

The main pressures that are commonly recognized as causing biodiversity loss are habitat loss and fragmentation, nutrient loading and pollution, the effects of invasive alien species, climate change and unsustainable use of land (Balmford et al., 2005; Chapin et al., 2000; Cook et al., 2006; Galloway et al., 1984; Hanski, 1994; Hogg et al., 1995; Lameire et al., 2000; Mack et al., 2000; Thomas et al., 2004). Of these pressures loss of suitable habitat and fragmentation, desiccation, eutrophication and acidification are considered the most important pressures for biodiversity in the densely populated Netherlands (Bruinderink et al., 2003; De Vries et al., 2009; Heijmans et al., 2008; Hettelingh et al., 2009; Lammers and Zadelhoff, 1996; Wamelink et al., 2009a), the study area of this paper. Acidification and eutrophication due to nitrogen deposition as well as desiccation due to lowering of the groundwater level are mostly associated with unsustainable land use resulting from intensified agricultural and industrial practices (Galloway et al., 1984, 2008; Van Ruijven and Berendse, 2010). Where acidification due to industrial activities has dropped dramatically,

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nitrogen deposition and the related acidification and eutrophication are still increasing on a European and global scale (Galloway et al., 2008). Nitrogen deposition levels in the Netherlands used to be very high, up to 60 kg/ha/y, and have presently decreased to 30–40 kg/ha/y. Eutrophication in Natura 2000 sites is not only due to nitrogen deposition but has several causes such as increased nutrient levels in ground water and surface water and mineralization of organic soil. This paper focuses on nitrogen deposition and not on nitrogen availability because it is the most important source of nutrient input on the national and international scale. Both eutrophication and acidification have well known negative impacts on soil conditions and plant biodiversity (De Vries et al., 2010; Hettelingh et al., 2009; Wamelink et al., 2003, 2009a). Desiccation is strongly related to agricultural activities needing a low groundwater table and excessive use of water irrigation, causing drought stress in nearby natural areas (Elmore et al., 2003; Moore, 2002; Van Ruijven and Berendse, 2010). This is a large bottleneck for wetlands, peatlands, bogs and other water related habitats, especially for small and isolated sites in intensively used agricultural areas.

Many vulnerable species will be at risk of population decline or local extinction if these pressures persist. So, unless we successfully mitigate the impacts of these pressures on biodiversity, the decline of natural areas and biodiversity is expected to continue (De Vries et al., 2009; Heijmans et al., 2008; Lewis et al., 2004; Sverdrup et al., 2012; Wamelink et al., 2009b).

Of a different magnitude and also directly influencing the persistence of populations survival is fragmentation of the natural landscape. Although the total natural area has increased by nature development projects on agricultural land since the National Ecological Network (NEN) has been introduced in 1990, lack of natural habitat and its fragmentation are still a major threat to biodiversity. Due to loss of spatial cohesion population survival is under pressure and species may become extinct (Beier and Noss, 1998; Hanski, 1994; Opdam et al., 2003).

In this paper the major goals are (1) to quantitatively identify which of the four pressures, acidification, desiccation, nitrogen deposition and habitat fragmentation are the most important bottlenecks, (2) to investigate how they influence the conservation status at these sites, and (3) to investigate how they influence the European biodiversity policy targets. The focus of this research is not only on the N2000 sites but on all natural areas, because the latter also contribute to the Birds and Habitats Directives; they also help to preserve the designated species and habitats and to get them in a sustainable state. To give an overview results are presented in one graph together to be able to assess the quality of the habitats of the four different pressures together.

2. Materials and method

2.1. Overview of the method

The present environmental conditions and spatial cohesion of all natural terrestrial and water areas in the Netherlands were evaluated, but limited by available data. For nitrogen deposition we have critical loads for estuaries and marine areas, thus they were included in the analysis. For soil pH and groundwater table we have no data for the water bodies, hence they were not included. For the combined maps we therefore did not include the marine waters, since they were only examined for critical load of nitrogen deposition. For the environmental conditions we chose three abiotic parameters, nitrogen deposition, spring groundwater table and soil pH. These parameters are indicative for the pressures eutrophication, desiccation and acidification, respectively. Evaluation was carried out based on limit values per habitat type. For nitrogen deposition the limit value is represented by the 'critical load', for mean spring groundwater table (MSL) the limit value is represented by the minimum tolerable groundwater level, and for soil pH the limit value is represented by the minimum tolerable pH (cf. van Dobben et al., 2006; Wamelink et al., 2011). For each habitat type combined with MSL and pH a range of occurrence was estimated, based on field measurements (Wamelink et al., 2011, 2012). This gives limit values for each vegetation type; within the limits a vegetation type can in principle occur, outside this range it cannot. We tested MSL and pH only one sided, both for the lower limits, so the pH and MSL can be too low, but not too high.

The present abiotic values per site were derived from the present nitrogen deposition in the Netherlands (Velders et al., 2010) and for MSL the actual groundwater table (Van der Gaast et al., 2009). Soil pH was inferred from vegetation relevés (following Wamelink et al., 2005). Limit values (i.e., 'no effect levels') of nitrogen deposition, MSL and soil pH were assigned to each site on the basis of the habitat type present at that site. Subsequently, the limit values of these parameters were confronted with their actual values to determine if the estimated field value exceeded the set limit values for the habitat type.

The spatial cohesion of ecological networks for species of the Habitats and Birds Directives were evaluated with the model LARCH (Opdam et al., 2003, 2008; Verboom and Pouwels, 2004). Model parameters per species can be found in Pouwels et al. (2008, http://edepot.wur.nl/45743) and Pouwels et al. (2007, http://edepot.wur.nl/22177) annex 2. Model parameters are:

1. Local population Distance (m): the distance between 2 habitat locations within which they will be clustered into one local population.
2. Network Distance (m): the distance between 2 local populations within which they will be clustered into 1 network population.
3. Network Step Stone Size: the minimum number of RUs for a habitat location to be considered a network cluster candidate.
4. Key Patch (–): the species' minimum number of reproductive units needed to form a key population.
5. MVP factor (–): the multiplication factor for the minimum area needed to form a network population when the strongest local population is a minimum viable population.
6. NW + KP factor (–): the multiplication factor for the minimum area needed to form a network population when the strongest local population is a key population.
7. NW7KP factor (–): the multiplication factor for the minimum area needed to form a network population when the strongest local population is a small population.

