Modelling and Mapping the impacts of atmospheric deposition on plant species diversity in Europe

CCE Status Report 2014

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The Coordination Centre for Effects (CCE: www.wge-cce.org), located at RIVM, is the Programme Centre of the International Cooperative Programme on Modelling and Mapping (ICP M&M: www.icpmapping.org) of Critical Levels and Loads and Air Pollution Effects, Risks and Trends under the Working Group on Effects (WGE) of the Convention on Long-range Transboundary Air Pollution (LRTAP Convention: www.unece.org/env/lrtap/welcome.html).

The work reported here has been performed by order and for the account of the Directorate for Climate, Air Quality and Noise of the Dutch Ministry of Infrastructure and the Environment, for the account of the European Commission under the Seventh Framework Programme, Theme [ENV.2011.1.1.2-1], Grant agreement no. 282910 'Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems (ECLAIRE)', and for the account of (the Working Group on Effects within) the trust fund for the effect-oriented activities under the Convention on Long-range Transboundary Air Pollution.

Report no. 2014-0075
ISBN 978-90-6960-276-9

Acknowledgements

The methods and results presented in this report are the product of close collaboration within the Effects Programme of the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP), under its long-term strategy and work plan, involving many institutions and individuals throughout Europe. Participants in the Effects Programme and National Focal Centres of the International Co-operative Programme (ICP) on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends are acknowledged for their commitment and contributions to the work of the Coordination Centre for Effects (CCE).

In particular, the CCE wishes to thank:
- the Ministry of Infrastructure and the Environment, and its department of Climate, Air and Noise in particular, for their continued support;
- the Working Group on Effects and the Task Force of the ICP on Modelling and Mapping for their collaboration and assistance;
- the EMEP Meteorological Synthesizing Centres and the EMEP Centre for Integrated Assessment Modelling for their collaboration in the field of atmospheric dispersion and integrated assessment modelling;
- The European Seventh Framework Programme, Theme [ENV.2011.1.1.2-1], Grant agreement no. 282910 'Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems' (ECLAIRE).

Summary

The focus of this report is on progress made, by the ICP M&M, with the modelling and mapping of critical thresholds and dose-response relationships of air pollution effects on the diversity of plant species in Europe. The idea is to extend and complete the existing European critical loads database with critical thresholds for biodiversity, to meet the new requirements of the LRTAP Convention and the European Union for the support of European air pollution abatement policies, taking into account synergies with other international policy issues.

Chapter 1 describes the results of an assessment of the impacts of the emission reduction scenarios that have been developed and used in the context of recent European air pollution abatement policies, using data from the current European critical loads database held at the CCE. The area at risk of acidification in Europe improves from 6% (8% in Natura 2000 areas) in 2005 to 2% (2% in Natura 2000 areas) in 2020. For eutrophication these percentages are 63% (78% in Natura 2000 areas) and 55% (65% in Natura 2000 areas), respectively.

The extension of ICP M&M work to include biodiversity endpoints more specifically was initiated in 2007 when the Executive Body agreed at its 25th session to encourage the Working Group on Effects 'to increase its work on quantifying effects indicators, in particular for biodiversity. These should also be linked to the integrated assessment modelling activities' (ECE/EB.AIR/91, para. 31). This was confirmed in the Long-term Strategy of the Convention till 2020, which 'set a vision for the next 10 years and beyond to address the remaining issues from existing activities and to meet emerging challenges with the aim of delivering a sustainable optimal long-term balance between the effects of air pollution, climate change and biodiversity' (ECE/EB. AIR/2010/4, para. 6a).

In 2012 the Working Group on Effects decided that a Call for Data on 'no net loss of biodiversity' indicators be issued by the CCE with a deadline of March 2014 in order to assess tentative methodologies and national data that had been reviewed by the CCE and National Focal Centres under the ICP Modelling and Mapping at various yearly CCE workshops and Task Force meetings since 2007. The Call for Data also aimed at addressing the EU 2020 headline target of 'halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2010, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss' (EU[1], 2011, p.12, Target 2, Action 7). *Chapter 2* describes the result of this Call for Data on biodiversity indicators and calculations, to which ten countries responded. Seven of them applied dynamic modelling. Respondents to the call suggested that further technical and conceptual work was needed to arrive at a harmonised indicator of no net loss of biodiversity.

Meanwhile, work continued on the identification of relationships between nitrogen-sulphur deposition and biodiversity response on a regional (EUNIS) scale with a focus on 'areas of special protection' such as Natura 2000 areas in the EU. An important goal is to derive a harmonised metric from the submitted variables and indicators with the objective of quantifying 'no net loss of biodiversity' on a regional scale. This harmonised metric would allow comparisons of the state of biodiversity between regions and countries. Finally, the indicator should be easily applicable to European policy support in the context of integrated assessment modelling and the GAINS system[2]. The progress made in the development of a new indicator, i.e. the Habitat Suitability (HS) index, includes the establishment of a link between modelled soil chemistry and the occurrence probability of plant species on a European scale. A description of the methodology and data for the implementation of the HS index on a European scale is provided in *Chapters 3 and 4*. A modelling methodology for the assessment of the HS index as a measure of the occurrence probability of plant species is introduced. Initial simulations with this model reveal the need to improve information on European natural vegetation and the list of desired species.

[1] COM(2011) 244 final: http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7[1].pdf; see also http://biodiversity.europa.eu/bise/policy/eu-biodiversity-strategy.

[2] The GAINS system consists of a combination of hard-linked (embedded in the GAINS computer code) and soft-linked assessment options. The latter are also known as 'ex-post' assessments under the LRTAP Convention. A component of the FP7 ECLAIRE project also contributes to this task.

These chapters include elements that form the basis of the Call for Data 2014/15, which was issued in November 2014 in response to the request of the Working Group on Effects at its 33rd session (Geneva, 17–19 September 2014).

This report concludes with submissions by National Focal Centres describing the methods and data used for their submission to the 2012–14 Call for Data on 'no net loss of biodiversity' indicators.

Publiekssamenvatting

Gemodelleerde effecten van de neerslag van stikstof op de natuur

Als stikstof vanuit de lucht op de bodem terechtkomt, werkt dat als een voedingsstof. Door te veel stikstof kunnen bepaalde plantensoorten verdwijnen of juist gaan overheersen. In internationale politieke gremia is daarom de vraag gesteld bij welke hoeveelheid stikstof (stikstofoxides en ammoniak) in de lucht natuurgebieden intact blijven. Het internationale Coordination Centre for Effects (CCE) helpt deze vraag te beantwoorden door een Europese database te beheren en te analyseren waarin de limieten ('kritische belastingsgrenzen') per type natuurgebied staan weergegeven. Landen uit het CCE-netwerk leveren hiervoor informatie.

In de afgelopen jaren hebben de landen nieuwe methoden getest om de kritische belastingsgrenzen te bepalen. Deze methode is gericht op de biodiversiteit: er wordt een relatie gelegd tussen de planten die typerend zijn voor een bepaald soort vegetatie en de omstandigheden in de bodem waaronder deze planten optimaal gedijen. In acht landen is vooruitgang geboekt met de toepassing en kwantificering van deze methode. Het blijkt essentieel om informatie te hebben over de typerende plantensoorten, maar dat is nog niet van alle vegetatiesoorten gelukt. Bossen zijn nog problematisch.

Momenteel zijn er twee methoden in gebruik om de kritische belastingsgrens te bepalen: bij de ene wordt de toegestane neerslag van stikstof begrensd door de stikstofconcentratie in het bodemvocht (in de laag van de bodem waar de wortels zitten), bij de ander gebeurt dat op basis van geobserveerde effecten van stikstof depositie op de natuur. De nieuwe methode - gebaseerd op de biodiversiteit - is hierop een aanvulling. Vanaf komend jaar worden aan de landen data over de belastingsgrenzen voor alle drie de methoden gevraagd.

Het CCE informeert beleidsmakers over de effecten van luchtverontreiniging op verschillende ecosystemen en wat het rendement van maatregelen is. De stikstofdepositie neemt al jaren af, maar op veel plekken in Europa verliezen ecosystemen nog steeds aan diversiteit.

Contents

Part 1
Progress CCE

1 Exposure of ecosystems to acidification and eutrophication in Europe: an update of EEA-Core Set Indicator 005*

Jean-Paul Hettelingh, Maximilian Posch, Jaap Slootweg, Liesbeth Mathijssen

1.1 Introduction

This chapter focuses on the impacts of the exposure to acidification and eutrophication of European natural areas, as classified in the European Nature Information System (EUNIS; Davies and Moss, 1999). Areas where policies of special protection apply under the EU Habitat Directive (EC, 1992), i.e. Natura 2000 areas, are addressed as a specific receptor, sensitive to impacts of nitrogen (N) deposition in particular. In this chapter an update is provided of the Core Set Indicator 005 'Exposure of ecosystems to acidification, eutrophication and ozone' (CSI 005) by computing and mapping exceedances of the critical loads for acidification and eutrophication. The exceedance of ozone thresholds, also included in the CSI 005, is not dealt with in this chapter.

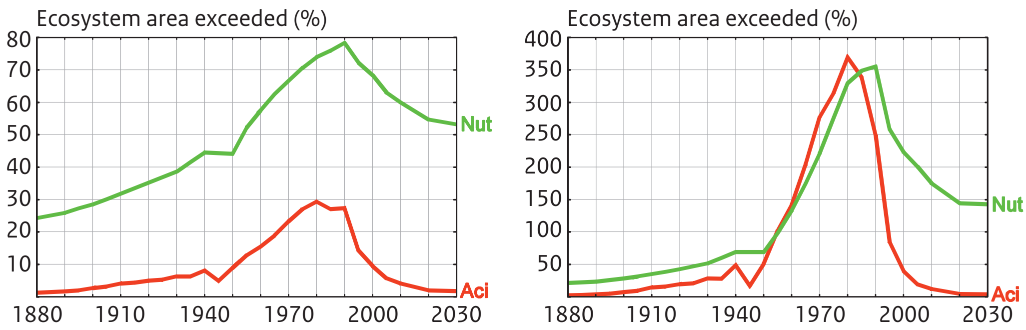
Results are based on the 2013[1] state of knowledge, with modelled deposition data from EMEP MSC-W[2] and critical loads from the Coordination Centre for Effects (CCE). The EMEP model was recently revised (Simpson et al. 2012) to cover a 0.50°×0.25° (about 28×28 km^2) longitude-latitude grid. In anticipation of the increased resolution of the EMEP model, National Focal Centres (NFCs) under the ICP Modelling & Mapping responded to a CCE call for data in 2010-2012 to update the scale (and protection requirements as appropriate) of their contribution to the European critical load database (see Posch et al. 2012). These new methods and data have enabled the re-calculation of exceedances and areas at risk caused by depositions (MSC-W 2013) from emissions under the revised Gothenburg Protocol, the Current Legislation scenario (GP-CLE) in 2020, and the Maximum Feasible Reduction (MFR) scenario in 2030. These emission scenarios were provided by the Centre for Integrated Assessment

* This chapter bears on work done by the CCE for Technical Report 11/2014 of the European Environment Agency, EEA (2014).

[1] Selected results of the different model and data versions used to support the revision of the Gothenburg Protocol can be found in the Annex to this chapter.

[2] Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP), Meteorological Synthesizing Centre West (MSC-W) at the Norwegian Meteorological Institute.

Figure 1.1: The temporal development since 1880 of the area at risk (in %; left) and magnitude (in eq $ha^{-1}yr^{-1}$; right) of exceedance (AAE) of critical loads for acidification (red) and of nutrient nitrogen (green) using the GP-CLE scenario depositions from 2010 onwards.



Modelling (CIAM) of the Task Force on Integrated Assessment Modelling (TFIAM) of EMEP.

Emissions in the base year 2005 and projected emissions according to the GP-CLE scenario in 2020 have been developed under the revised Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (UNECE 2012a,b) to the LRTAP Convention. Historic emissions since 1880, used in this chapter to illustrate the long-term trend of the CSI 005, have been derived from Schöpp *et al.* (2003). The historical CSI 005 trends are based on deposition patterns following different versions of the EMEP model (e.g. Hettelingh *et al.* 2013), and the most recent critical load database (Posch *et al.* 2012). The 1980–2000 depositions were downloaded from the EMEP website (www.emep.int/mscw) and they were calculated on the 50×50 km^2 EMEP grid. For the years 2010-2030 depositions are based on EMEP calculations with a newer model version on the 0.50°×0.25° longitude-latitude grid. This chapter partly bears on work performed under the LRTAP Convention (ICP M&M 2013; WGE 2013a,b). In this chapter the location and trends of critical load exceedances, i.e. the CSI 005 indicator, are provided until 2030.

Furthermore, results of a tentative assessment of a selected indicator for biodiversity, i.e. species richness in grasslands, are presented. These biodiversity-related results are based on the tentative application of a N dose-response relationship (Stevens et al. 2010a,b) on specific European grasslands that are distinguished according to the European Nature Information System (EUNIS[3]), i.e. classes E1, E2 and E3. This use of the dose-response relationship can illustrate species richness — for any N emission scenario — as a percentage compared with a hypothesized 100% species richness at zero N deposition. It should be noted that the assessment results of this biodiversity indicator are uncertainty prone.

1.2 Trends of acidification and eutrophication since 1880

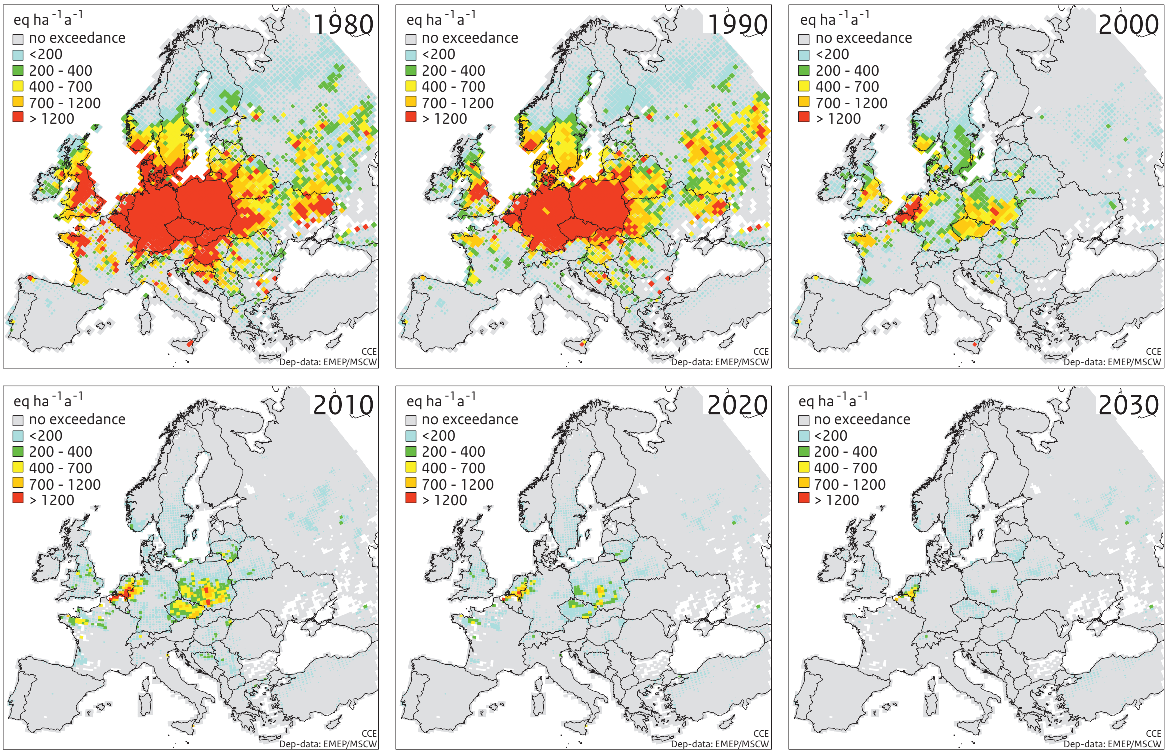
New methods and data as described above have enabled the revision of calculated exceedances and areas at risk caused by depositions (MSC-W 2013) due to a combination of the revised Gothenburg Protocol and Current Legislation scenario (GP-CLE) provided by the CIAM at the International Institute for Applied Systems Analysis.

Exposure in a natural area for which critical loads are available is calculated as the Average Accumulated Exceedance (AAE; Posch et al. 2001), i.e. area-weighted average of the exceedance of all critical loads in an area. The AAE can be computed for any region, i.e. for all natural areas in a country, for any class of natural areas (EUNIS classification) or for a subset of natural areas (e.g. Natura 2000 areas). Figure 1.1 illustrates the European ecosystem area, where critical loads are exceeded, and the AAE based on emission trends since 1880 (Schöpp et al. 2003), deposition patterns following different versions of the EMEP model (e.g. Hettelingh et al. 2013) and the most recent critical load database (Posch et al. 2012).

Assuming the GP-CLE scenario to be implemented as of 2010, Figure 1.1 shows that both the percentage of the European ecosystem area of which critical loads for acidification are exceeded, i.e. the area at risk of

[3] See http://eunis.eea.europa.eu/about.jsp.

Figure 1.2. Average Accumulated Exceedance (AAE in eq ha^{-1}yr^{-1}) of critical loads for acidification in 1980 (top left), 1990 (top centre), 2000 (top right), 2010 (bottom left), 2020 under the revised Gothenburg protocol (GP-CLE scenario) emission reduction agreements (bottom centre), and in 2030 under Maximum Feasible Reductions (bottom right).



acidification (%; left), as well as its AAE (eq ha^{-1}yr^{-1}; right) in 2030 are similar to 1880, i.e. about 2% and 5 eq ha^{-1}yr^{-1}, respectively. The peaks of the acidified area and AAE occur in 1980.
Figure 1.1. also illustrates that areas where critical loads of nutrient nitrogen are exceeded, continue to remain a serious issue under GP-CLE emissions. Eutrophication affects about 55% (54% in the EU28) of the European ecosystem area in year 2020 (target year for the Revised Gothenburg Protocol) with an AAE of about 144 eq ha^{-1}yr^{-1} (159 eq ha^{-1}yr^{-1} in the EU28). In 2030, assuming a further implementation of GP-CLE abatement after 2020, the area at risk of eutrophication is slightly lower, i.e. 53% (51% in the EU28). Note that the European area at risk of eutrophication has increased in comparison to computations made with “old” (EMEP and critical loads) methods and data available for in support of the negotiations for the revised Gothenburg protocol, i.e. 42% with an AAE of 109 eq ha^{-1}yr^{-1} on the EMEP resolution of 50×50 km^2 (Reis et al. 2012; see also Table A.2 in the Annex to this chapter).