Also needed are a habitat quality map, with varying quality per species and vegetation type combination and a density factor (RU/100 ha) for population species.

Based on actual species distribution data and the spatial configuration of ecosystems, viable meta-populations were identified. A viable population is defined as a population that has a high probability to survive for a long time (e.g. over 95% in a period of 100 years, Opdam et al., 2003). Subsequently, for 80 species the spatial bottlenecks were analysed. These 80 species cover over three quarters of all species from Annex II and IV of the Habitats Directive and Annex I of the Birds Directive in the Netherlands. For the other one quarter of the species no or not reliable enough data are available to parameterise the model.

Calculations were done for grid cells of 250 m × 250 m and for each grid cell the dominant vegetation type, if more than one was present, was used. Below the habitat map and method to determine the environmental and spatial bottlenecks are described in more detail.

2.2. Habitat types map

Habitat maps are necessary to determine if the local values of abiotic parameters are outside the ranges of habitat types. A map of Natura 2000 sites and habitat type is available. But, nature outside the N2000 sites also contributes to the targets set by the EU. Therefore, an alternative vegetation description system with detailed spatial information, the so called 'nature management types' (Schipper and Siebel, 2009), was used. All appointed nature management types on the map were translated into habitat types, including the designated Natura 2000 sites (Annex 4). The resulting proxy habitat map was used to assess local limit values of the environmental conditions and spatial cohesion. The use of this map introduces several uncertainties:

1. The relation of the nature management types and the habitat types is not a one to one relation, but a many to many relation. This makes the translation more difficult and it is possible that a wrong habitat type is assigned to a natural area. To narrow down the possibilities, the list of habitat types is used to check whether a translated habitat type is actually present within the Natura 2000 site or not. Only actual present habitat types are used for the translation.
2. A consequence of the case mentioned above is that a single management type may contain more than one Habitat type. If that occurs, Habitat types are merged together. Examples of this are the dry and moist dune forest types (H2180A, H2180B). The moist dune forests are mostly embedded in the dry forest and have a small surface area. They have different limit values regarding the groundwater table; the moist type has a limit of 60 cm below surface, and the dry type has no limit value. In these cases we used the most limiting requirement for the area, as is normally done for Natura 2000 sites. However, in some cases we deviated from this rule to prevent a huge overestimation of drought stress, e.g. for the dune forest the moist part is only present for a minor part of the surface area. Other habitat types that are not included for this reason are all Humid dune slacks subtypes (H2190), Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (H6430) and Depressions on peat substrates of the Rhynchosporion (H7150).
3. The habitat types are assigned to natural areas via the nature management types. However, the designated habitat type does not have to be, already, present in that area due to unfavourable environmental conditions or only present for a part of the designated area. The habitat type can also represent a target for the future, to be obtained by mitigating unfavourable processes or situations. In this case we assess the potential vegetation type.

2.3. Eutrophication

For each habitat type a critical nitrogen deposition load (CL) was calculated by van Dobben et al. (2006, see also Annex 1 for the CL). They applied the model SMART2 and calculated at which nitrogen deposition no significant effects on plant species composition of the habitat types are expected. The CLs per habitat type were linked with the habitat types of the proxy habitat map thus providing a map with limit values for nitrogen deposition. A map of current values for nitrogen deposition was adopted from Velders et al. (2010). The deposition was spatially combined with the limit values of the habitat type and subsequently the amount of CL exceedance was calculated. Eutrophication is identified as a bottleneck in areas where the present nitrogen deposition exceeds the limit value.

2.4. Desiccation

The surface area of desiccated habitat was calculated analogous to the surface area with nitrogen deposition exceedance. Desiccation was only calculated for habitat types where the groundwater table influences the occurrence of the type, i.e. dry vegetation types (MSL > 80 cm below surface) were not included. Limit values for the spring groundwater table were calculated following Wamelink et al. (2011, see also Annex 1 for limit values), who estimated minimum spring ground water levels per habitat type, based on field measurements. These limit values were linked to the habitat types of the proxy habitat map analogous to the limit values of nitrogen deposition. Actual spring groundwater tables were adapted from van der Gaast et al. (2009) and spatially combined with the limit values of the habitat types. Subsequently, the limit value exceedances were determined. Desiccation is identified as a bottleneck in the areas where the actual spring ground water table exceeds the limit value, i.e. the lower 5% limit value of the range of a habitat type.

2.5. Acidification

The third abiotic parameter was evaluated is soil pH. Minimum soil pH values per habitat type were inferred according to Wamelink et al. (2011, see also Annex 1 for limit values). Current soil pH values at the habitat sites where estimated based on the species composition of vegetation relevés made between 1990 and 2011 (Hennekens and Schaminée, 2001). For each relevé the soil pH was calculated as the average of the indicator values of the species in the relevé, following Wamelink et al. (2005). If for a combination of habitat area and habitat type more than one relevé was available the average pH for these relevés was calculated. The estimated actual pH was compared with the lower limit for the habitat type at each site. Acidification is identified as a bottleneck in the areas where the estimated pH is lower than the minimum limit pH, i.e. the lower 5% limit value of the range of a habitat type.

2.6. Spatial cohesion

For a species to survive in a network of habitats, two conditions have to be fulfilled (Opdam et al., 2003):

1. The total network is large enough to prevent synchronous extinction of all local populations.
2. The dispersal of species across the landscape balances local extinction and recolonisation rates.

The model LARCH confronts the spatial configuration of suitable habitat patches with the surface area requirements and dispersal distances for each species (Opdam et al., 2003; Verboom and Pouwels, 2004). The model also uses the permeability of the landscape for species to determine if habitat patches belong to the same habitat network and allow local populations to belong to one meta-population, taking account of barriers like infrastructure or natural borders (Bruinderink et al., 2003; Van der Grift and Pouwels, 2006).