Finally it can be noted from Figure 1.1, that computed eutrophication already existed in 1880. The area at risk then is already exceeding 26%, which is likely to be caused by emissions of reduced N in particular (Kopáček and Posch, 2011). The peaks of eutro-phication come a decade later than acidification, due to the fact that policies focussed on sulphur reduction and not on curbing N emissions. N emission reduction seemed less urgent at the time and started later.

1.3 Maps and Tables of acidification and eutrophication since 1980

In this section both maps and country tables of the CSI 005 indicator are provided for acidity and eutrophication. The CSI 005 indicator (exposure) is characterised by both the magnitude (AAE; eq ha^{-1}yr^{-1}) as well as area (% of ecosystems) of critical load exceedance. The AAE is given for all ecosystem areas in Europe and for Natura 2000 areas in the EU28. The area at risk is expressed in this chapter as the percentage of the ecosystem area in a country where deposition exceeds critical loads. Results in the maps and tables in the following section are based on the GP-CLE and MFR scenarios for 2020 and 2030, respectively.

1.3.1 CSI 005 for acidification

Figure 1.2 shows the exposure and area at risk in European countries in the EMEP domain as of 1980. The success of the reduction of acidifying emissions since 1980 is clearly demonstrated by a reduction of

Table 1.1. Ecosystems at risk of acidification (% of total ecosystem area) and the exceedance (AAE in eq $ha^{-1}yr^{-1}$) in each country between 1980 and 2030.

Acidification	1980		1990		2000		2005		2010		GP-CLE 2020		MFR 2030	
	Area	AAE	Area	AAE	Area	AAE	Area	AAE	Area	AAE	Area	AAE	Area	AAE
Albania	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Armenia	7	27	7	25	0	0	0	0	0	0	0	0	0	0
Austria	43	590	18	100	1	2	1	1	0	0	0	0	0	0
Azerbaijan	2	7	10	53	0	0	1	1	1	1	1	2	1	1
Belarus	76	736	73	671	18	52	15	38	12	28	6	10	5	7
Belgium	99	3411	95	1271	49	227	13	62	7	20	1	3	0	0
Bosnia-Herzegovina	31	528	25	386	16	90	12	61	10	41	2	1	1	0
Bulgaria	18	212	10	97	0	0	0	0	0	0	0	0	0	0
Croatia	35	442	11	98	4	26	5	32	4	17	2	3	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	100	5123	100	3681	95	763	85	546	75	343	50	123	11	13
Denmark	96	1942	86	1066	49	317	36	112	20	26	1	2	0	0
Estonia	26	134	22	93	0	1	0	0	0	0	0	0	0	0
Finland	34	69	24	32	1	0	0	0	0	0	0	0	0	0
France	24	322	20	122	12	43	10	39	7	13	3	3	0	0
Georgia	13	47	11	28	0	0	3	4	3	4	4	7	3	4
Germany	95	4238	93	2299	47	230	28	89	18	47	5	13	0	1
Greece	10	65	7	43	2	7	3	19	2	9	1	1	0	0
Hungary	73	1898	55	780	24	105	22	90	8	38	5	11	1	1
Iceland	18	12	22	19	7	3	8	5	4	1	3	1	7	7
Ireland	33	153	19	63	14	38	3	3	0	0	0	0	0	0
Italy	18	219	12	77	3	12	1	4	0	1	0	1	0	0
Latvia	46	458	44	431	21	38	14	23	9	13	3	3	1	0
Lithuania	77	1123	71	1024	37	211	34	170	34	154	30	86	26	36
Luxembourg	86	1995	59	725	18	187	14	102	13	80	12	32	0	0
Macedonia, FYR	19	120	18	96	3	6	11	39	6	12	0	0	0	0
Moldova	33	404	30	160	1	2	1	2	0	0	0	0	0	0
Netherlands	87	6171	86	3687	82	1739	77	1192	74	864	63	518	52	321
Norway	35	215	37	219	21	76	8	13	5	6	2	1	2	1
Poland	100	3175	100	2451	65	419	46	243	43	217	24	74	5	7
Portugal	4	19	4	14	4	15	2	3	1	2	0	1	0	0
Romania	45	346	37	275	4	16	3	11	1	3	0	0	0	0
Russia	22	81	23	92	2	3	2	2	1	1	0	0	0	0
Serbia & Mont.	39	388	32	253	12	28	17	52	13	30	0	0	0	0
Slovakia	86	2471	83	1573	21	134	10	45	6	24	3	6	0	0
Slovenia	35	609	23	190	3	9	2	5	0	1	0	0	0	0
Spain	3	28	3	16	1	6	1	4	0	0	0	0	0	0
Sweden	59	366	59	311	36	107	12	18	9	11	6	4	5	3
Switzerland	49	700	26	191	7	29	12	52	9	32	5	18	3	12
Turkey	1	3	1	3	1	1	1	2	1	3	1	3	1	3
Ukraine	73	859	62	579	4	10	2	4	1	2	0	0	0	0
United Kingdom	76	774	53	323	26	115	14	37	7	17	3	6	1	1
EU28[1]	**43**	**758**	**37**	**464**	**18**	**82**	**10**	**39**	**7**	**26**	**4**	**9**	**2**	**3**
Europe[2]	**30**	**370**	**28**	**251**	**10**	**40**	**6**	**19**	**4**	**12**	**2**	**5**	**1**	**2**

[1]The 28 countries of the European Union

[2] European Parties under --> to the LRTAP Convention for which critical loads data are available.

the area with exceedances of, e.g., more than 1200 eq ha^{-1}yr^{-1} (red shading) between 1980 and 2030. The reduction of both the area at risk as well as of the magnitude of the exceedance of critical loads for acidification is confirmed in Table 1.1. The European area at risk of acidification is reduced from 30% (43% in the EU28) in 1980 to 2% in 2020 (4% in the EU28). Finally, in 2030 under MFR, only 1% of the ecosystems is computed to have an exceedance of critical loads for acidification.

As is shown in Table 1.2 the percentages do not significantly increase if the focus is on Natura 2000 areas. In Table 1.2 results are shown for the revised Gothenburg Protocol in the base year 2005, in 2010 and in the Protocol target year 2020. Application of MFR is shown for 2030. In 2005 the ecosystem area at risk (all EUNIS classes) in the EU28 is 10% (Table 1.1), while the percentage of Natura 2000 areas at risk in that year is 8% (Table 1.2). In 2020 the percentage Natura2000 areas at risk of acidification

Table 1.2. The Natura 2000 area (%) at risk of acidification and the exceedance (AAE in eq ha^{-1}yr^{-1}) in the EU28 countries between 2005 and 2030.

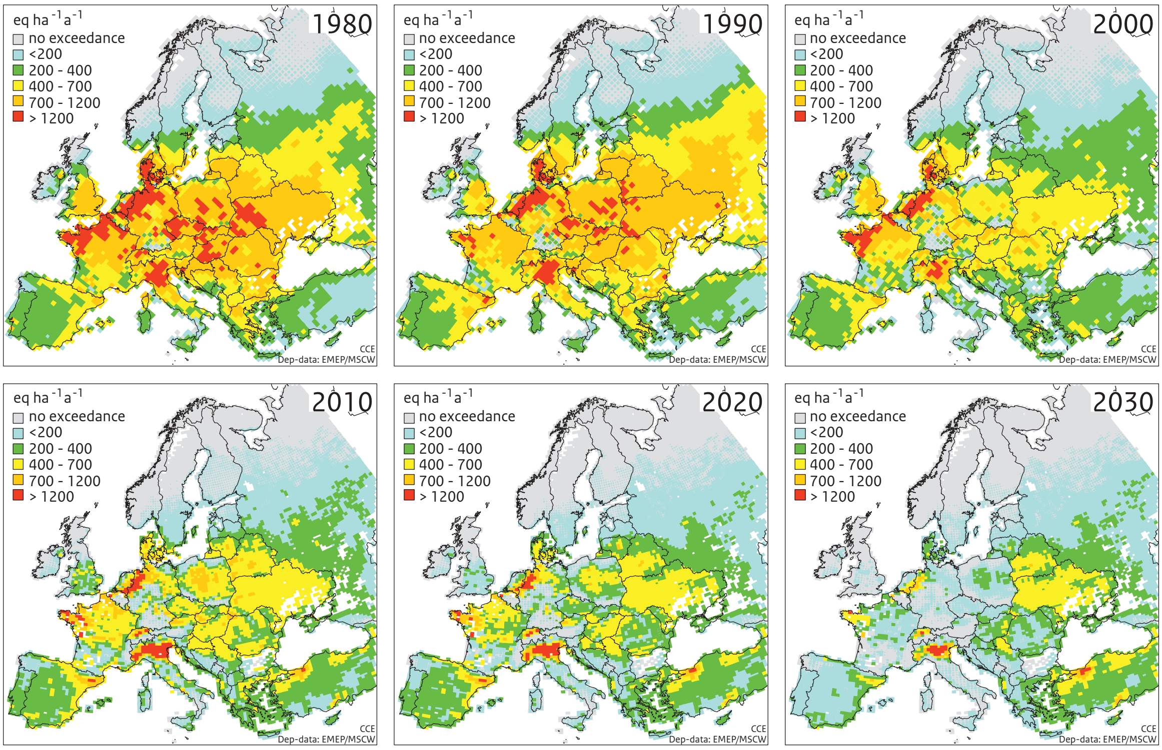
Acidification	2005		2010		GP-CLE2020		MFR2030	
	Area	AAE	Area	AAE	Area	AAE	Area	AAE
Austria[a]	–	–	–	–	–	–	–	–
Belgium[a]	–	–	–	–	–	–	–	–
Bulgaria[a]	–	–	–	–	–	–	–	–
Croatia[b]	–	–	–	–	–	–	–	–
Cyprus[c]	0	0	0	0	0	0	0	0
Czech Rep.	78	479	65	300	41	107	10	11
Denmark[c]	23	67	12	19	1	1	0	0
Estonia[c]	0	0	0	0	0	0	0	0
Finland[c]	0	0	0	0	0	0	0	0
France	10	40	7	13	3	3	0	0
Germany	27	79	16	40	4	11	0	0
Greece[c]	5	23	3	10	1	2	0	0
Hungary[c]	15	43	3	11	1	3	0	0
Ireland	2	5	2	3	2	1	0	1
Italy	0	1	0	0	0	0	0	0
Latvia[c]	14	24	9	14	4	5	3	1
Lithuania[c]	41	192	40	170	35	90	30	33
Luxembourg[c]	28	206	27	164	25	65	1	1
Malta[b]	–	–	–	–	–	–	–	–
Netherlands	76	1.046	73	732	62	401	48	223
Poland[a]	–	–	–	–	–	–	–	–
Portugal[c]	2	5	1	3	1	2	1	1
Romania[c]	3	13	1	4	0	0	0	0
Slovakia[c]	13	56	8	30	3	6	0	0
Slovenia	2	5	1	1	0	0	0	0
Spain[c]	1	2	0	0	0	0	0	0
Sweden	12	16	9	10	5	3	5	2
United Kingdom[a]	–	–	–	–	–	–	–	–
EU28	**8**	**32**	**5**	**16**	**2**	**6**	**1**	**2**

[a]NFC submittd critical load, but did not distinguish Natura 2000 areas.

[b]No information on Natura 2000 areas (yet).

[c]NFC did not submit critical loads (CCE background database used).

Figure 1.3 Average Accumulated Exceedance (AAE in eq ha^{-1} yr^{-1}) of critical loads for eutrophication are exceeded by N deposition between 1980 (top left), GP-CLE 2020 (bottom centre) and MFR 2030 (bottom right).



in the EU28 is 2%, which does not change in 2030 under MFR. Compared to 2005 the protection of Natura 2000 areas against acidification increases by 75% and 87% in 2020 and 2030, respectively.

1.3.2 CSI 005 for eutrophication

Figure 1.3 shows the exposure to eutrophication (AAE in eq $ha^{-1}yr^{-1}$) , and ecosystem area (all EUNIS classes) at risk (%) in Europe as of 1980 to 2020 under GP-CLE and 2030 under MFR.

The trend of areas in Europe between 1980 and 2020 (GP-CLE) and 2030 (MFR) where critical loads for eutrophication are exceeded confirms the continued stress to European ecosystems, in Central Europe in particular (Figure 1.3). The broad Central European area of high exceedances in 1980 (red shading) is markedly reduced in 2020 under current legislation, but still occurs in western France and the border areas between the Netherlands, Belgium and Germany, as well as in northern Italy. These areas at relatively high risk are further reduced when N emissions are mitigated due to the application of maximal feasible reduction techniques in 2030.

The downward trend since 1980 of the area at risk of eutrophication is confirmed in Table 1.3. Since 1980 the area at risk of excessive N deposition has decreased from 75% to 55% in 2020 under the revised Gothenburg Protocol. The area at risk is reduced to about 49% when maximum feasible reductions are applied. The area at risk of eutrophication in the EU28 decreases from 80% in 1980 to 67% in 2005 and further to 40% in 2030 when MFR would be applied.

Note, that with the 'old' methods and data used to support the revision of the Gothenburg (Reis et al. 2012) the area at risk of eutrophication in the EU27 was computed to be higher than with the current methodology and data, i.e. 73% in 2005 and 62% in 2020 (see also Table A.2 in the Annex to this chapter).
However, it turns out that the risk of eutrophication is significantly higher when computed for Natura 2000 areas (Table 1.4). In 2005 and 2020 the area at risk of Natura 2000 areas is computed to become 78% and 65% respectively. The risk of eutrophication in Natura 2000 areas in 2030 is reduced to 47% under MFR.

Table 1.3: Areas at risk (%) of eutrophication and the Average Accumulated Exceedance (AAE in eq $ha^{-1}yr^{-1}$) from 1980 to 2030 for all EUNIS classes. The exceedances in 2020 and 2030 are computed according to the GP-CLE and MFR scenario, respectively.

Eutrophication	1980		1990		2000		2005		2010		GP-CLE 2020		MFR 2030	
	Area	AAE	Area	AAE	Area	AAE	Area	AAE	Area	AAE	Area	AAE	Area	AAE
Albania	100	474	100	465	100	374	92	289	87	241	81	218	75	191
Armenia	99	456	99	571	97	315	100	383	100	414	100	455	100	442
Austria	100	749	100	675	99	411	81	316	70	230	51	134	16	19
Azerbaijan	97	332	100	515	95	256	100	321	100	350	100	397	100	356
Belarus	100	730	100	932	100	423	100	460	100	466	100	397	100	369
Belgium	74	289	50	95	37	61	4	7	2	3	1	1	0	0
Bosnia &Herzegovina	87	500	88	529	78	285	72	233	70	177	67	131	61	87
Bulgaria	100	728	100	667	91	181	77	165	63	123	38	52	27	18
Croatia	100	859	100	733	99	479	96	502	89	362	82	262	68	127
Cyprus	100	236	100	297	100	323	100	281	100	259	100	243	100	252
Czech Rep.	99	1275	99	1161	97	646	94	516	91	388	80	229	42	52
Denmark	100	1243	100	1147	100	1028	100	718	100	533	99	365	94	197
Estonia	61	130	76	200	48	75	37	38	35	33	18	16	10	8
Finland	24	20	33	33	26	23	11	7	8	4	3	1	2	0
France	100	726	99	623	97	485	89	437	84	333	74	230	43	72
Georgia	93	377	88	286	67	100	83	276	84	308	86	351	86	329
Germany	82	940	73	743	66	527	57	373	54	316	46	218	27	59
Greece	100	501	100	453	100	361	100	377	98	285	95	219	91	172
Hungary	100	1133	100	862	100	509	100	667	100	501	90	370	66	215
Iceland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	40	79	35	64	45	114	24	39	17	23	11	14	6	5
Italy	94	704	93	685	84	431	74	367	63	271	48	195	28	88
Latvia	99	500	100	642	93	251	93	201	92	179	75	112	56	63
Lithuania	100	825	100	977	99	412	98	390	99	416	97	318	85	184
Luxembourg	100	1499	100	1258	100	1154	100	727	100	699	97	504	92	235
Macedonia, FYR	100	537	100	472	100	345	91	280	83	216	73	151	60	113
Moldova	100	1004	100	768	100	492	100	407	100	347	100	309	93	272
Netherlands	96	1996	95	1793	93	1233	90	957	88	792	85	559	75	373
Norway	23	35	33	69	28	56	5	5	3	2	1	1	0	0
Poland	95	852	95	869	79	384	74	328	74	350	64	223	40	68
Portugal	100	302	100	305	100	304	100	264	100	234	99	194	86	98
Romania	100	931	100	858	98	552	99	493	96	356	92	269	83	165
Russia	64	159	71	221	51	88	48	78	45	67	40	52	39	51
Serbia & Mont.	100	585	100	516	97	274	83	345	80	275	74	196	62	127
Slovakia	100	1212	100	1223	100	677	98	524	95	415	89	287	77	129
Slovenia	99	807	99	722	96	384	91	265	75	157	34	42	4	3
Spain	99	370	100	464	100	396	99	400	96	308	95	273	85	143
Sweden	61	163	83	232	70	193	36	62	30	42	19	19	10	7
Switzerland	100	914	100	730	98	538	75	579	74	510	66	403	57	297
Turkey	99	198	99	255	99	258	99	269	100	288	100	292	100	341
Ukraine	100	1070	100	1055	100	619	100	520	100	489	100	424	100	388
United Kingdom	80	421	76	324	72	310	53	170	43	96	27	38	7	6
EU28	**80**	**518**	**84**	**505**	**78**	**336**	**67**	**280**	**63**	**221**	**54**	**159**	**40**	**73**
Europe	**75**	**333**	**79**	**361**	**69**	**225**	**63**	**200**	**60**	**175**	**55**	**144**	**49**	**115**

Table 1.4. The Natura 2000 area (%) at risk of eutrophication and the AAE in the EU28 countries between 2005 and 2020.

Eutrophication	2005		2010		GP-CLE2020		MFR2030	
	Area	AAE	Area	AAE	Area	AAE	Area	AAE
Austria[a]	–	–	–	–	–	–	–	–
Belgium[a]	–	–	–	–	–	–	–	–
Bulgaria[a]	–	–	–	–	–	–	–	–
Croatia[b]	–	–	–	–	–	–	–	–
Cyprus[c]	100	325	100	301	100	282	100	304
Czech Rep.	91	446	87	329	69	186	31	38
Denmark[c]	100	687	100	527	99	377	95	223
Estonia[c]	48	52	46	45	28	20	13	8
Finland[c]	5	3	4	2	2	1	1	0
France	86	389	81	290	70	195	36	56
Germany	55	323	51	269	42	179	23	46
Greece[c]	100	369	98	278	96	211	93	165
Hungary[c]	100	672	100	508	92	381	68	224
Ireland	18	30	13	18	8	11	5	4
Italy	76	331	63	237	47	163	25	68
Latvia[c]	94	194	93	174	78	107	59	59
Lithuania[c]	97	387	98	405	95	306	86	175
Luxembourg[c]	100	709	100	687	95	474	86	194
Malta[b]	–	–	–	–	–	–	–	–
Netherlands	88	826	87	681	84	465	72	297
Poland[a]	–	–	–	–	–	–	–	–
Portugal[c]	100	257	99	229	99	195	89	105
Romania[c]	99	434	93	304	89	222	77	128
Slovakia[c]	97	494	93	390	86	267	73	120
Slovenia	88	240	67	136	28	36	3	2
Spain[c]	99	381	97	291	96	256	83	131
Sweden	41	82	32	58	18	30	12	13
United Kingdom[a]	–	–	–	–	–	–	–	–
EU28	**78**	**337**	**73**	**257**	**65**	**189**	**47**	**84**

[a]NFC submitted critical load, but did not distinguish Natura 2000 areas.

[b]No information on Natura 2000 areas available

[c]NFC did not submit critical loads (CCE background database used).

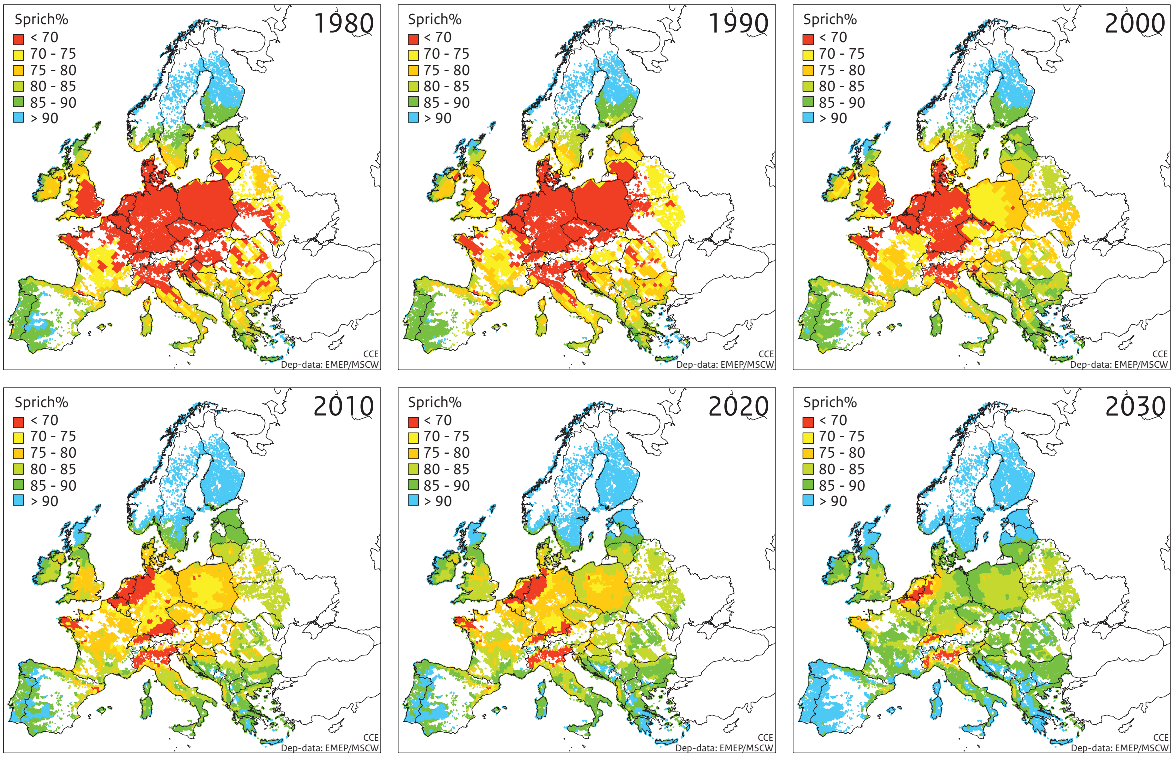
1.4 Tentatively assessing plant species diversity in selected European ecosystems[4]

Excessive nitrogen is known to affect plant species richness and a functional relationship between deposition and species richness can be derived (Bobbink et al. 1998; Stevens et al. 2004; Emmett et al. 2007), whereby species richness is considered a proxy for ecosystem multi-functionality.

The invitation by the Executive Body of the LRTAP Convention in 2007 to its Working Group on Effects "...to consider further quantification of policy relevant effect indicators such as biodiversity change, and to link them to integrated modelling work" (UNECE 2007) has stepped up work by International Cooperative Programmes to review biodiversity indicators (Hettelingh et al. 2009; WGE 2013a,b) and possibly apply them in scenario analyses.

[4] This text relies upon Hettelingh *et al*. (2015). A summary has also been published in WGE (2013a).

Figure 1.4. Species richness in grasslands (EUNIS classes E1, E2 and E3) in 1980 (top left), 1990 (top middle), 2000 (top right), in 2010 (bottom left), 2020 under the revised Gothenburg Protocol (bottom middle) and Maximum Feasible Reductions scenario in 2030 (bottom right).



This section describes a tentative assessment on a broad scale in Europe of adverse effects of N deposition on plant species richness by applying European nitrogen deposition to an available dose-response relationship for selected grasslands. This relationship has been taken from a European gradient study by Stevens et al. (2010a,b). The tentative percentages of species richness provided in this chapter are compared to a hypothetical 100% protection at zero N deposition. The values should be used in a relative rather than absolute context, i.e. for comparing N emission reduction scenarios with respect to species richness.

Stevens et al. (2010b) surveyed 153 semi-natural acid grasslands on a transect across the Atlantic biogeographic zone of Europe with total atmospheric N deposition ranging from 2.4 to 43.5 kg N ha^{-1} yr^{-1}, covering much of the range of deposition found in the industrialised world. The surveyed grasslands were dominated by species such as *Agrostis capillaris*, *Festuca ovina* and *F. rubra*, *Potentilla erecta* and *Galium saxatile* in Belgium, Denmark, Germany, Ireland, Northern Ireland, the Isle of Man, the Netherlands, Norway, Sweden and Great Britain. The large number of sites surveyed in Great Britain derives from the intensive national survey of the earlier work and from the fact that *Violion caninae* grasslands cover a much larger area than in other countries in the study (Stevens et al. 2004). All surveys were conducted between 2002 and 2007 and between May and September, using a consistent methodology; none was either fertilized or in the vicinity of a point source of nitrogen and many were in areas where nature conservation policies applied. Within each site, five randomly located 4 m^2 vegetation quadrants were surveyed. Within each quadrant all vascular plants and bryophytes were identified to species and cover was estimated by eye according to the classical phyto-sociological approach.

For all of the sites, well documented dispersion models were used for estimating the deposition of nitrogen (see Stevens *et al.*, 2010b). Finally, the relationship between N deposition and species richness is fitted with a negative exponential curve (dose-response or D-R function).

The harmonized European land-cover map (Cinderby et al. 2007) was used for the regionalized application of the above-mentioned D-R function. The analysis was carried out for EUNIS classes E1 ('Dry grasslands'), E2 ('Mesic grasslands') and E3 ('Seasonally wet and wet grasslands') restricted to locations with precipitation between 490 and 1970 mm yr^{-1}, altitude below 800 m and soil pH < 5.5. The limitation of available precipitation data excluded areas located east of 32 °E, resulting in a coverage of about 446,000 km^2.

Figure 1.4 shows how the area with a computed species richness below 70% (red shading) in 1980 clearly diminishes in subsequent decades.

It should be noted that the outcome of regional assessments of species richness does not significantly change when the analysis is restricted to E1, E2 and E3 grasslands within Natura 2000 areas. Table 1.5 shows the area-weighted average species richness per country by overlaying Natura 2000 areas on the European background database (Reinds et al. 2008). It turns out that the overall area-weighted average species richness in E1, E2 and E3 grasslands in 1980 (high N deposition) is lower than in 2020 under GP-CLE, i.e. 82%. Application of MFR in 2030 is computed to lead to a further increase of

Table 1.5 Area-weighted average species richness per country in Natura 2000 areas with EUNIS classes E1, E2 and E3 grasslands west of 32°E between 1980 and 2020 (GP-CLE scenario) and the MFR scenario for 2030 compared to a hypothetical species richness of 100% at zero N deposition.

	Tentative species richness (%) in specific Natura 2000 grasslands (EUNIS codes E1,E2,E3)						
Country/ Year	**1980**	**1990**	**2000**	**2005**	**2010**	**2020 (GP-CLE)**	**2030 (MFR)**
Austria	63	66	72	72	75	78	83
Belgium	54	58	60	65	67	70	75
Bulgaria	74	75	84	84	85	87	88
Croatia	62	64	70	73	76	79	84
Czech Rep.	56	59	68	75	77	80	86
Denmark	64	67	68	75	78	82	86
Estonia	83	81	85	88	89	91	93
Finland	91	90	91	93	94	95	96
France	71	73	75	76	78	80	85
Germany	56	59	64	70	71	74	83
Greece	85	86	87	86	88	89	90
Hungary	66	73	79	75	78	81	85
Ireland	83	84	82	86	87	87	89
Italy	77	77	82	80	82	84	87
Latvia	78	74	85	87	87	89	91
Lithuania	71	69	80	81	81	84	87
Luxembourg	59	62	64	73	73	76	82
Netherlands	50	52	57	61	64	68	71
Norway	92	89	92	95	95	96	97
Poland	65	65	74	77	76	79	84
Portugal	88	88	88	90	90	90	93
Romania	70	71	78	79	82	84	87
Slovakia	64	63	74	79	81	84	88
Slovenia	66	68	73	71	74	77	82
Spain	88	87	87	88	89	90	93
Sweden	79	79	81	85	86	89	91
Switzerland	54	61	64	67	68	71	76
United Kingdom	74	77	77	83	85	86	88
EU28	**71**	**72**	**76**	**79**	**80**	**82**	**86**

plant species richness, to reach 86% in acid grasslands.

Finally, it should be understood that this tentative assessment of species richness on a regional scale is quite uncertain. Uncertainties include the appropriateness of:
(a) assuming species richness to be a suitable indicator for assessing scenario-specific "no net loss of biodiversity";
(b) assuming 100% species richness at zero N deposition;
(c) applying on a regional scale, a dose-response relationship obtained from a gradient study of site specific information;
(d) having grasslands be the targeted receptor in all countries, while countries may in fact be interested in a favourable conservation status of the biodiversity in other than grassland ecosystems; and
(e) allowing an extrapolation from E1.7 and E1.9 to E1, E2 and E3 grasslands.

The CCE is currently collaborating with National Focal Centres of the ICP M&M to improve the choice of indicators for the assessment of "no net loss of biodiversity". A call for data in this respect, to be conducted by the CCE, has been issued by the Working Group on Effects of the LRTAP Convention in 2012 with a deadline in 2014. Initial results of this call for data are described in Chapter 2 of this report.

1.5 Summary, conclusions and recommendations

In this chapter the Core Set Indicator for the "Exposure of ecosystems to acidification, eutrophication and ozone" (CSI 005) is reviewed with focus on acidification and eutrophication. Methods and data developed and used in 2013-2014 under the LRTAP Convention in the field of national emissions, atmospheric modelling and of critical loads were used to compute exceedances of critical loads for acidification and eutrophication. In addition, a dose-response relationship between N deposition and plant species richness, which has been scientifically established for specific sites, has tentatively been applied to selected European acid grasslands.

In this chapter information is provided on time series of the CSI 005 indicators for acidification and eutrophication in Europe as a whole since 1880, and for countries separately since 1980 for selected years. However, the focus in this summary is on the effects of acidifying and eutrophying depositions due to emissions in the base year 2005 and target year 2020 of the revised Gothenburg Protocol established in 2012. In addition simulation results are shown for 2030 assuming an application of maximum feasible emission reductions.

The area at risk of acidification in Europe improves from 6 % (8% in Natura 2000 areas) in 2005 to 2 % (2% in Natura 2000 areas) in 2020. For eutrophication these percentages are 63% (78% in Natura 2000 areas) and 55% (65% in Natura 2000 areas), respectively. The area at risk of eutrophication would be further reduced to cover 49% in 2030 when maximum feasible emission reductions would be implemented. Finally, species richness in grasslands in Natura 2000 areas would increase from 71% in 1980 to 82% in 2020.

In Chapters 3 and 4 of this report, methods are proposed for identifying indicators to assess scenario-specific changes of biodiversity in European nature.

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Annex 1.A: *CSI 005 using 'old' methods and data*

This annex summarizes the CSI 005 indicator values, area at risk (%) and AAE (eq ha^{-1}yr^{-1}), computed with the methods and data that have been used in support of the revision of the Gothenburg Protocol (see Reis et al. 2012; Hettelingh et al. 2013) in 2012.

Table A.1: The ecosystem area at risk (% of total ecosystems) of acidification and the exceedance (AAE) in each country between 1980 and 2020.

Acidification	**1980**		**1990**		**2000**		**2005**		**2010**		**2020**	
Country	**Area**	**AAE**	**Area**	**AAE**	**Area**	**AAE**	**Area**	**AAE**	**Area**	**AAE**	**Area**	**AAE**
ALBANIA	0	1	0	0	0	0	0	0	0	0	0	0
AUSTRIA	50	771	23	179	1	4	1	2	0	0	0	0
BOSNIA AND HERZEGOVINA	30	542	25	390	17	107	12	41	7	20	6	22
BELGIUM	98	4715	69	1652	30	566	27	402	20	193	15	111
BULGARIA	21	320	14	167	1	18	0	0	0	0	0	0
BELARUS	81	994	80	923	19	76	15	36	11	17	7	6
SWITZERLAND	51	891	30	281	11	45	8	31	6	20	3	11
CYPRUS	0	0	0	0	0	0	0	0	0	0	0	0
CZECH REPUBLIC	98	4564	96	2935	30	302	24	221	21	140	19	97
GERMANY	97	5325	94	3108	61	462	50	296	31	128	24	87
DENMARK	97	2931	91	1754	57	537	50	315	41	101	17	24
ESTONIA	20	113	17	79	0	0	0	0	0	0	0	0
SPAIN	6	57	5	35	2	23	3	17	0	0	0	0
FINLAND	25	95	18	63	4	7	2	4	1	2	1	1
FRANCE	26	421	21	174	14	65	10	44	7	18	4	11
UNITED KINGDOM	81	1180	61	566	35	234	32	181	22	83	15	46
GREECE	10	73	8	50	3	15	3	16	2	5	1	1
CROATIA	35	500	11	103	4	25	4	18	3	10	3	6
HUNGARY	77	2376	59	993	23	128	12	59	7	27	6	19
IRELAND	40	265	27	125	19	71	17	56	8	18	7	13
ITALY	1	4	0	0	0	0	0	0	0	0	0	0
LITHUANIA	77	1356	74	1240	35	234	34	195	31	125	30	84
LUXEMBOURG	84	2360	60	877	15	182	13	134	13	77	13	52
LATVIA	46	494	42	460	21	46	16	31	8	10	4	5
MOLDOVA	36	497	30	205	2	2	0	0	0	0	0	0
MACEDONIA, FYR	18	145	17	117	13	22	9	21	2	5	0	0
NETHERLANDS	88	8293	87	5024	84	2449	82	1925	78	1368	75	1048
NORWAY	34	207	36	210	18	56	14	37	10	20	7	12
POLAND	100	4296	100	3443	84	876	74	658	53	320	41	196
PORTUGAL	7	37	7	32	9	44	9	61	3	13	3	12
ROMANIA	90	1520	87	1327	52	259	49	242	23	52	12	15
RUSSIAN FEDERATION	39	172	41	228	2	5	1	2	1	1	1	1
SWEDEN	56	290	55	245	26	54	13	16	6	5	4	3
SLOVENIA	37	740	25	261	4	10	1	1	0	0	0	0
SLOVAKIA	86	2704	83	1739	24	142	9	67	8	33	7	21
UKRAINE	85	1332	83	971	11	34	4	10	2	3	1	2
SERBIA + MONTENEGRO	38	418	30	271	13	35	18	50	8	14	8	17
EU-27	**45**	**956**	**41**	**630**	**22**	**133**	**17**	**93**	**10**	**41**	**7**	**25**
All	**43**	**574**	**41**	**435**	**13**	**69**	**9**	**47**	**6**	**21**	**4**	**13**

Table A.2: The ecosystem area at risk (% of total ecosystems) of eutrophication and the exceedance (AAE) in each country between 1980 and 2020.