Spatial bottlenecks are defined as habitat networks where the species is currently present, but are not sustainable, i.e. do not hold viable populations, according to the model output. LARCH was run for each species separately. The analysis was carried out for all natural areas in the Netherlands, including the Natura 2000 sites. In total 80 species were included in the evaluation, wintering birds (63) were excluded (for a species list see Annex 2).

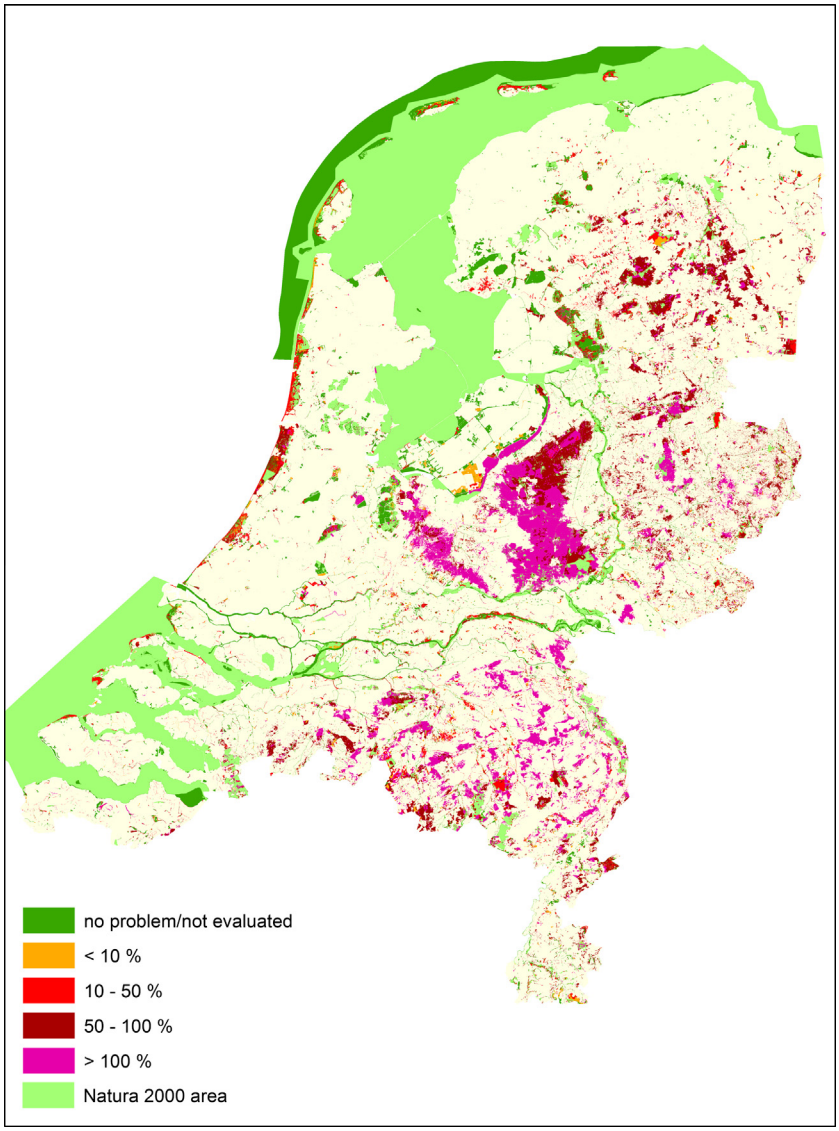

Fig. 1. Exceedance of the critical load (CL) for nitrogen deposition for natural areas in the Netherlands based on habitat types. Exceedances are given as percentage of the CL and specific for each habitat type present at a site (for the CL per habitat type see Annex 1).

2.7. Combined maps

To evaluate if the Netherlands fulfils its targets for the four pressures, eutrophication, acidification, desiccation and spatial cohesion, the maps per abiotic parameter and the spatial cohesion map were combined by counting the number of pressures causing a problem per examined site. To determine the possible contribution of natural areas to the conservation status of habitat types and species outside N2000, the analysis was carried out for all natural sites.

3. Results

3.1. Eutrophication

Nitrogen deposition in the Netherlands exceeds the critical load in approximately 70% of the examined surface area (Annex 3). Although the exceedance occurs all over The Netherlands, there are some areas without exceedance e.g. in the clay areas in the west of the country (Fig. 1). The exceedance is highest in the south-eastern parts of the Netherlands on sandy soils, which have the highest density of pig and poultry farming, major emitters of nitrogen and acid compounds. In some areas, the critical load is exceeded for almost all habitat types (Fig. 1). The exception is the 'Spartina swards' (H1320). Six out of 67 examined types show only marginal exceedances, 'Salicornia and other annuals colonizing mud and sand' (H1310), 'Atlantic salt meadows' (H1330), 'Embryonic shifting dunes' (H2110), 'Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation' (H3150), 'Water courses of plain to montane levels with the *Ranunculion fluitantis* and Callitricho-Batrachion vegetation' (large Potamogeton, H3260B) and 'Rivers with muddy banks with *Chenopodion rubri* p.p. and Bidention p.p. vegetation' (H3270). These are all habitat types of nutrient rich wetlands (Wamelink et al., 2011). For 26 habitat types the CL is exceeded on more than 95% of the surface area in the Netherlands. These types are, for example, fens (e.g. H7210) and nutrient poor waters (e.g. H3110), inland heaths (H4030) and free blown sand (H2330), *Juniperus communis* formations (H5130), nutrient poor grasslands (e.g. H6230), raised bogs (H7110) and transitions mires (H7140) and beech and old forest stands (e.g. H9160).