	1980		1990		2000		2005		2010		2020	
country	**ex %**	**AAE**	**ex %**	**AAE**	**ex %**	**AAE**	**ex %**	**AAE**	**ex %**	**AAE**	**ex %**	**AAE**
ALBANIA	100	453	100	444	99	331	99	298	99	267	99	223
AUSTRIA	100	881	100	795	100	444	99	371	92	250	79	166
BOSNIA AND HERZEGOVINA	97	514	99	551	87	240	88	258	78	197	77	162
BELGIUM	100	1606	100	1267	100	1011	100	823	99	623	89	419
BULGARIA	100	826	100	767	93	258	94	235	80	133	70	106
BELARUS	100	834	100	1065	100	451	100	386	99	358	95	272
SWITZERLAND	100	1119	100	910	99	573	99	607	98	519	95	342
CYPRUS	49	62	58	112	49	103	66	120	66	123	66	127
CZECH REPUBLIC	100	1875	100	1737	100	1129	100	995	100	838	100	728
GERMANY	95	1385	92	1096	84	672	82	553	73	406	65	305
DENMARK	100	1679	100	1559	100	1268	100	1000	100	784	100	647
ESTONIA	98	253	100	363	78	120	69	89	53	51	42	37
SPAIN	91	238	95	334	93	258	95	329	92	236	91	208
FINLAND	56	89	71	117	56	76	46	52	40	36	31	23
FRANCE	98	891	98	769	97	584	98	514	95	396	89	302
UNITED KINGDOM	30	197	27	154	23	121	25	133	21	94	17	57
GREECE	98	447	99	397	100	288	100	290	99	231	99	210
CROATIA	100	961	100	829	100	513	100	512	99	425	99	345
HUNGARY	100	1267	100	976	100	538	100	537	100	429	100	354
IRELAND	87	546	85	501	84	560	87	572	83	471	80	415
ITALY	76	552	77	551	61	237	68	316	60	235	55	179
LITHUANIA	100	1001	100	1179	100	502	100	516	100	466	100	369
LUXEMBOURG	100	1617	100	1352	100	1161	100	1025	100	856	100	718
LATVIA	100	575	100	730	99	264	99	268	97	216	94	166
MOLDOVA	100	1040	100	793	100	513	96	314	92	251	92	246
MACEDONIA, FYR	100	546	100	481	100	321	100	304	100	251	100	217
NETHERLANDS	96	2500	96	2251	94	1525	91	1284	87	1099	85	844
NORWAY	24	37	34	74	25	40	19	25	14	15	10	8
POLAND	100	1491	100	1523	100	795	100	751	100	633	99	532
PORTUGAL	84	103	90	110	86	110	97	190	83	99	76	80
ROMANIA	66	296	55	248	31	67	20	22	8	5	3	2
RUSSIAN FEDERATION	53	135	62	224	29	43	27	31	19	20	19	20
SWEDEN	66	194	88	271	71	193	54	126	46	93	40	68
SLOVENIA	100	887	99	801	99	394	96	326	91	207	79	117
SLOVAKIA	100	1341	100	1356	100	707	100	640	100	521	100	431
UKRAINE	100	1195	100	1206	100	608	100	481	100	402	100	371
SERBIA + MONTENEGRO	99	586	100	519	98	248	97	292	92	215	90	206
EU-27	**80**	**582**	**84**	**562**	**76**	**335**	**73**	**313**	**68**	**237**	**62**	**188**
All	**67**	**371**	**73**	**408**	**54**	**194**	**51**	**176**	**45**	**134**	**42**	**109**

2 Summary of National Data

Jaap Slootweg, Maximilian Posch, Jean-Paul Hettelingh

2.1 Introduction

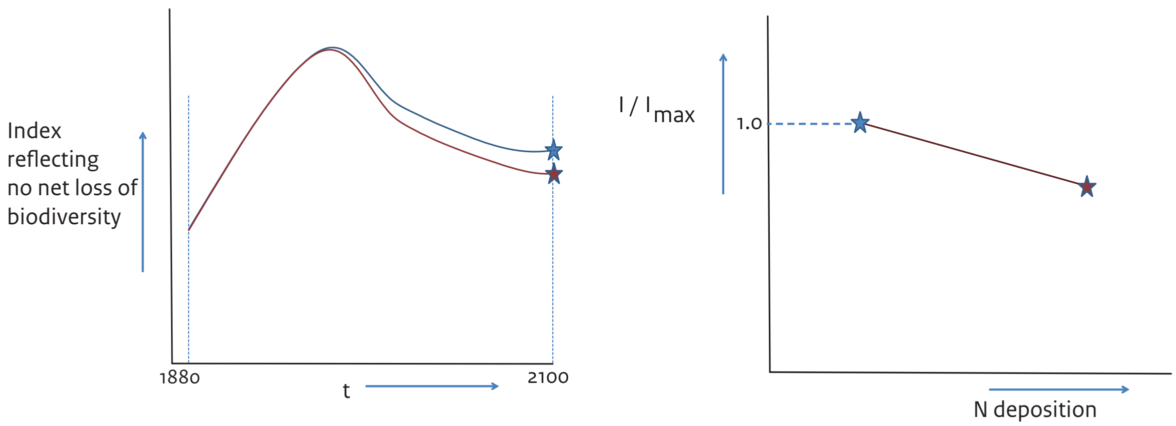
At the 22nd CCE workshop and 28th session of the Task Force on Modelling and Mapping (Warsaw, 16–19 April 2012) consensus was reached to propose a call for data to enable the regional assessment of country-specific endpoints for biodiversity. In response to this proposal the 31st session of the Working Group on Effects stated:
'*Modelling air pollution impacts on vegetation and biodiversity required a broad agreement on biodiversity indicators. CCE and the ICP on Modelling and Mapping proposed a generic indicator to be chosen by a Party in view of its environmental requirements. The indicator should provide a metric for 'no net loss of biodiversity' in regional (Task Force on Integrated Assessment Modelling) assessments of emission reduction scenarios. The proposed call for data would focus on that simple generic biodiversity indicator. National Focal Centres would be encouraged to help develop simple 'regional' dose-response functions based on European Nature Information System (EUNIS) habitat classification and dynamic soil-vegetation modelling.*' (ECE/EB.AIR/WG.1/2012/2). And, in the same document: '*the Working Group welcomed the proposal for a call to National Focal Centres to help develop a regional simple EUNIS class-specific "biodiversity function"*.' Accordingly, in 2012 the CCE issued the Call for Data, with a deadline in March 2014. The full text with instructions to the National Focal Centres (NFCs) can be found in Appendix A.

This chapter describes the results of the 2012–14 Call for Data. More detailed information on the national contributions – the national reports – can be found in Part 3.

2.2 A metric to describe loss of biodiversity

Many indices for measuring loss of biodiversity have been proposed and applied both in literature and within bodies such as the Convention on Biological Diversity (CBD) and the International Union for Conservation of Nature (IUCN). At its 25th session in 2007 the Executive Body of the LRTAP Convention agreed to encourage the Working Group on Effects 'to increase its work on quantifying effects indicators, in particular for biodiversity.' The effects community under the LRTAP Convention seeks to develop indicators that enable cross-border comparisons of country impacts. Therefore, a metric

Figure 2.1 Example of the development over time of a biodiversity index for a low (red) and high deposition scenarios, each ending in an Dose-Response(D-R) point (left) and a graphic representation of the normalised D-R points (right).



needed to be developed to support the scenario analysis of biodiversity impacts in a similar way to that in which critical load exceedance is used in integrated assessment.

A possible way to achieve this was proposed in the Call for Data 2012–14 (see Appendix A) and is summarised as follows:

1. Select ecosystem types for which data is available for multiple sites in selected EUNIS classes and in related sites of special protection (Natura 2000) if possible.
2. Run a dynamic soil model to equilibrium (steady state) for a low (e.g. background deposition) and high (e.g. current legislation) nitrogen deposition scenario within each EUNIS class.
3. Apply a vegetation model to calculate plant species presence and calculate the chosen biodiversity index within each EUNIS class.

The CCE divided all indices for a site by the maximum value of the index to normalise to one.

Figure 2.1 (left) shows a possible time series of the computed biodiversity index for a low (red) and high deposition scenario.

Figure 2.1 (right) shows two points in a selected target year relating the biodiversity index corresponding to the low deposition scenario and to that of the high nitrogen deposition scenario. The function connecting these points is considered the dose–response function (D–R function). The points are called dose–response points (D–R points).

In the call NFCs were asked to submit D–R points for the sites of their choice, grouped by EUNIS class, preferably at level 3. They were also asked to specify the plant species and their abundance, as well as a reference state. With these data it would be possible to (re)produce indices of all kinds, including those based on a reference state (e.g. Bray-Curtis index).

2.3 NFC submissions

Table 2.1 lists the countries and the EUNIS classes for which D–R points were submitted and the number of sites for each class. The Netherlands (NL) and the United Kingdom (GB) submitted data for different ecosystem types. All other countries provided date for forests (EUNIS class G) only, mostly ICP forest sites. Switzerland (CH) applied another approach to derive D–R functions for many sites in mountain hay meadows (E2.3) and in evergreen alpine and subalpine heath and scrub (F2.2). A description of this approach can be found in their national report (see Part 3).

Table 2.2 shows the methodology the countries applied. The CCE suggested running dynamic models up to 2100 for the scenarios:

- **BKG** – reducing all anthropogenic emissions to zero, leading to 'background' depositions
- **GP** – implementing the Gothenburg Protocol and keeping depositions constant until the last year of the simulation.

Other approaches are classified as:
M – measured
O – other.

Table 2.1 Number of sites submitted by the countries for each EUNIS class

	Austria AT	Switzer-land CH	Czech Republic CZ	Germany DE	France FR	United Kingdom GB	Italy IT	Nether-lands NL	Total
B1.3								1	1
D1								1	1
D1.1						2			2
D1.2						2			2
D2								1	1
D2.2						2			2
E1.2						2			2
E1.7						2			2
E2.2						2			2
E2.3		133							133
E3.5						2			2
F2.2		37							37
F4.1						2			2
F4.2						2		1	3
G1.5								1	1
G1.6	1	17		4					22
G1.7	1		5				2		8
G1.8			2		1			1	4
G3.1	3	2		1	1				7
G3.2			1						1
G3.F					1				1
G4.6	1						2		3
Total	6	189	8	5	3	18	4	6	239

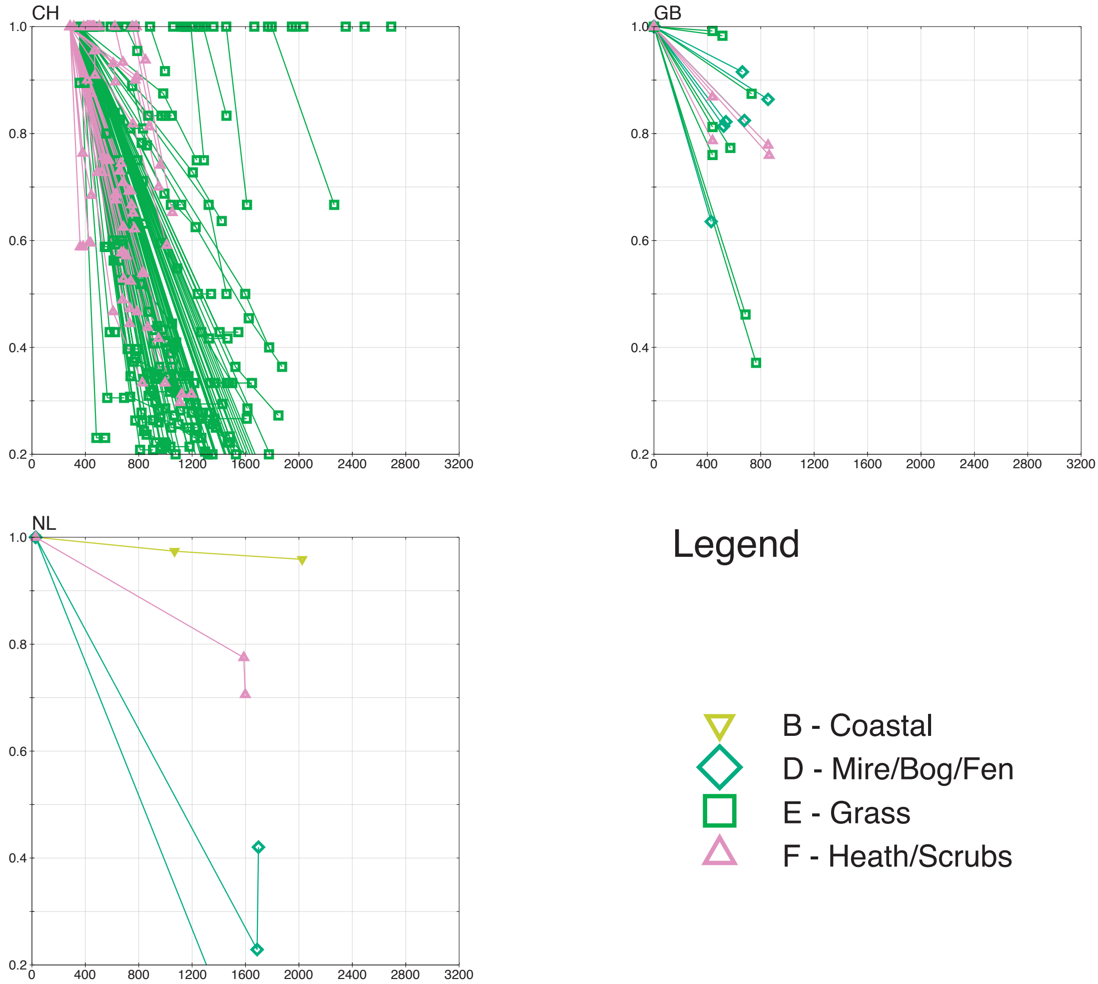
Table 2.2 Methodology applied by the countries

Country Year	AT	CH	CZ	DE	FR	GB	IT	NL
1750		O						
1880							BKG	
1995 – 2009			M		M			
2010		O						
2050								BKG,GP,O
2100	O	BKG,GP,O		BKG,GP			BKG	
2500						O		

BKG = 'background' depositions; **GP** = Gothenburg Protocol; **M** = measured; **O** = other

Some soil processes influencing pH and C:N ratio can take centuries to achieve equilibrium, but processes related to nitrogen concentration in the soil solution act relatively quickly. The vegetation models which need pH and/or C:N ratio require the soil chemistry at long-term equilibrium. Therefore, most countries ran their soil model until 2050 or even 2500. France and the Czech Republic determined their biodiversity index on relevées, sampled in recent years at corresponding deposition levels. The

Figure 2.2 The submitted D-R-points (connected per site) for non-forest ecosystems in Switzerland (top left), United Kingdom (top right) and the Netherlands



corresponding soil chemistry was obtained by measurements and calibration. This method focuses on the fast nitrogen processes only.
Note from Table 2.2 that both Switzerland (CH) and Italy (IT) used a historical year to obtain an additional (reference) D–R point. This point has a very low deposition. The United Kingdom (GB) made scenario runs with zero deposition.

2.4 Submitted D–R functions

The submitted D–R points for each site are linearly connected; thus forming a D–R function. NFCs submitted two or three D–R points for each site and therefore the D–R function consists of one or two segments. Figure 2.2 shows all D–R segments for *non-forest* ecosystems; Switzerland (CH), the Netherlands (NL) and the United Kingdom (GB) submitted data for the EUNIS classes B (Coastal), D (Mire/Bog/Fen), E (Grass) and F (Heath/Scrubs). Nearly all segments have negative slopes; higher nitrogen deposition results in fewer (typical) species.

Most countries focused on forests; five of the eight submissions contained *only* data for forest ecosystems. Figure 2.3 shows the D–R segments for forests. Most of the slopes are negative, but for many sites the index *rises* with an increasing nitrogen deposition.
The Netherlands and Switzerland chose a very low nitrogen deposition as a reference state.

Figure 2.3 The submitted D-R-points (connected per site) for forest ecosystems in Austria (AT), Switzerland (CH), Czech Republic (CZ), Germany (DE), France (FR), Italy (IT) and the Netherlands (NL).

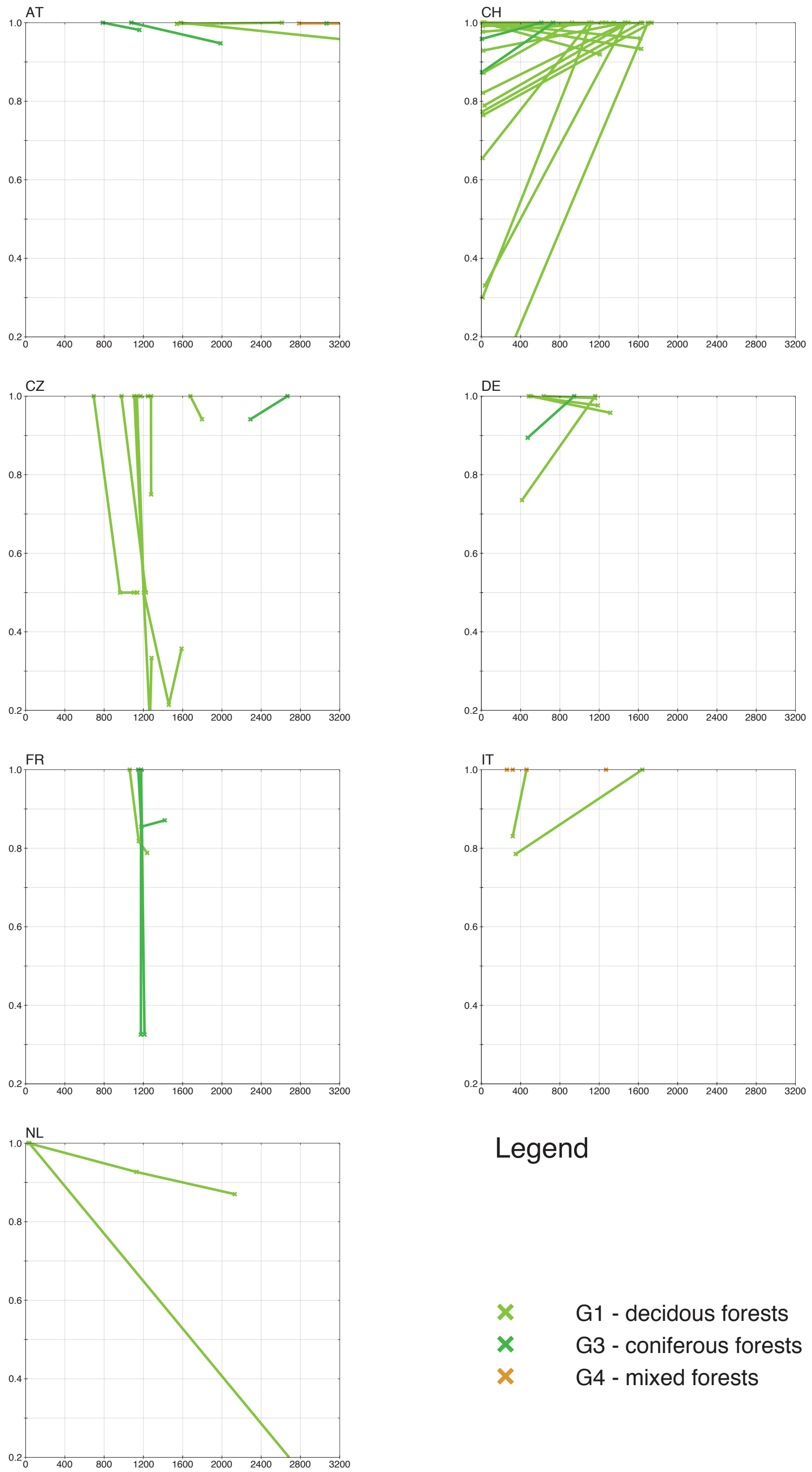
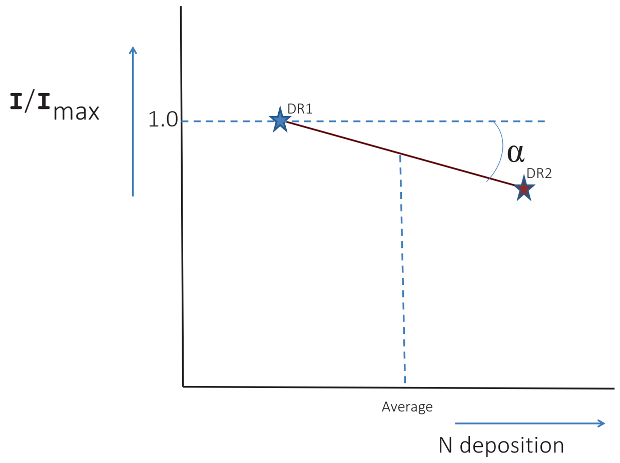


Figure 2.4 The slope of a D-R segment, normalized to one.



2.5 Conclusions regarding the D–R functions

Generally, for non-forests, biodiversity decreases with an increasing nitrogen deposition. However, for forests, the conclusion is unclear. Although most of the slopes are negative, for many sites the index increases with a higher nitrogen deposition, which means that no unidirectional relation between nitrogen deposition and biodiversity has been established for forests. We can deliberate on the reasons why: The Netherlands and Switzerland chose a very low nitrogen deposition as a reference state. It could be that this results in too little nitrogen for the typical species to occur and that an optimum deposition with a higher value for the chosen index lies somewhere on the first segment. Another reason could be that the chosen index reflects another aspect of biodiversity, instead of the effect that nitrogen might have, for example, the number of species increases but the species typical of the ecosystem disappear, thereby altering the habitat.

Another conclusion is that the slope of the segments and the extremes of the D–R functions vary considerably from country to country. Countries chose their index and method. Although the CCE normalised the functions to a maximum of one, there is no correction for the intrinsic sensitivity of the indices to change. All this makes comparing D–R functions between countries a challenging exercise.

How do the data of a single country compare to data from N-addition experiments, as assembled by Bobbink and Hettelingh (2011)? Such a comparison is described in the following section.

2.6 Comparing the D–R points to data from the nitrogen addition experiments

Switzerland submitted the most D–R-data, with an observation-based species richness related to (modelled) nitrogen deposition for grasslands and scrubs. Bobbink and Hettelingh (2011) report data for grasslands and scrubs from N-addition experiments for the same ecosystem types. The index used in that study is the species richness ratio, i.e. the number of species after the N addition divided by the number of species before.

The change in biodiversity in relation to N deposition is defined here by the slope of each segment, computed according to the following equation (see Figure 2.4):

$$\tan \alpha = \frac{I_{DR2} - I_{DR1}}{\max(I_{D1}, I_{D2}) \cdot (Ndep_{DR2} - Ndep_{DR1})} \quad (2.1)$$

The slopes of the D–R segments are plotted against the average deposition of each segment in Figure 2.5 for grasslands and in Figure 2.6 for scrubs. Both the slopes of the D–R segments in the Swiss data and those from the N-addition experiments are negative and seem to level off with higher depositions. This is consistent with the findings of Stevens et al. (2010),

Figure 2.5 A scatter plot of slopes of all D-R segments as a function of the average deposition of that segment for Swiss grasslands (left) and derived from the N addition experiment data (right)

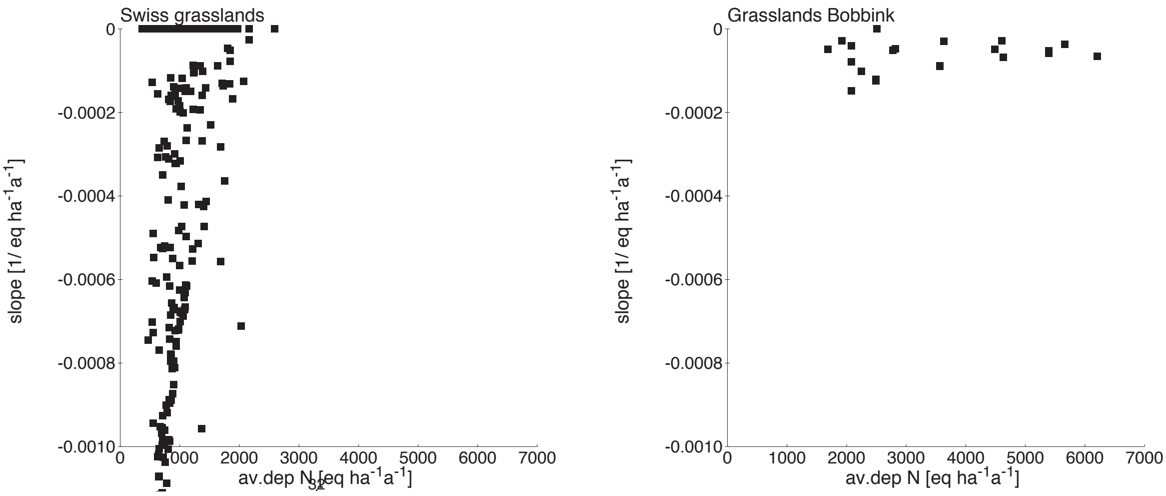
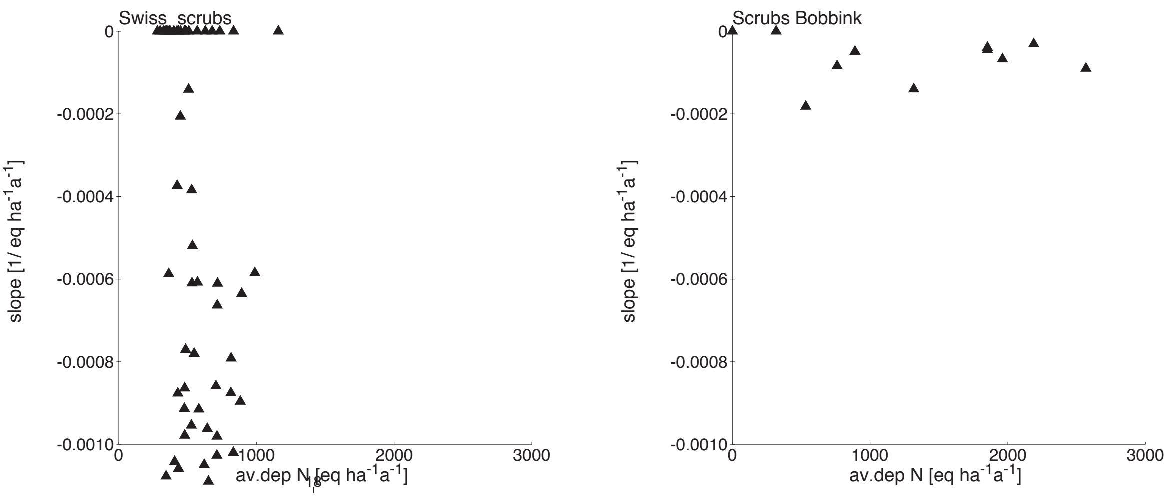


Figure 2.6 A scatter plot of slopes of all D-R segments as a function of the average deposition of that segment for Swiss scrubs (left) and derived from the N addition experiment data (right).



who describe a dose–response function of nitrogen deposition and species richness with an exponential decay.

It is clear that in the Swiss study the (average) depositions are lower than those in the addition experiments. The N additions correspond to considerably higher average depositions, but also increase the nominator of the slope (see eq. 2.1). This results in slopes closer to zero.
However, another explanation for the differences is that the Swiss study looked at oligotrophic species only (see national report, Part 3). These species are by definition more sensitive to elevated nitrogen deposition, and the richness of this species subset will decline even at low depositions.

2.7 Summary and outlook

The 2012–14 Call for Data aimed at deriving a harmonised metric from submitted variables and indicators with the objective of quantifying 'no net loss of biodiversity' on a regional scale. It was proposed to upscale the chosen approach (and indicators) from individual sites, using the EUNIS classification. Emphasis should be put on Natura 2000 sites.
Ten countries responded to the Call for Data on biodiversity indicators and calculations. Seven of them applied dynamic modelling. Respondents to the call suggested that further technical and conceptual work was needed to arrive at a harmonised indicator of 'no net loss of biodiversity'. The analysis of metrics used to characterise 'no net loss of biodiversity' by the respondents did not lead to any overall relationship with neither nitrogen deposition nor critical loads at a regional level. This was partly due to the fact that the chosen metrics were not homogeneous in their response to nitrogen deposition.
The review of the Call for Data results during the 24th CCE workshop and 30th meeting of the Task Force on Modelling and Mapping (Rome, 7–10 April 2014) highlighted that NFCs had used several different metrics to assess biodiversity:

- habitat suitability
- red list species
- species cover
- species abundance
- functional diversity
- ecosystem services.

As a result of the different (NFC) presentations in response to the Call for Data, the Task Force came to the conclusion that a common biodiversity indicator such as habitat suitability would be useful in addition to indicators that meet specific parties' requirements. This indicator will be calculated using lists of species characteristic of EUNIS habitats. In addition, it was noted that there was a need to define a reference situation in order to assess the evolution of the biodiversity index towards a target situation to be selected for use in, for example, integrated assessment. This could be based on a 'reference' scenario (to be defined). The decision on the target situation requires inputs from policy (ICP M&M, 2014).
At its 33rd session (Geneva, 17–19 September 2014) the Working Group on Effects requested the CCE to organise a new Call for Data and report its results to the 31st meeting of the ICP Modelling and Mapping Task Force to be held in Zagreb (Croatia) in 2015 and to the Working Group at its 34th session (17–18 September 2015).

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Stevens CJ, Duprè C, Dorland E, Gaudnik C, Gowing DJG, Bleeker A, Diekmann M, Alard D, Bobbink R, Fowler D, Corcket E, Mountford JO, Vandvik V, Aarrestad PA, Muller S, Dise NB, 2010. Nitrogen deposition threatens species richness of grasslands across Europe. *Environmental Pollution* 158, 2940–2945

Annex 2A: Updated Swedish critical loads

Sweden has submitted an update of its critical loads of acidity for lakes as well as empirical N critical loads. Figures 2.7 and 2.8 show the differences from the previous submission.

The area covered by empirical critical loads decreased but it is still well spread over the country (Figure 2.8). For the critical loads for acidity the reverse is true (Figure 2.7); nearly all of the country is now covered. There are some slight changes in the assessed sensitivity of the Swedish ecosystems.

Figure 2.7 Maximum critical loads of sulphur (CLmaxS) as submitted in 2014 (left) and the previous submission in 2012 (right).

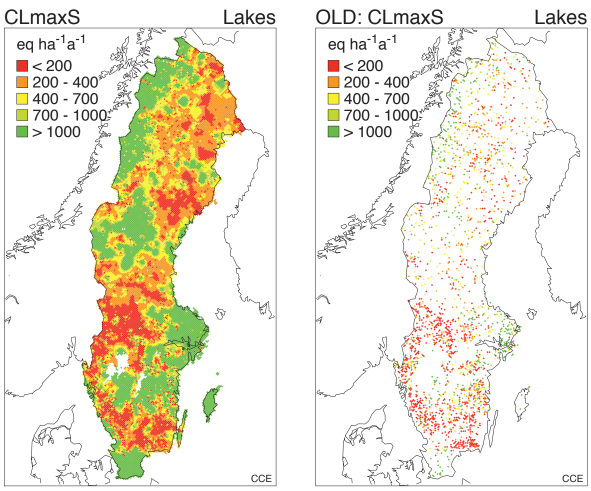
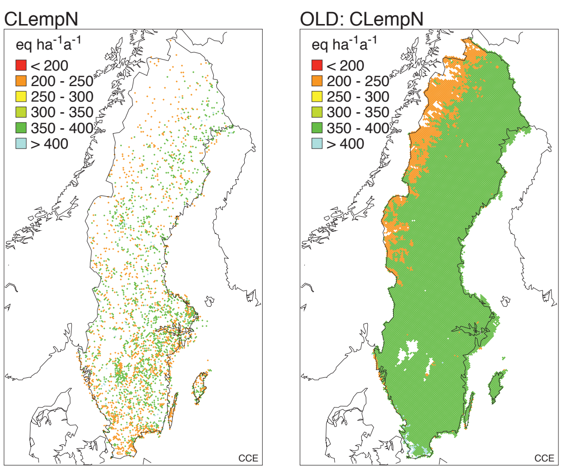


Figure 2.8 Empirical critical loads of nitrogen as submitted in 2014 (left) and the previous submission in 2012 (right)



Part 2
Progress in Modelling

3 Deriving critical loads based on plant diversity targets

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3.1 Introduction

In 2007, at its 25th session, the Executive Body of the LRTAP Convention requested the Working Group on Effects 'to consider further quantification of policy-relevant effect indicators such as biodiversity change, and to link them to integrated modelling work' (ECE/EB.AIR/91, para. 31). Biodiversity is also addressed in the Long-term Strategy (until 2020) of the LRTAP Convention (UNECE 2010). Furthermore, the EU Biodiversity Strategy to 2020 calls in its 'Action 7' for 'no net loss of biodiversity and ecosystem services' (EU 2011). In the 2008 and especially the 2009 CCE Status Reports (Hettelingh et al. 2008, 2009) theoretical considerations and a few national applications on this subject were reported. Biodiversity was also considered in the review and revision of the empirical critical loads (Bobbink and Hettelingh 2011). The main issues are the choice of indicator(s) quantifying biodiversity (changes) and the establishment of a link to nitrogen (N) and sulphur (S) deposition. Furthermore, the chosen methodology should be applicable on a regional (European) scale to make it useful and usable for integrated assessments. In this chapter we suggest a way to derive critical loads of N and S using a (steady-state) vegetation model and an agreed-upon plant diversity index value as criterion.

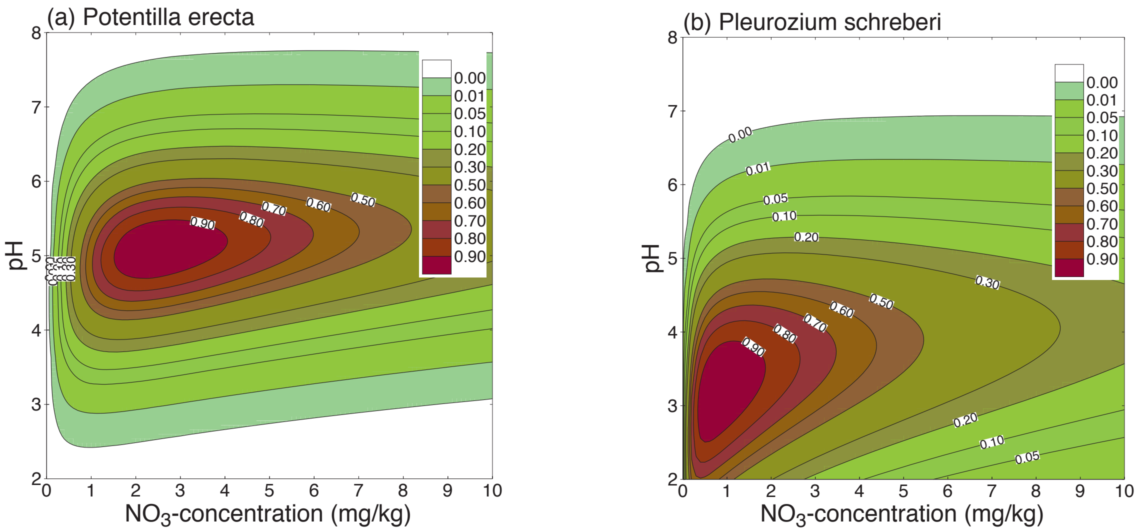
3.2 The Habitat Suitability Index

At the 2014 CCE Workshop and ICP Modelling & Mapping Task Force meeting (Rome, 7–10 April) it was agreed that the Habitat Suitability index (HS index or HSI) should be used for common European biodiversity modelling. The HS index is defined as the arithmetic mean of the 'normalised' probabilities (suitabilities, possibilities) of occurrence of the species of interest. In mathematical form this reads:

$$HS = \frac{1}{n}\sum_{j=1}^{n}\frac{p_j}{p_{j,max}} \tag{3.1}$$

where n is the number of species, p_j the occurrence probability of species j, and $p_{j,max}$ the maximum occurrence probability of species j. For convenience, the HS index can be normalised to 1, i.e. divided by its maximum value. The species entering into the equation should be 'typical' or 'desired' species for the respective habitat, the choice of species being the responsibility of each country. The probabilities

Figure 3.1 Isolines of normalised occurrence probabilities as a function of the NO_3 concentration and pH for two species (PROPS model; T=7°C, P=700 mm/yr).



to compute the HS index are obtained either from observations or, more likely on a large regional scale, by soil–vegetation models.

Note that the term 'habitat suitability index' is a frequently used term in conservation biology, but mostly referring to wildlife in general (e.g. O'Neil et al. 1988; Brooks 1997); it is also used in the EU BioScore2.0 project (Van Hinsberg et al. 2014). The HS index is related to the Habitat Quality index defined by Rowe et al. (2009), except that it does not consider the (negative) contribution of undesired species. It is also related to the 'biodiversity score' as defined by Van Dobben and Wamelink (2009; see also Van Dobben et al. 2015).

3.3 Deriving critical loads

Several vegetation models have been developed for use within the ICP M&M community, such as the Veg-model (Belyazid et al. 2015), the BERN model (Schlutow et al. 2015), the MultiMOVE model (Rowe et al. 2015), and the PROPS model (Reinds et al. 2012; see also Rowe et al. 2015).
In the following, using the PROPS model as an example, it is described how to derive critical loads from the output of such a model. We assume that the chosen vegetation model computes the probability of occurrence of every species *j* at a site (*j*=1,…,*n*) as a function of site parameters (soil, climate, …):

(3.2) $$p_j = M_j(NO_3, pH, \mathbf{s}),\ j = 1, \dots, n$$

where *M* is the model and the index *j* indicates that the model parameters depend on the species. The vector **s** stands for all other site/climate parameters (e.g. temperature and precipitation in the PROPS model) determining p_j; NO_3 is the soil nitrate concentration (mg/kg) in the rootzone; and *pH* is the soil solution pH (as in the PROPS model). Other models (even other PROPS model versions) use different parameters and variables, but they have to be such that they can be linked to the deposition of N and S, in general with the aid of a soil chemistry model. In Figure 3.1 isolines of the normalised occurrence probabilities in the NO_3–pH plane for two common species are depicted (modelled with PROPS).