3.2. Desiccation

For the 30 groundwater dependent habitat types (out of 63) approximately 91% of the surface area suffers from desiccation. Similar to nitrogen deposition, the exceedance of the minimum mean spring groundwater table occurs all over the country (Fig. 2). When looking at the habitat types only for one type the exceedance is less than 50% of the surface area, Lowland hay meadows (*Alopecurus* type, H6510B) and for three more types the exceedance covers less than 75% of the area, Dunes with *Salix repens ssp. argentea* (Salicion arenariae, H2170), Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli (sand district, H9160A) and Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alnion incanae, H91E0C) (Annex 3). Twenty-one out of the thirty groundwater dependent habitat types show desiccation effects for almost their complete surface area (>95%). The total surface area is just over 170,000 ha, i.e. just over one-fifth of the total terrestrial natural areas in the Netherlands.

3.3. Acidification

Approximately 40% of the examined surface area has an estimated soil pH that is below the minimum for the habitat type at that site; i.e., they suffer from acidification. Most of the acidified areas are located on the inland sandy soils (Fig. 3 and Annex 3). In the coastal dune area the pH is at most places high enough for the designated habitat types. Of the 55 examined Habitats only three types show major problems regarding the soil pH, the fixed coastal dunes with herbaceous vegetation ("grey dunes"; chalk rich; H2130A), natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation (H3150) and rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi (H6110), of which the latter only cover small areas in the Netherlands. Most inland forests have estimated pH values slightly below their lower limit over larger parts of their areas, as do the Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia; H6210) and the young dunes (H2120).

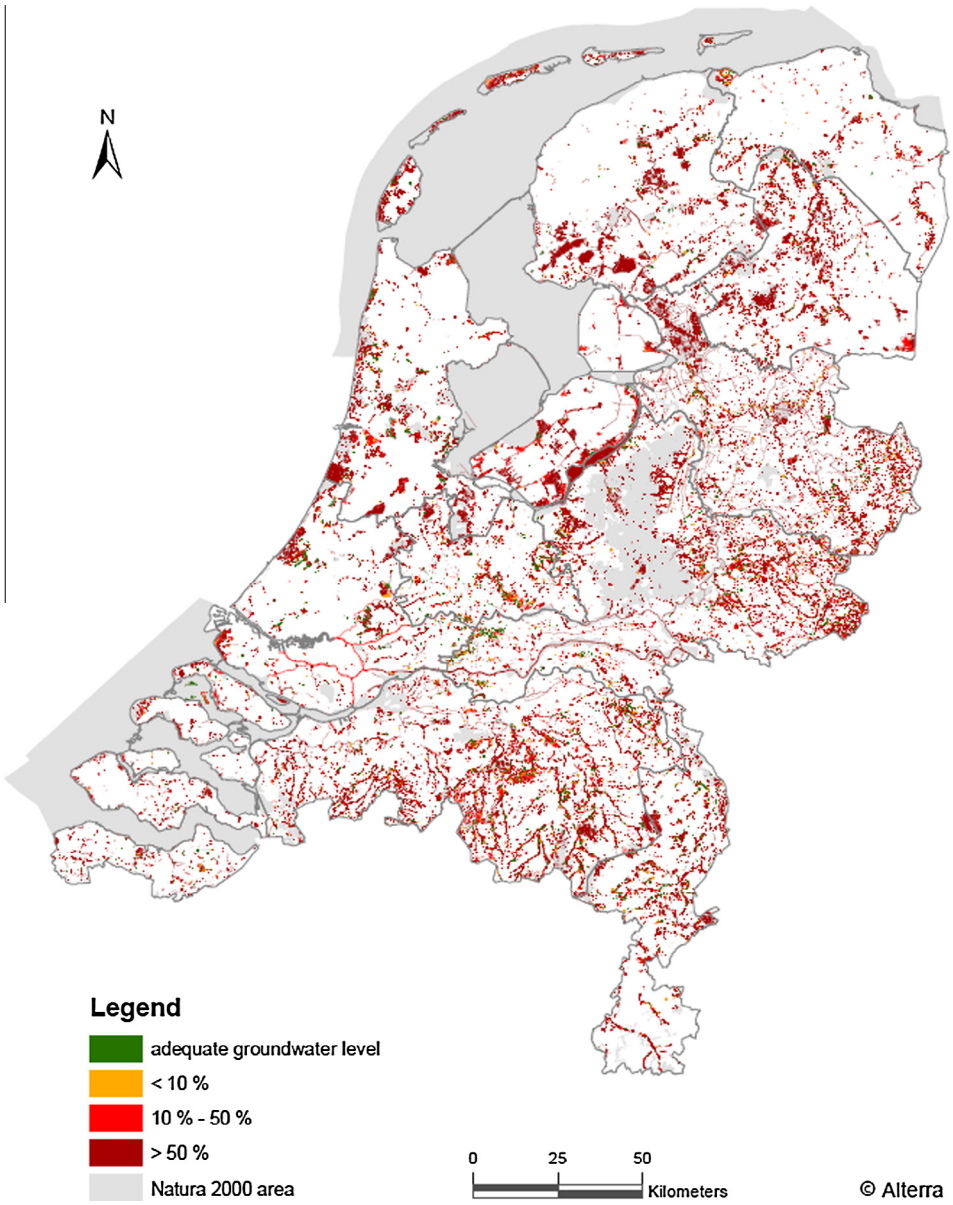

Fig. 2. Exceedance of the spring groundwater table for natural areas based on habitat types in the Netherlands. Only groundwater dependent habitat types are given (for the minimum spring groundwater table per habitat type see Annex 1).