For a given vegetation unit/habitat/ecosystem, the normalised probabilities of all typical/desired species are computed and the HS index is determined according to eq. 3.1. In Figure 3.2 the isolines of the HS index in the NO_3–pH plane are shown for the vegetation unit 'Frisian-Danish coastal heaths' (unit E10 in the European Vegetation Map, Bohn et al. 2000/2003; Bohn et al. 2007), consisting of 24 species for which data are available in the PROPS model (including the two in Figure 3.1). The figure shows that the maximum HS index would be achieved for a soil solution pH around 4.9 and a soil NO_3 concentration of about 2 mg/kg.

Figure 3.2 Isolines of the normalised Habitat Suitability index for 'Frisian-Danish coastal heaths' as a function of the NO_3 concentration and pH (PROPS model; T=7°C, P=700 mm/yr).

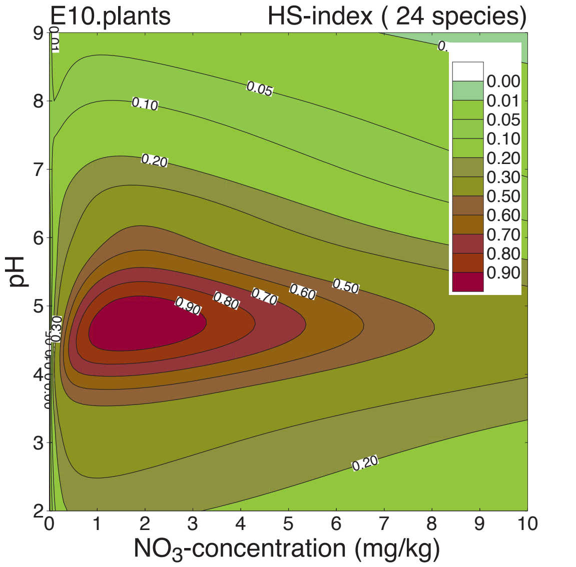
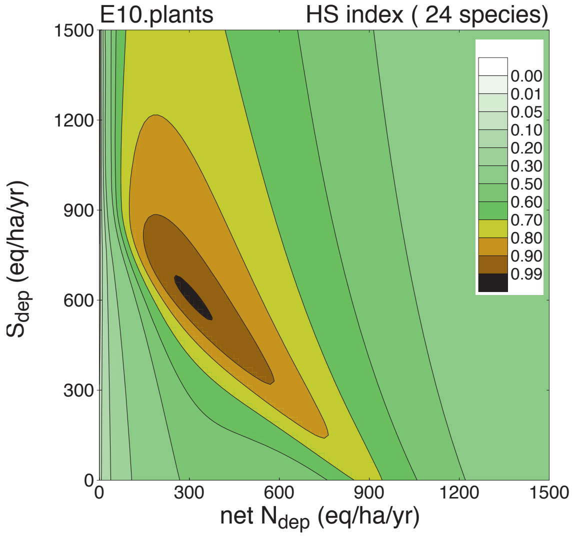


Figure 3.3 Isolines of the Habitat Suitability (HS) index for 'Frisian-Danish coastal heaths' as a function of N and S deposition, computed with the PROPS model and the SMB model (N_i+N_u=0).



For use in emission reduction assessments, the soil chemical variables in Figure 3.2 have to be converted into N and S depositions. This can be conveniently done with the SMB model. Converting the soil NO_3 concentration to soil solution N concentration (in eq/m³) via $[N] = NO_3\rho/62\theta$, with ρ the bulk density (kg/dm³) and θ the volumetric water content (m³/m³), one obtains for the N deposition, N_{dep}:

$$(3.3) \qquad N_{dep} = N_i + N_u + Q[N]/(1 - f_{de})$$

where N_i and N_u are the long-term average immobilisation and net uptake (removal) of N, *Q* is the runoff (percolation flux) and f_{de} the denitrification fraction (see ICP M&M 2014).

The corresponding S deposition, S_{dep}, is obtained by using [H⁺] (from *pH*) to compute the ANC leaching, ANC_{le}, and from the charge balance (see ICP M&M 2014):

$$(3.4) \quad S_{dep} = BC_{le} - Cl_{le} - ANC_{le} - Q[N]$$

where the subscript *le* denotes the leaching of base cations (*BC*), chloride (*Cl*) and ANC.

In Figure 3.3 isolines of the HS index for 'Frisian-Danish coastal heaths' as a function of N and S deposition are displayed, computed with the SMB model from the data displayed in Figure 3.2, using 'average' site parameters. It shows that in this case the HS index is maximal at an N deposition of about 300 and an S deposition of 600 eq/ha/yr.

To derive critical loads from the data shown in Figure 3.3, a limit for the HS index has to be chosen, which is a 'political' choice. To illustrate the procedure, we selected a value of 80% of the maximum HS index as the limit, which is illustrated as the red line in Figure 3.4a. There is no unique way to derive critical loads from this. Without going mathematical details, the black bold line in Figure 3.4b graphically illustrates a way to arrive at a nitrogen-sulphur critical load function (N-S CLF) for biodiversity. Obviously, one could also choose a polygon with more nodes (better approximating the isoline), but for simplicity we restrict the function to one defined by two nodes.

Figure 3.5 shows the N-S critical load function defined by the four quantities (two points), denoted as CLN_{min}, CLS_{max} and CLN_{max}, CLS_{min}. The definition of an exceedance is a generalisation of the one for the acidity CLF. A technical description and routines to calculate it can be found in Appendix B of this Report.

Figure 3.4 (a) As Figure 3.3, but with an HS index limit value of 80% of the maximum HSI (red line); (b) a nitrogen-sulphur critical load function (N-S CLF) derived from the chosen HS index limit value (black line).

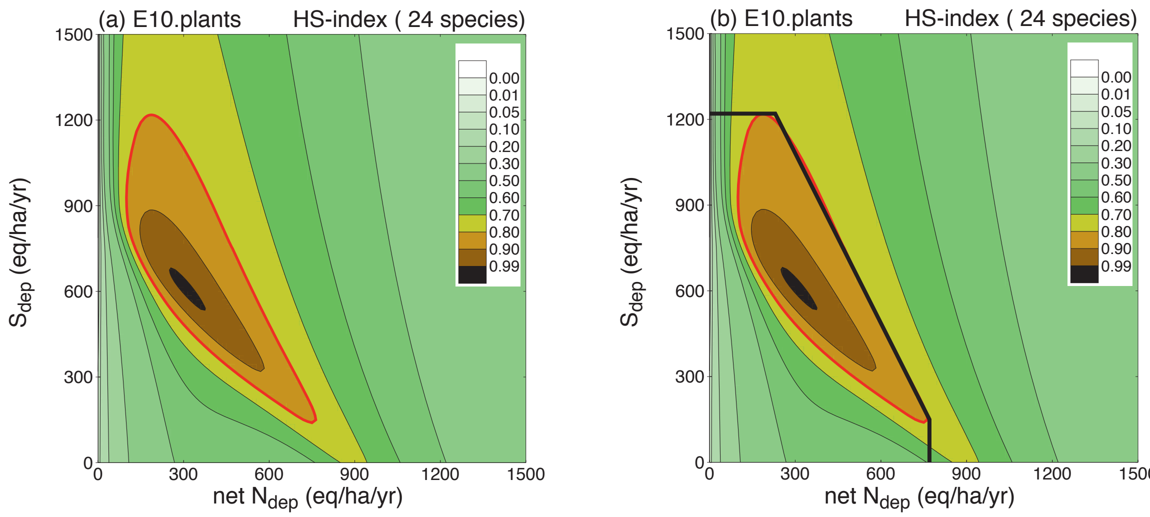
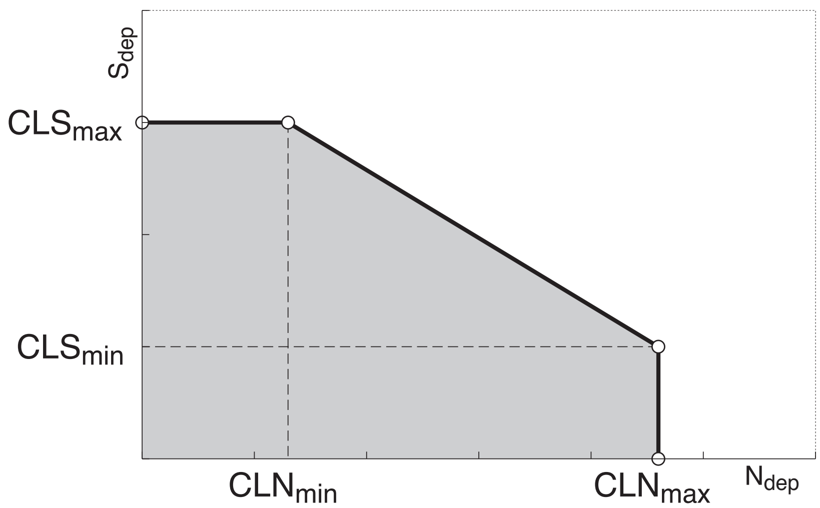


Figure 3.5 The N-S critical load function defined by two points (four values): (CLN_{min},CLS_{max}) and (CLN_{max},CLS_{min}).

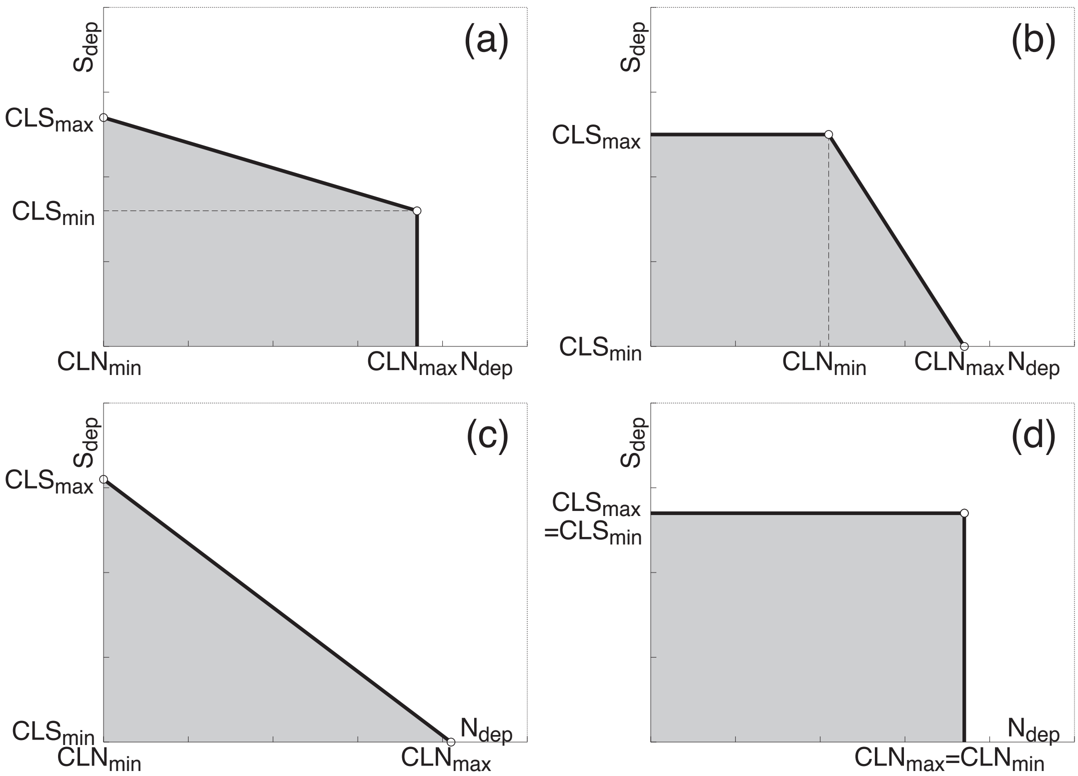


This general type of critical load function also encompasses special cases, characterised by one node having the value zero or by two nodes coinciding (see Figure 3.6).

Finally, note that the 'correspondences' with the classical critical load function for acidity, defined by $CL_{max}S$, $CL_{min}N$ and $CL_{max}N$, intersected with the nutrient N critical load $CL_{nut}N$ (or $CL_{emp}N$) are: CLN_{min} = $CL_{min}N$, CLS_{max} = $CL_{max}S$; and, if $CL_{nut}N$ < $CL_{max}N$: CLN_{max} = $CL_{nut}N$ and CLS_{min} = $CL_{max}S\cdot(CL_{max}N-CL_{nut}N)/(CL_{max}N-CL_{min}N)$; otherwise CLN_{max} = $CL_{max}N$ and CLS_{min} = 0 (compare Posch et al. 1993).

In summary, critical loads of N and S deposition could be derived along the lines sketched in Figure 3.4b, once a threshold value of the HS index is agreed upon. To do this on a European scale requires a list of typical species for every habitat/vegetation type (preferably linked to EUNIS) mapped across

Figure 3.6 Special cases of the N-S critical load function: (a) CLN_{min} = 0, (b) CLS_{min} = 0, (c) CLN_{min} = 0 and CLS_{min} = 0, and (d) CLN_{min} = CLN_{max} and CLS_{min} = CLS_{max}.



Europe and linked to a soil chemistry and vegetation model chain (see also Chapter 4). This work should benefit of the response to the ICP M&M Call for Data 2014/15 (issued in November 2014) and the work in 2015 under the ECLAIRE project.

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4 VSD+PROPS: Recent developments

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4.1 Introduction

In this chapter we describe the current status of the VSD+PROPS model, which generates plant species occurrence probabilities as a function of soil chemistry and climatic variables. The PROPS database is described and some examples of site applications are provided, as well as a description of how the model could be applied to Europe using regional soil, vegetation and climate data.

4.2 Methods

4.2.1 The VSD+ model

The VSD+ model is a single-layer dynamic soil chemistry model including cation ion exchange and C and N dynamics (Bonten et al. 2009). VSD+ was developed as an extension of the VSD model (Posch and Reinds 2009), which itself is the simplest extension of the steady-state Simple Mass Balance (SMB) model to a dynamic model with an annual time step. VSD was specifically made to calculate the effects of deposition of nitrogen (N) and sulphur (S) on soil acidification on a regional/national scale in support of the review of effects-based Protocols under the LRTAP Convention. More recently, the effects of nitrogen deposition on biodiversity, greenhouse gas emissions (notably N_2O) and carbon sequestration have become policy-relevant. To calculate these effects, VSD has been extended with an explicit calculation of the C and N balance. The changes in the soil organic matter contents are calculated using the RothC-26.3 model (Coleman and Jenkinson 2005). Essentially, RothC is a five-compartment soil organic carbon model. The compartments (pools) are:

- Decomposable Plant Material (DPM)
- Resistant Plant Material (RPM)
- Microbial Biomass (BIO)
- Humified Organic Matter (HUM)
- Inert Organic Matter (IOM).

The fraction of C turnover that is converted to CO_2 depends on the clay content of the soil. The turnover rates for the various carbon pools, k_x (x=DPM, RPM, BIO, HUM), are calculated from reference turnover rates $k_{x,ref}$ by correcting for temperature, moisture and soil cover.

The mineralisation and immobilisation of N are dependent on the turnover of the C pools; in the event that the C turnover releases insufficient N for plant uptake, the transfer of N to the HUM pool is reduced until sufficient N is available for uptake. The model further includes N uptake, nitrification, denitrification and N leaching. VSD+ can calculate not only soil acidification, but also parameters like N availability, the C/N ratio of the soil, C sequestration and NO_3 and NH_4 concentrations in the soil solution.

4.2.2 The PROPS model

The PROPS model estimates the occurrence probability of plant species as a function of soil chemistry and climate. The model was fitted to presence-absence data using a logistic regression technique (e.g., Ter Braak and Looman 1986). In this technique, the occurrence probability of a plant is estimated based on presence-absence data (Figure 4.1; every dot with a y-value equal to 1 indicates that the plant species is present (for parameter *x*); when the species is not present the value is 0).

If *p* is the probability that a species will occur, the odds that a species occurs is *p*/(1–*p*). The logit of *p*, defined as the log of the odds, varies between –∞ and ∞, and is approximated (fitted) by a quadratic polynomial:

$$(4.1) \quad z = \text{logit}(p) = \log\frac{p}{1-p} = a_0 + \sum_{i=1}^{n} a_i \cdot x_i + \sum_{i=1}^{n}\sum_{j=1}^{n} a_{i,j} \cdot x_i \cdot x_j$$

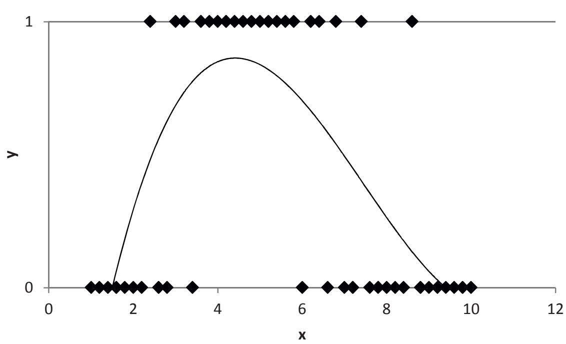
with $a_{i,j} = a_{j,i}$ for all *i* and *j*. The number of (normalised) variables x_i is $n = 4$: temperature, precipitation, an N variable (e.g. soil N concentration or C/N ratio), all log-transformed, and pH, resulting in 1+4+10 = 15 parameters to be determined. Furthermore, the explanatory variables have been normalised:

$$(4.2) \quad x_{norm} = \frac{x - x_{mean}}{x_{std}}$$

where *x* is the log-transformed value of the explanatory variable, x_{mean} is the average value and x_{std} the standard deviation of the explanatory variable from the database that is used to fit the model. From eq. 4.1 the probability *p* is then obtained as:

$$(4.3) \quad p = \frac{1}{1 + \exp(-z)}$$

Figure 4.1 Example of occurrences of plant species against an abiotic parameter *x*. When the value is 1, the species occurs and when the value is 0 it doesn't (from Reinds et al. 2012)



4.2.3 The PROPS database

Databases
Two databases were used to parameterise and validate the PROPS model. The first database contains information on plant species occurrence for 16,000 relevés, mainly in the Netherlands, Austria, Ireland, Denmark and the United Kingdom (Table 4.1), and associated measurements of at least one soil parameter (pH, total soil N content (N_{tot}), soil C/N ratio (C/N) or dissolved NO_3 (NO_3)). In addition, the mean annual temperature and precipitation for each site were obtained from the CRU meteorological data set (Mitchell et al. 2004), using data from the grid cell corresponding to the location of the relevé. Soil pH was measured in water, calcium chloride extract or potassium chloride extract. The pH values in potassium chloride extract were recalculated to pH values in water, using the following relationship based on measured data in the Netherlands:

$$(4.4) \quad pH_{H_2O} = 1.576 + 0.805 \cdot pH_{KCl}$$

The second database includes information on plant species occurrence in approximately 800,000 relevés in Europe (collected in the EU BioScore project, van Hinsberg et al. 2014) without measured soil parameters. Therefore, we estimated the soil parameters at these sites using the plant species composition and the probability curves fitted from the first dataset (see below). As with the first dataset, climatic data were obtained from Mitchell et al., 2004.

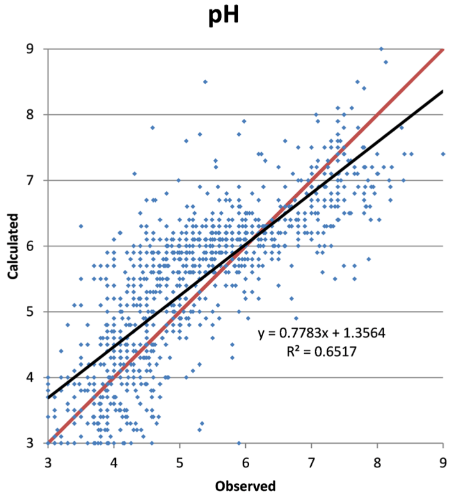
Table 4.1 Number of sites with species composition and measured soil parameters

Dataset	pH	NO_3	C/N	N_{tot}	pH+NO_3	pH+C/N	pH+N_{tot}
Netherlands	6781	1330	2421	2943	1282	2355	2815
Austria	630	0	630	630	0	630	630
Ireland	411	429	430	430	410	411	411
Denmark	760	0	503	141	0	503	32
United Kingdom	586	193	240	240	193	240	240
ICP-Forest	529	0	518	528	0	518	528
Other	189	54	102	112	54	102	112
Total	9886	2006	4844	5024	1939	4759	4768

Calculation of soil parameters

The first dataset, with measured soil parameters, was split into a calibration part (90% of the dataset) and a validation part (10% of the dataset). For each species in the calibration part of the dataset we fitted one-dimensional occurrence probability curves (see Figure 4.1) in response to the four explanatory variables of eq. 4.1, i.e. pH, N_{tot}, C/N and NO_3. We were able to fit occurrence probability curves for 949 species for pH, 736 species for N_{tot}, 301 species for NO_3 and 819 species for C/N. By using these occurrence probability curves from the calibration part we could calculate the soil parameters at the sites of the validation set and compare them to the measured values at the site. The best estimate for the soil parameters was assumed to be the value at which the occurrence probability of all species is highest, i.e. at the maximum of the product of the probabilities of all occurring plant species in the relevé concerned. It was (arbitrarily) assumed that at least five plant species with a probability curve had to be present to obtain a proper estimate of the soil parameters. Tree species were excluded from the procedure as these only very slowly react to (changes in) abiotic conditions, and species with more than one optimum were excluded because this probably indicates an unsuccessful fit to the data. The comparison of calculated to measured soil parameter values in the validation set confirmed that there is a significant correlation ($r^2 > 0.3$) between measured and calculated pH and C/N ratio. At part of the sites, however, a substantial deviation between the measured and calculated values occurs (Figure 4.2). Results for N_{tot} and especially for NO_3 were not so good with r^2-values < 0.3. Further fine-tuning of the procedure may improve the estimates of soil parameters.

Figure 4.2 Validation of calculated pH and C/N; the 1:1 line is in red; the black line indicates the regression between estimated and observed values.



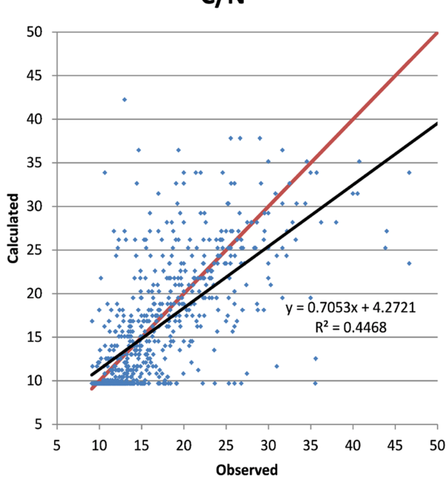
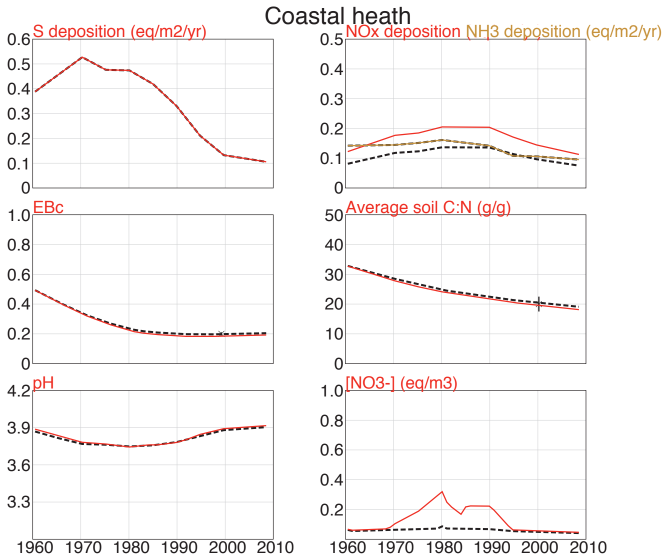


Figure 4.3 Results of the VSD+ model applied to a north-western European coastal heath. Dotted lines are the results of the reference scenario, solid lines of the scenario run with 50% more NO_x deposition.



The procedure applied to estimate the soil parameters for the validation set was also applied to obtain the soil parameters at the BioScore sites (response curves could be regarded as an alternative for species indicator values (e.g. Ellenberg et al. 1991). This resulted in a dataset of around 380,000 relevés combined with estimated soil parameters, temperature and precipitation. This dataset was then used to fit the four-dimensional response curve with precipitation, temperature, pH and one of the N parameters as explanatory variables for every species (see eq. 4.1).

Several combinations of pH, temperature, precipitation and one of the N parameters and their interactions were tested to fit the response curves. In the following, we will use the results of eq. 4.1 with pH, NO_3, temperature and precipitation as explanatory variables.

4.2.4 Indices

In previous assessments with VSD+PROPS (Reinds et al. 2012), the Simpson and Bray-Curtis indices were used as a measure for plant species diversity. They are both based on species abundances. The PROPS model, however, computes occurrence probabilities, not abundances. A study on the use of various diversity indices using field data showed that the relation between occurrence probability and abundance is weak, with rank correlations generally below 0.5 (Gomez 2014). In this chapter we therefore use the Habitat Suitability index, *HS*, as a measure of species diversity, as it is based on probabilities (Rowe et al. 2009; here limited to the positive indicator species):

(4.5) $$HS = \frac{1}{n}\sum_{k=1}^{n}\frac{p_k}{p_{k,max}}$$

where *n* is the total number of positive (desired) species, p_k is the probability of occurrence of positive (desired) species *k*, and $p_{max,k}$ the maximum probability of occurrence of species *k* (Rowe et al. 2009). This index was agreed upon at the 2014 CCE Workshop and ICP Modelling & Mapping Task Force meeting (Rome, 7–10 April).

4.3 Site application of VSD+PROPS

To demonstrate the effect of changes in environmental pressure on plant species diversity, VSD+PROPS was applied to a poor, sandy north-western European site. For illustrative purposes we assumed a base cation weathering 250 eq ha^{-1} a^{-1}, a CEC of 40 meq kg^{-1}, a water leaching rate of 270 mm a^{-1}, an average temperature of 7.5°C and a soil moisture content of 0.14 m^3 m^{-3} for this site. We ran VSD+ with two deposition scenarios (Figure 4.3), increasing the NO_x deposition in the second scenario by 50% compared to the first.

VSD+ results show a steady decline of C/N ratio in the soil as a result of high N input and of base saturation as a result of high acid inputs (S+N). Increasing NO_x deposition by 50% has limited effects

Figure 4.4 Isolines of occurrence probabilities of the three species modelled.

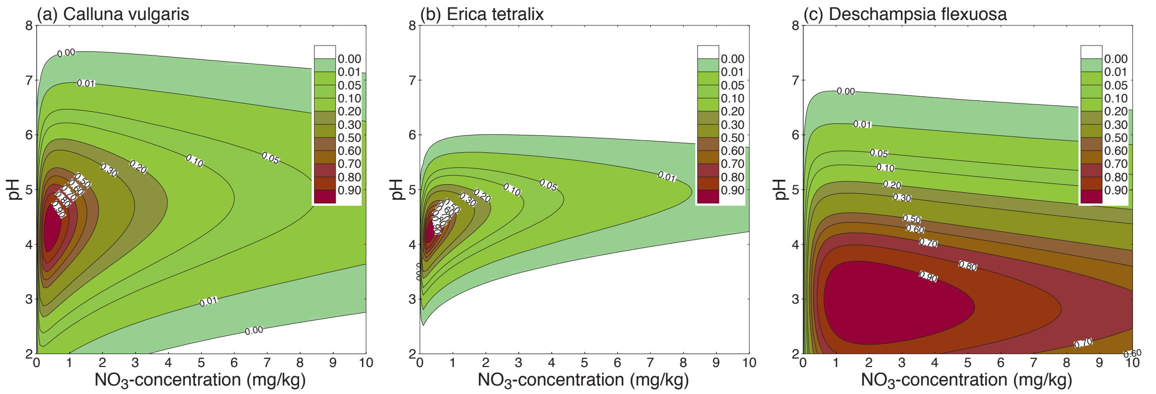
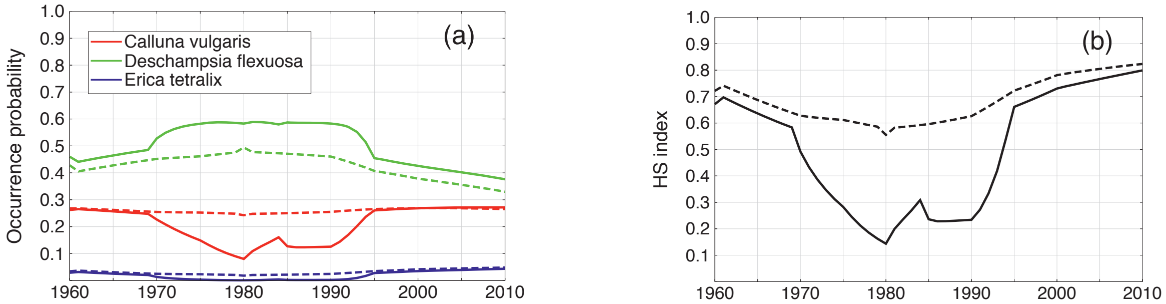


Figure 4.5 Temporal development of (a) occurrence probabilities of the three species and (b) the Habitat Suitability index using the two heather species; both under the reference scenario (dashed lines) and the elevated N scenario (solid lines).



on C/N ration and pH, but leads to a much higher NO_3 concentration in the soil solution.

For this coastal heath site, we then ran the PROPS model using this VSD+ output. To illustrate the effects of soil chemistry on plant species occurrence we selected three species for PROPS: two heather species (*Calluna vulgaris* and *Erica tetralix*) and one grass (*Dechampsia flexuosa*). The isolines of occurrence probabilities (Figure 4.4) show that these species prefer low pH, but that, as expected, *D. flexuosa* has higher occurrence probability at high N concentrations than the two heather species.

VSD+PROPS simulations show an increase in occurrence probability for *D. flexuosa* between 1970 and 1995 (Figure 4.5), coinciding with the period of elevated NO_3 concentrations (see Figure 4.3). At the same time, occurrence probabilities of the heather species decrease. This effect is amplified in the high N deposition scenario.

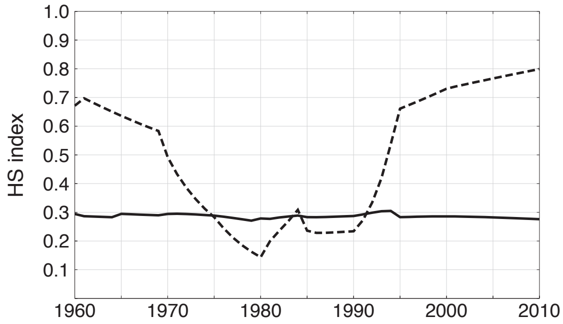
Since the HS index should be computed for desired species only, for the purpose of illustration, we selected the two heather species as desired. Their HS index shows a sharp decrease in the period with high NO_3 concentration, but recovers when N deposition is reduced and NO_3 concentrations decline.

4.4 Recommendations

A proper selection of species to be included in the HS index is crucial. If we use all 24 species listed as 'typical' for this vegetation type, the temporal development of the HS index is very different (Figure 4.6) and shows only limited effects of the simulated soil acidification and eutrophication.

The choice of species to be included in the habitats used in regional assessments thus requires extensive expertise and consensus building. For the CCE background database, a first attempt was made to assign species to EUNIS classes using the Map of the

Figure 4.6 Temporal development of the HS index based on the two selected heather species (dashed line, compare Figure 4.5) and all 24 species of the vegetation type (Frisian-Danish coastal heaths, solid line).



Natural Vegetation of Europe (Bohn et al. 2000/2003). This map provides regional patterns of natural vegetation in Europe for 740 vegetation units. The map is accompanied by extensive descriptions of the vegetation units, including lists of 'dominant and most frequent species' and 'diagnostically important species'. So far the list of dominant species has been used for PROPS testing and applications (see above). It should be noted that PROPS parameters are not available for all these species.

By overlaying this vegetation map with the soil map and land cover (EUNIS) map, combinations of soil, EUNIS and vegetation type were obtained for which tentative simulations with VSD+PROPS were made. Simulations were limited to valid combinations of EUNIS and vegetation type, because due to the differences in map detail, EUNIS and vegetation type may not match.

The first simulations revealed several issues that need to be addressed. First, the Map of the Natural Vegetation of Europe provides the *potential* natural vegetation. This implies that in the low altitude regions of Europe, grasslands hardly occur, as the potential vegetation is forest. Since these nutrient-poor lowland natural grasslands are important for plant species diversity, an alternative approach is needed to assign relevant species for these habitats.

Second, the lists of 'dominant and most frequent species' also contains species that are not necessarily 'desired'. Consequently, computed habitat suitability indices deviate from what they would be if they were based on desired species only. The lists of 'diagnostically important species' per vegetation unit may be more suitable for computing HS indices; this will be explored in future simulations.

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Part 3
NFC Reports

This part brings together the Reports of the National Focal Centres (NFCs) documenting their country's submission of data and assessments in response to the CCE's Call for Contributions, issued in 2012/13 (see also Appendix A).

The reports have not been thoroughly edited, but sometimes shortened (e.g., general descriptions of models, such as SMB or VSD) and minor corrections and harmonisations have been carried out. However, the responsibility for the substance of the National Reports remains with the National Focal Centres and not with the National Institute for Public Health and the Environment.

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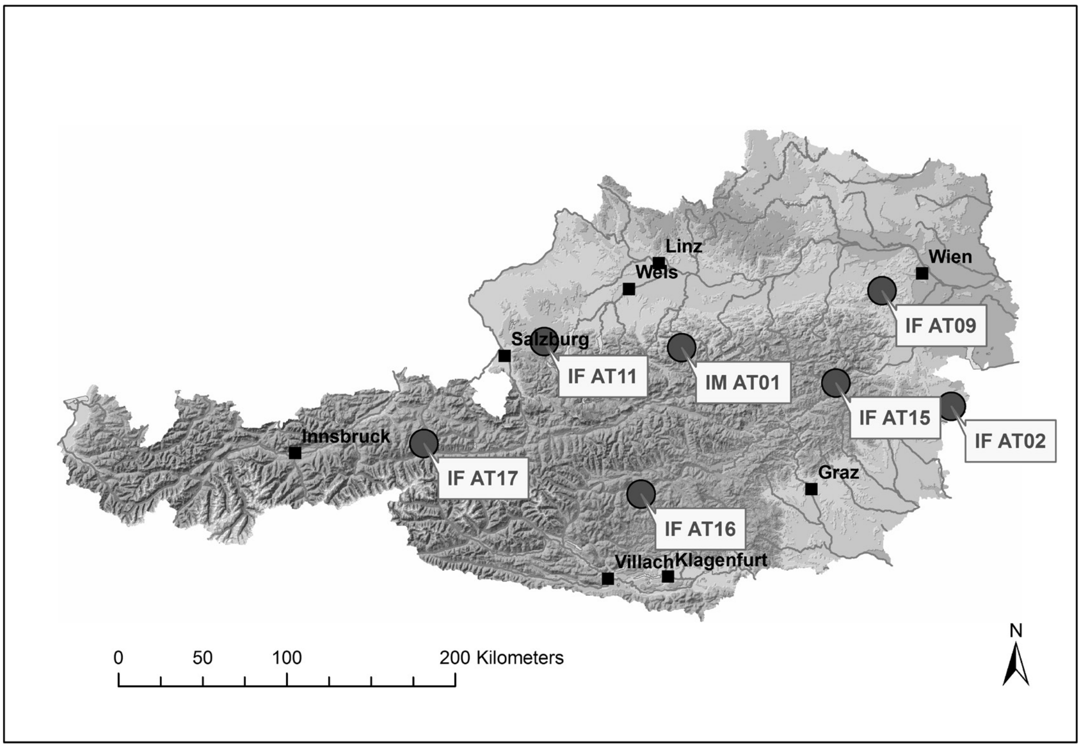
Status

In response to the 2012-2014 Call for Data to test dynamic modelling of vegetation changes at selected sites in a country, the dynamic model VSD+ (including the PROPS module) was calibrated for 8 permanent soil-vegetation plots from the ICP Forests (Level II) and the ICP Integrated Monitoring program. These sites have already been used in the last calls. The improved versions of VSD+ and the new vegetation model PROPS were tested with the available field data. Furthermore, different biodiversity metrics for the detection of eutrophication effects were derived.