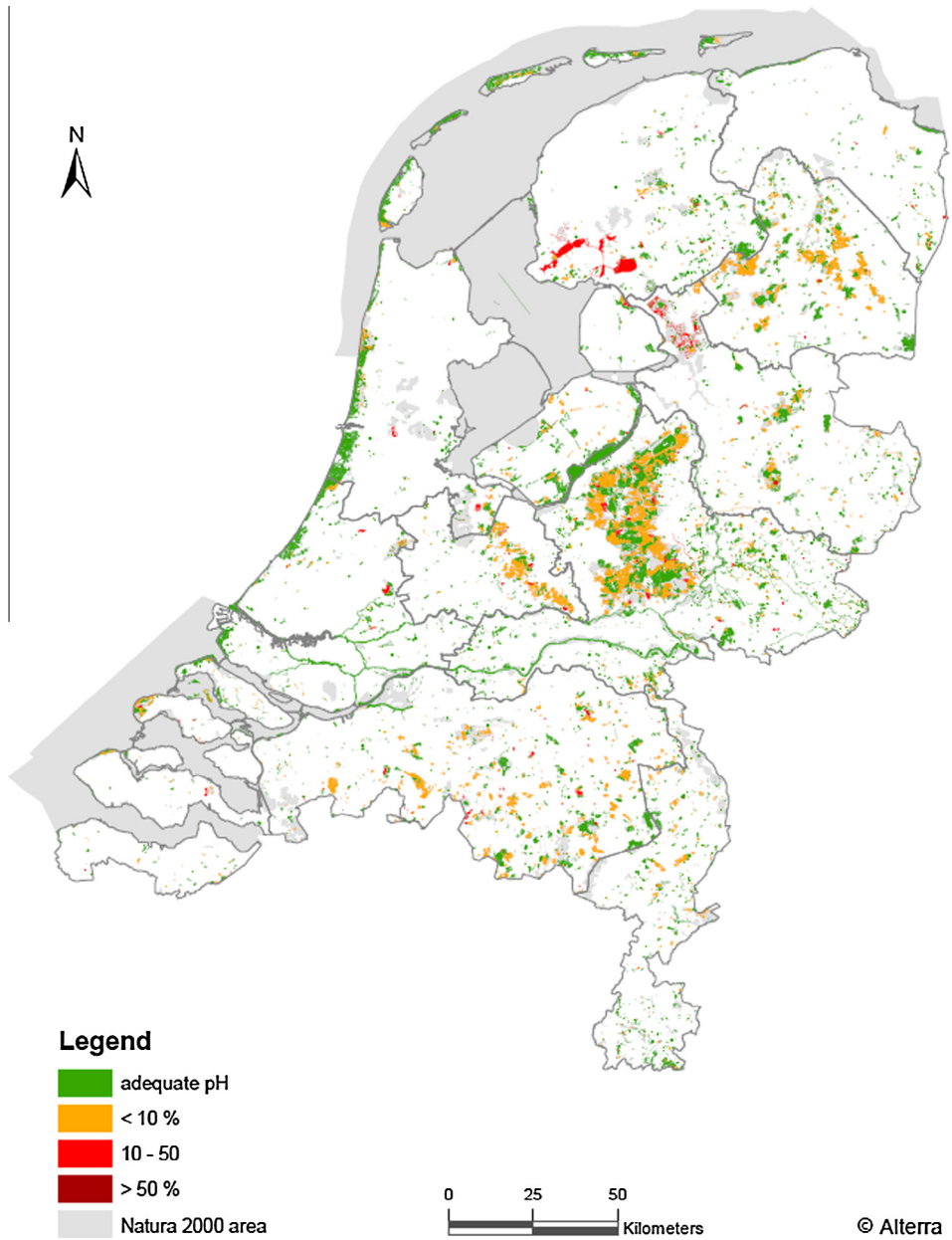

Fig. 3. Natural areas with too low soil acidity (soil pH) based on habitat types in the Netherlands. Exceedances are given as percentage of the minimum pH of the habitat type present in the area (for the minimum pH per habitat type see Annex1).

3.4. Spatial cohesion

The spatial cohesion was calculated per species separately and then aggregated into one map. As an example we give the results for the stag beetle (*Lucanus cervus*, Fig. 4). Based on populations with known distribution the spatial cohesion was calculated, giving a large non-fragmented area in the centre of the Netherlands resulting in a viable population and two populations with a non-viable network, i.e. the network is not large enough to hold a stable population for more than one hundred years, in the surrounding area, that are isolated due to lack of habitat and barriers (Fig. 5). In the very South of the Netherlands a fourth non-viable population is present. The maps of spatial cohesion for all evaluated species show a good cohesion in most areas (Fig. 5), but spatial cohesion problems occur for up to six species. The problem areas are situated all over the country and are not only present in the small scale landscapes in the east, but also in the larger areas in the middle.

3.5. Combined pressures

The four investigated pressures were combined and the spatial result is given in Fig. 6. About two-third of the examined sites is suffering from at least one of the four pressures, the dominant pressure being nitrogen deposition, often in combination with desiccation or acidification (Annex 5). Combinations of more than two pressures are relatively scarce. Unaffected natural areas can be found all over the Netherlands and for many different habitat types. None affected areas make up the largest category, followed by areas where the CL is exceeded and areas where the CL and the MSL are exceeded. Almost all areas where the MSL is exceeded the CL is also exceeded.

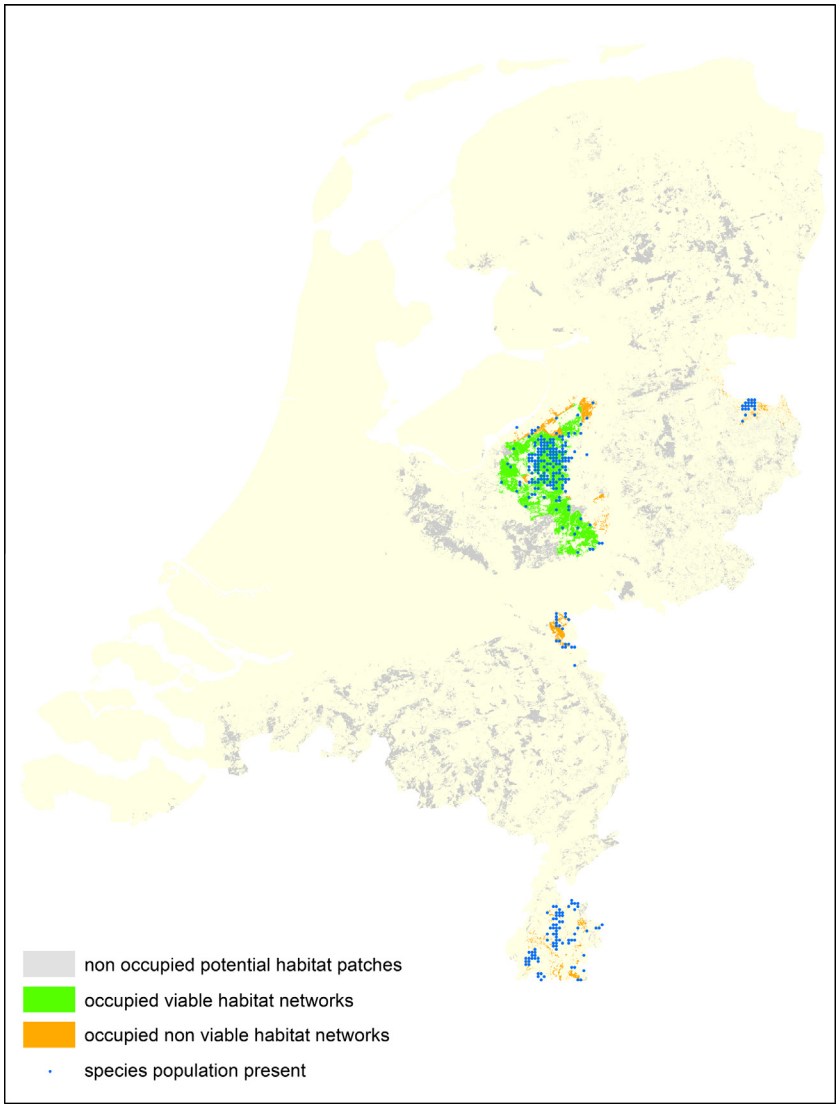

Fig. 4. Spatial cohesion for the stag beetle (*Lucanus cervus*). Spatial cohesion is only calculated for habitat where the species is present; potential habitat and networks are excluded.

4. Discussion

The results clearly show that there are still major bottlenecks in the spatial and environmental conditions for species and natural areas including the Natura 2000 network before set targets are met for all species and habitat types in the Netherlands as stated under the Birds and Habitats Directives. This is the case for all investigated parameters, i.e. eutrophication, acidification, desiccation and spatial cohesion. The biggest bottlenecks are related to nitrogen deposition and desiccation. This agrees with earlier results showing high nitrogen deposition levels for the Netherlands (Hettelingh et al., 2009). Desiccation effects of this magnitude were also reported by Aggenbach et al. (2007). They stated that for 96% of the groundwater dependent Natura 2000 sites hydrological measures were necessary to bring them in a favourable conservation status. The acidification effects are nowadays only minor compared to eutrophication and desiccation. This shows that measures taken to reduce sulphur emission did pay off (Menza and Seip, 2004; Wright et al., 2005).

Spatial cohesion also shows bottlenecks all over the country, though less severe than the abiotic problems. For most of the areas which lack spatial cohesion, this is the case for mostly one to three species, with a maximum of six species (Fig. 7). The spatial cohesion was only evaluated for natural areas inside the Netherlands. However, especially at the borders with Germany and Belgium, the cohesion may be underestimated due to the national limitation. See for instance our example for the stag beetle (Fig. 4). Natural areas in Germany and Belgium could lead to larger and better networks of habitats. Opermanis et al. (2012) showed that the connectivity for border crossing Natura 2000 sites was rather good. This indicates that we indeed underestimate the connectivity in regions near the borders of the Netherlands. So by leaving out the bordering countries we overestimate the spatial cohesion problems, especially, but not only, in the border area.

To solve these bottlenecks further development of the national ecological network (NEN) but also the international ecological network is recommended (Pan European Ecological Network, PEEN; Jongman et al., 2010). Overpasses for highways and railways as already built at many places in the Netherlands will help to defragment the landscape (Clevenger and Waltho, 2005; Corlatti et al., 2009), at least for animals and should in respect of our findings be continued. However, this will connect only natural areas on a short distance, also connection over long distances should be made, e.g. by developing new natural areas as stepping stones or

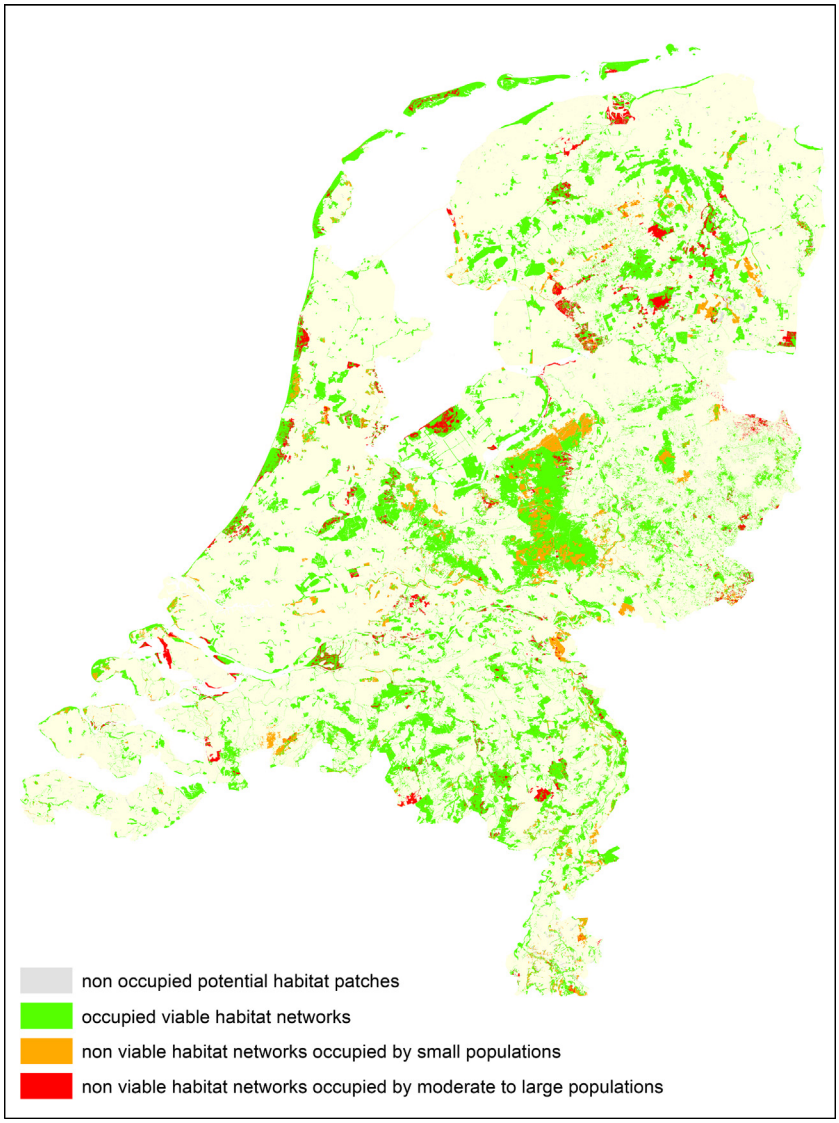

Fig. 5. Spatial cohesion for all evaluated appendix II and IV, including all breeding birds designated under the Habitats and Birds Directives (92/43/EEC) in the Netherlands. Given are the bottlenecks and the number of species with insufficient spatial cohesion. Potential but non-occupied habitat is excluded from the results.

corridors (Vos et al., 2008). Gaps between natural areas may also be closed in agricultural areas by applying sustainable farming. This would mean that farmers should use fewer fertilizers and pesticides on, part of, their land. Borders of arable fields could benefit from this and may be able to sustain more natural species. Also parts of the land could, temporary, be taken out of production and be used as stepping stones or corridors by plants and animals. Also linear elements as hedgerows and small streams could serve as green infrastructure in the agricultural landscape to improve connectivity between nature areas (Grashof-Bokdam et al., 2008; Schippers et al., 2009). The NEN connects the Natura 2000 sites spatially. Therefore, not only the ratified Natura 2000 sites were taken into account, but all other natural areas situated outside de Natura 2000 network in the Netherlands. This is especially important, because most of the species from the Birds and Habitats Directives are co-dependent on habitat that is present outside the Natura 2000 network. Following the definitions of EU directives and the need to report about the conservation status on the national level, habitats that occur outside the assigned areas of the Habitats Directive are included in the analysis.

When the above mentioned pressures are combined, about two third of the natural areas in the Netherlands suffer from at least one pressure. Most of the wet areas suffer from a combination of nitrogen deposition and desiccation, making them extra vulnerable, since desiccation often causes the mineralization of organic matter that comes available due to a lower groundwater table (Stevens et al., 2011). A lower groundwater table often leads to higher mineralization, especially in the peat districts, and thus nitrogen availability increases even more. Habitats will then suffer from nitrogen deposition and excessive mineralization on top of the desiccation. Less abiotic quality will also influence the spatial cohesion via a lower carrying capacity for the species investigated.

4.1. Uncertainties

In this project at several stages (spatial) data has been merged. We consequently used the most limiting factor as the qualifying factor, e.g. when more than one habitat type is present in one nature management unit the most vulnerable one was used in the calculations. This gives an overestimation of the problems when

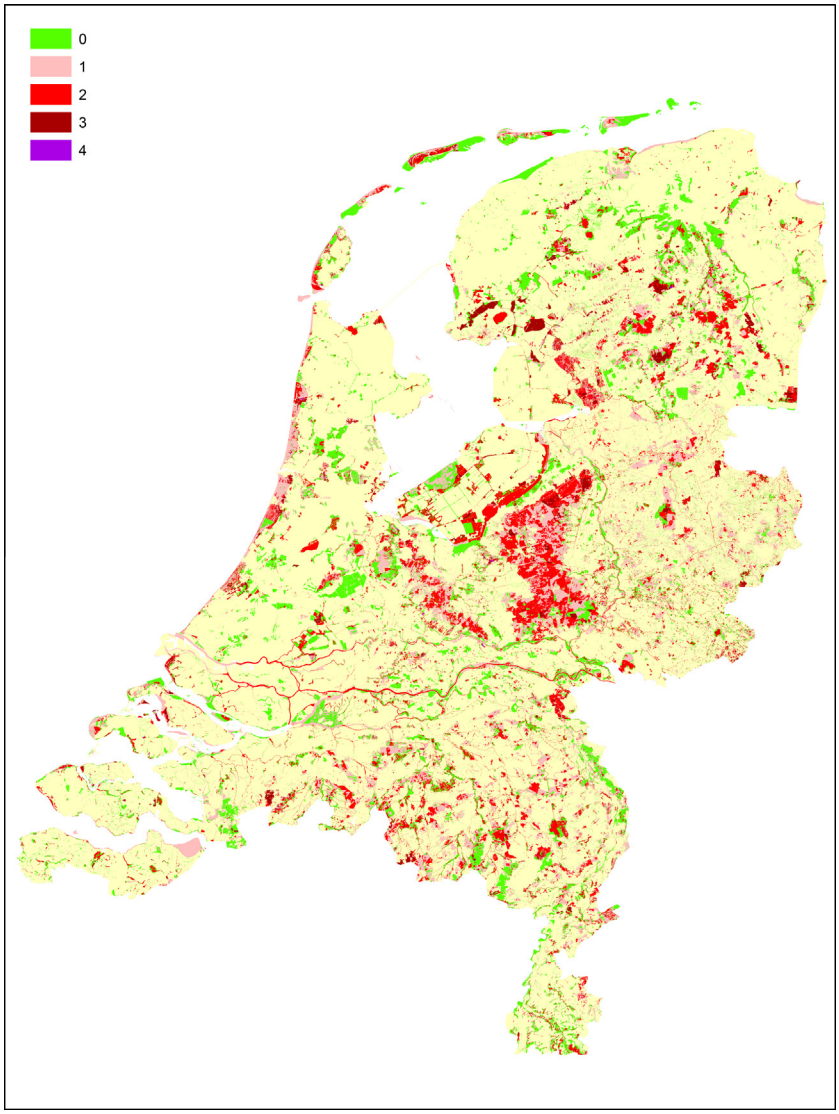

Fig. 6. Number of problems for natural areas in the Netherlands, based on the exceedances of the critical load, groundwater table, soil acidity and spatial cohesion.

looking at their total surface area. However, it is line with the principle that as long as no information is available to narrow down the problem; the most limiting/vulnerable type should be used for calculations and protection. The spatial conditions are now independently assessed from the abiotic quality. This could be combined, however this makes it more difficult to disentangle the separate effects of abiotic quality and spatial cohesion. Many multifunctional forests are now qualified as problematic. Most of them are forests for timber production with no or only marginally nature targets. This leads to an overestimation of the problems for multifunctional forests.

Although a lot of information about all the natural sites is available, it is not complete. This may lead to deviations and effects of abiotic circumstances and spatial cohesion may both be over and under estimated. The effect may be largest for acidification where for a large part of the surface area no information is available and smallest for the effects of nitrogen deposition, where the information is almost complete. Although information is available on the local scale, it should be carefully used only after validation with local information. On a national scale the results are more robust.

For the spatial cohesion an underestimation due to lack of information about semi natural areas is most likely. Semi natural areas may contribute to the spatial cohesion for some species, but often information is lacking. No environmental information pressures were used for the modelling of the spatial cohesion, which may lead to an overestimation of the population sizes and thus an underestimation of the spatial problems.

The soil pH values are based on derived indicative values for soil pH from plant species composition in small plots (relevés). Although, they can be estimated relatively quite accurate (Wamelink et al., 2005) it introduces uncertainty in the results. The relation between estimated and measured soil pH is around 60% (Wamelink et al., 2005), which is high for ecological studies, but still introduces uncertainty. Plant species are known to be able to survive unfavourable conditions, as long as they have established themselves (time lag); species are still present, while the (abiotic) conditions, such as soil pH, have already changed and became less favourable for them. If in the meantime no new plant species that are adapted to the new circumstances colonize the plot, or are available in the seed bank, the indication for soil pH based on the species presence will not change. Only after the arrival of new spe-

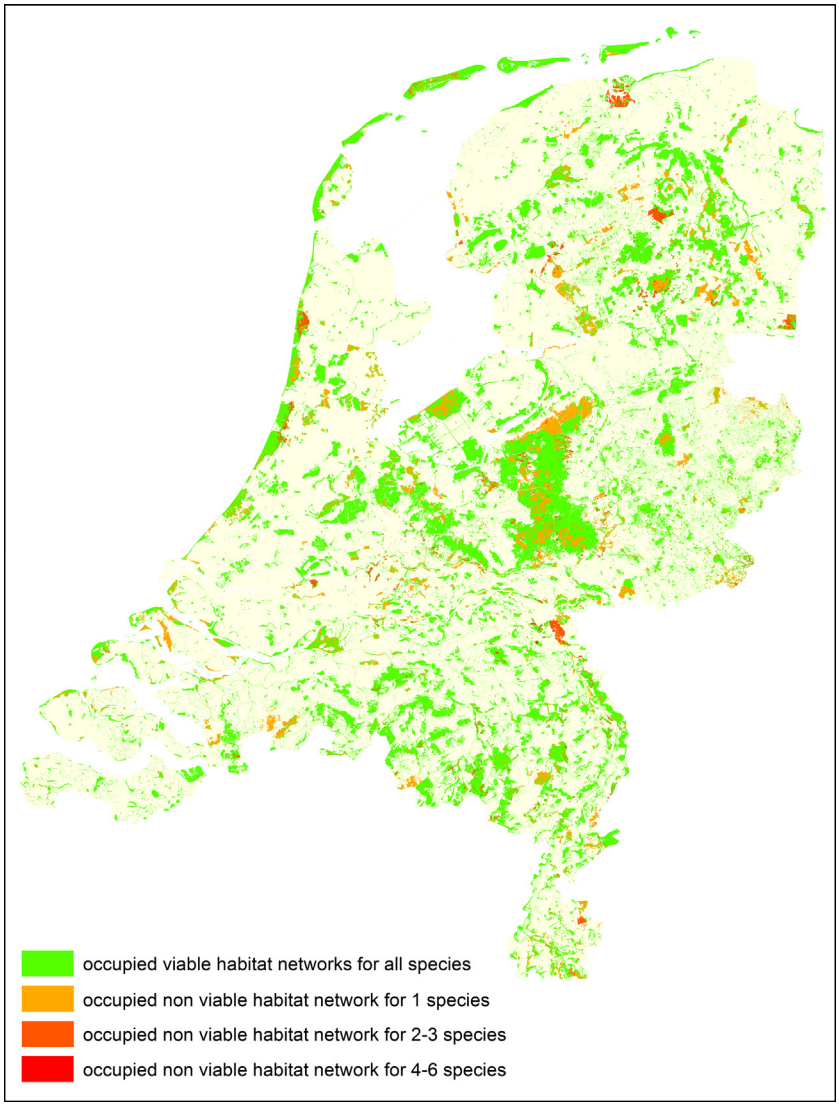

Fig. 7. Number of species with spatial problems.

cies or disappearance of species the change can be identified by the indicator values for soil pH. This not only plays a role in species indication, but even in the evaluation of the spatial cohesion, as was shown by Helm et al. (2006).

The habitat map used is a proxy based on nature management types. Some of these types are already present, but for others or parts of the designated area the quality still has to be developed. It is possible that some management types are too ambitious when present environmental conditions are taken into account. The opposite could also occur, though this is less likely. In general this will lead to an overestimation of the problems, especially for the abiotic parameters, including nitrogen deposition.

To conclude, this research has shown that environmental and spatial conditions are unfavourable to meet the biodiversity target set by the European Union for the Natura 2000 network, habitat types and species in the Netherlands. The Dutch government has to take extensive measures to improve those conditions. To fulfil the targets of Natura 2000 more mitigating measures together with measures at the sources of the pressures are necessary. This can partly be achieved by reducing the nitrogen output and thus deposition, since this appears to be the major pressure. However, a key solution may lie in sustainable farming, which needs a major transformation in European agricultural policy.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2013.05.012.

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