Soil-vegetation modelling for sites

Data sources
Dynamic models were calibrated for 6 ICP Forests sites and two plots in the ICP Integrated Monitoring site Zöbelboden (Figure AT.1). Chemical soil parameters, soil water and atmospheric deposition samples were collected frequently and analysed at all sites.

Figure AT.1 Location of the 6 ICP Forests sites and the ICP Integrated Monitoring site (with two plots) used for dynamic soil-vegetation modelling in Austria. See Table AT.1 for site codes and description.



Site description

The ICP Forests and Integrated Monitoring sites are the best investigated forest ecosystems in Austria. They span an altitudinal range from 290 to 1540 m a.s.l., a mean annual temperature between 5 to 9.6 °C and precipitation between 600 and 1600 mm. They are characterised by different soil and bedrock conditions and exposed to contrasting amounts of nitrogen (N) and sulphur (S) deposition. All sites were, at least historically, managed. The main tree species are Norway spruce and European beech (Figure AT.1, Table AT.1). See Neumann et al. (2001) for a detailed description of the ICP Forests sites and the Austrian report to the 2011 CCE Call for Data for the ICP Integrated Monitoring site Zöbelboden.

Parameter setting for VSD+

Soils at most of the sites are characterized by a high proportion of coarse fraction, but the chemical soil parameters were analyzed from the fine fraction (<2 mm). This fact was taken into account by reducing the soil depth by the respective depth of the coarse fraction. All further parameters (CEC, base saturation, etc.) were calculated with the reduced soil depth.

Total deposition of N and base cations were estimated with a canopy exchange model according to Adriaenssens et al. (2013) using bulk deposition measurements. In brief, the total deposition of SO_4^{2-} was assumed to equal the throughfall, whereas the total deposition of NO_3^- and NH_4^+ was calculated based on the throughfall and canopy uptake. Thereto, Na^+ was used as a tracer ion and the weak acids were included in the model and were calculated based on the cation-anion balance. For the canopy uptake of NO_3^- and NH_4^+ we used the relative uptake efficiency of NH_4^+ to H^+ and NH_4^+ to NO_3^- that equals 6. All fluxes are expressed on an equivalent basis per hectare and year. Subsequently, the results were scaled to the modeled EMEP grid cell values. Finally time series were derived from historic depositions of NO_3^-, NH_4^+ and SO_4^-, provided by the CCE. In order to match with measured data, the historical depositions were apriori modified by multiplying with a variable factor, while for the adjustment of the projected depositions a constant factor was used (Schöpp et al. 2003). We defined two N deposition scenarios: a low deposition scenario reflecting potential future emissions under the Gothenburg protocol and a high deposition scenario with no reduction after the year 2010.

Deposition of base cations was taken from van Loon et al. (2005) for the year 2000. An increase of 70% was assumed from 1880 to 2000 and 50% from 1970

Table AT.1 Site description of the ICP Forests and the ICP IM sites used for dynamic soil-vegetation modelling in Austria. Alt: Altitude above sea level; T: mean annual temperature; P: annual precipitation; CLemp: empirical critical load of nitrogen for eutrophication effects.

Site name	Site code	Alt [m]	T [°C]	P [mm]	Soil type(s)	Total N Deposition [kg $ha^{-1}yr^{-1}$]*	EUNIS classes	CLemp [kg $ha^{-1}yr^{-1}$]
LTER Zöbelboden IP1	AT01_1	895	7.2	1618	Rendsic Leptosols/ Chromic Cambisols/ Hydromorphic Stagnosols	26.9	Mixed Abies - Picea - Fagus woodland (G4.6)	10-20
LTER Zöbelboden IP2	AT01_2	879	7.2	1618	Lithic and Rendsic Leptosols	25.2	Mixed Abies - Picea - Fagus woodland (G4.6)	10-20
Unterpullendorf	AT02	290	9.6	630	Eutric Stagnic Vertic Cambisol	15.0	Thermophilous deciduous woodland (G1.7)	10-20
Klausen-Leopoldsdorf	AT09	510	8.2	804	Endostagnic Endoskeletic Luvisol	11.5	Fagus woodland (G1.6)	10-20
Mondsee	AT11	860	7.4	1330		14.5	Abies and Picea woodland (G3.1)	10-15
Mürzzuschlag	AT15	715	6.0	933	Eutric Calcaric Endoskeletic Cambisol	8.3	Abies and Picea woodland (G3.1)	10-15
Murau	AT16	1540	5.0	918	Hyperdystric Endoskeletic Cambisol	1.7	Abies and Picea woodland (G3.1)	10-15
Jochberg	AT17	1050	5.7	1358	Eutric Stagnic Episkeletic Fluvisol	5.0	Abies and Picea woodland (G3.1)	10-15

*mean wet and dry inorganic N deposition between 1995 and 2010

to 2000 (Hedin et al. 1994). A further decrease of 10% until 2009 was estimated from the throughfall data.
Reduction factors (rf*), temperature (TempC) and water retention (Theta) was calculated with the model Methyd on daily (AT01) or monthly (all other sites) meteorological data. C, N, base cation uptake as well as litterfall were modeled with the model GrowUp. Management was defined by a standard forest yield model and field data. After the year 2010 tree thinning was simulated to achieve a steady state of the stand biomass. Tree species specific biomass data were not adapted to measurements but taken from the Growup database. The following pairs of parameters were calibrated with VSD studio: lgKAlBC and lgKHBC, Cpool_o and CNrat_o, Ca_we and Mg_we.
We used PROPS to model the effect of soil chemical changes to vegetation. For each site all plant species of the respective EUNIS class – as defined in PROPS – were modelled (see Table AT.1). Several biodiversity indicators were calculated for each year: Shannon index (Shannon), species numbers (SpecNum) and two specific indices related to species groups (oligotrophic: w_mean_p_Oligo, eutrophic: w_mean_p_Eutro). The latter should reflect eutrophication effects in indicator species according to Ellenberg's nutrient value: First, species with low

(1-3) and high indicator values (7-9) were grouped. Species with low Ellenberg values 1-3 are bound to nutrient-poor sites; species with N values 7-9 prefer nutrient-rich sites. Ellenberg values were transformed in order to upgrade species with extreme site preferences (original values 1, 2, 3 transformed to 3, 2, 1 and 7, 8, 9 to 1, 2, 3). Then we calculated a weighted mean occurrence probability for each year and group. The selection of these indicators were stimulated by the findings of Dirnböck et al. (2014), where only oligotrophic species have shown changes in cover in long-term European forest data.
The simulation period was set to 1950 as the starting year and 2100 (GP Scenario) as the end of the model runs.

Results and Discussion

VSD+ has been changed since the last call for data (2011/12). The integration of a different carbon model (RothC) has significantly improved the model performance. As a result, C pools and C/N ratios can be modelled with satisfactory accuracy (Figure AT.2). Chemistry of soil solution however, is highly variable (Figure AT.3). Since NO_3^- is used as an indicator for changes in plant occurrence probability, predictions should be more reliable. It has been discussed (ICP Modelling and Mapping Meeting 2014, Rome) that C/N ratio should be used instead of NO_3^-, because model accuracy was shown to be higher and because C/N ratio is less prone to confounding effects.

Furthermore, carbonate bedrock is taken into account in the current VSD+ version. However, we were not able to model soil solution pH value with satisfactory reliability (Figure AT.3). Further work is necessary to improve the model output and the model calibration.

Vegetation modelling is still in progress. The PROPS model is currently extended with regard to its underlying soil-vegetation data base and with regard to the derived biodiversity metrics. Our work did therefore focus on first test runs and on the definition of practicable metrics. We conclude that

- It is crucial that a representative set of soil-vegetation data records are used in PROPS to derive statistical response curves of the plant species. The Federal Research and Training Centre for Forests, Natural Hazards and Landscape, Austria has provided approx. 500 such records, and PROPS can be better applied for Austria during the next CCE Call for Data.
- The choice of species should reflect only those species which are “indicator species” in the potential natural plant community which is characteristic of the plot. This should be a suit of 5-15 species selected from national plant community catalogues. In the next call for data, it is intended to apply the BERN model to define the indicator species for each of the Austrian plots.
- The use of the most practicable biodiversity metrics has been discussed and agreed upon at the ICP Modelling and Mapping Task Force meeting in Rome, April 2014. The indices that were

Figure AT.2 Comparison of modelled (VSD+) and measured topsoil C pool and C/N ratio of 8 forest sites in Austria. Soil chemical measurements were taken from the years 1992, 1995, 2004 and 2008.

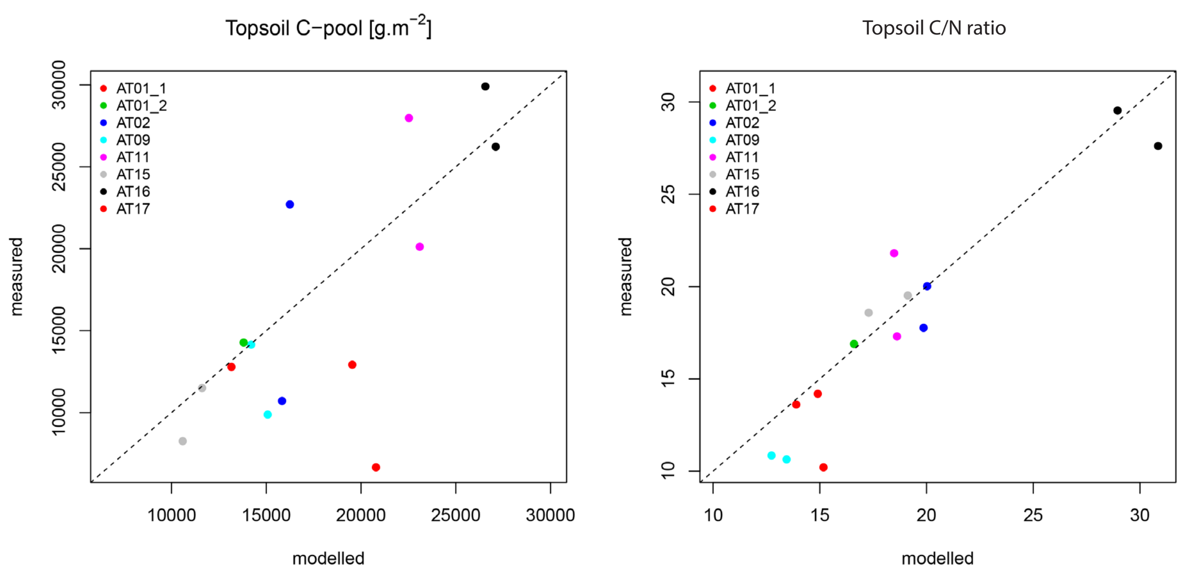
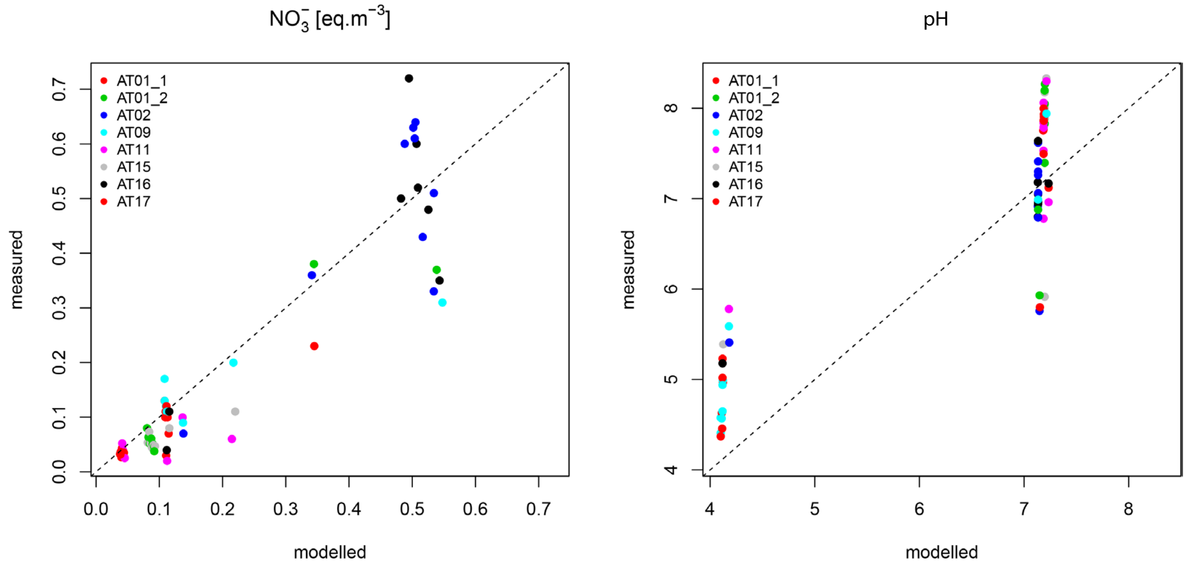


Figure AT.3 Comparison of modelled (VSD+) and measured soil water NO_3^- concentrations and pH values for the 8 forested sites in Austria. Measured annual mean values from the years 1993 until 2009 were used.



used in the Austrian NFC were a valuable input to the discussions. The agreed index, the so-called 'habitat suitability index', will be calculated during the work for the next call for data.

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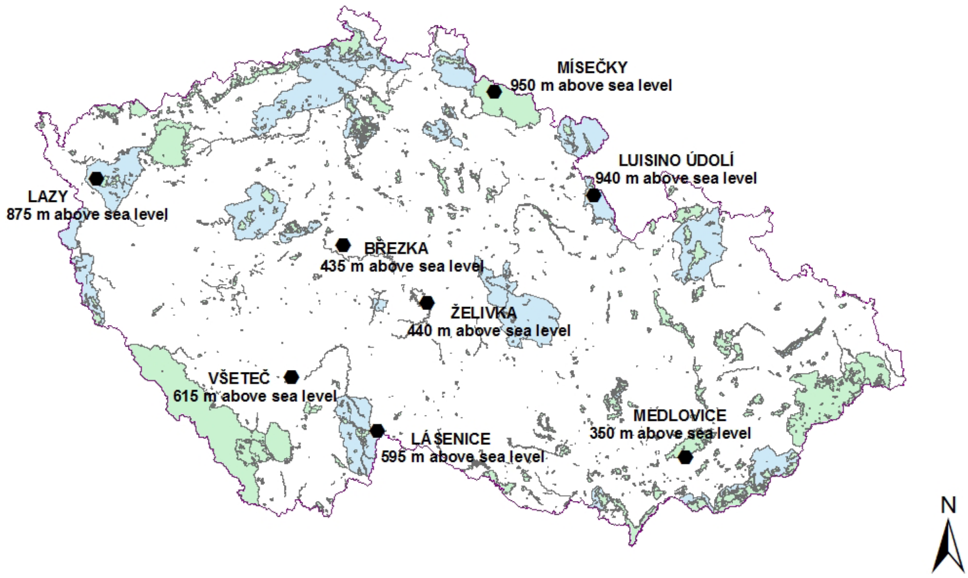
Introduction

The aim was to compare nitrogen atmospheric deposition to biodiversity in the eight forest plots of intensive monitoring (level II) included in the International Cooperative Programme for Forests (Figure CZ.1). The plots in question are Mísečky, Želivka, Lásenice, Všeteč, Lazy, Luisino údolí, Medlovice, and Březka. Monitoring of the forest plots operated by the Forestry and Game Management Research Institute has provided data on the environmental properties of the forests since 1994 (Boháčová et al. 2010). The evaluation of the relationships between nitrogen (N) depositions and biodiversity are partial results of the grant project entitled "Forest soil state as a determining factor of health state development, biodiversity and filling productivity and outside productivity functions of forests", which is performed under the sponsorship of the Ministry of Agriculture of the Czech Republic (Novotný et al., 2013). Atmospheric sulphur (S), oxidized and reduced N depositions, meteorological characteristics and soil properties, including soil solution chemistry, have been related to the forest ground vegetation (herbal floor). The data set incorporated into four tables was prepared for the last Call for Data 2012/14 and processed with the use of measurement data only.

Figure CZ.1 Location of the forest plots included in the Call for Data. Blue and green background areas in the figure belong to Nature 2000 and national protected areas, respectively. Source: Agency of Nature and Landscape Protection (2013).



Forests of the Czech Republic, indicated by the selected plots in Figure CZ.1, fall into four forest habitats according to typological classification. These are mostly beach wood forests characterized by classes L5.1 or L5.4 of the Catalogue (Chytrý et al. 2001), which comprise mountain acidophilous spruce-beech woodland Callamagrostio-villosae ass. (Mísečky), acid oak-beech woodland with Deschampsia flexuosa (Želivka), fresh beech woodland with Galium odoratum (Všeteč), acid fir-beech woodland of Deschampsio-flexuosae-Abietinum ass. (Lásenice) and acid spruce-beech woodland of Luzulo-Fagetum montanum ass. (Lazy). These habitats can be summarized as G1.7 Medio-European acidophilous beech forests in the EUNIS classification. Acid beech-oak woodland with Carex sp. (Březka) and fresh beech-oak forest with Luzula luzuloides and Galium odoratum (Medlovice), characterized by classes L7.1 and L6.4, respectively, can be compared with the category G1.8 Medio-European acidophilous oak forests. Another category consists of climax spruce stands with beech and maple admixture (L9.1) and can be classified into the EUNIS system as G3.2 Hercynian subalpine spruce forests (Luisino údolí). The transfer of typology of forests to EUNIS classes was carried out according to the above-mentioned catalogue (Chytrý et al. 2001).

Methodology

Table CZ.1 presents the main characteristics of the examined forest plots such as soil types and textures, background rocks, the main tree species and their average annual growth. The soil texture is represented by a soil layer of 40 centimetres from the surface. Annual growth of trees is represented by wood increments (in dry mass) calculated on the basis of tree height and thickness measurements (thickness of trees must be greater than 7 cm). Tree growth monitoring has been performed in five year intervals since 1999 (Mísečky, Želivka, Březka, Lazy) or 2004 (Všeteč, Lásenice, Luisino údolí, Medlovice). Most of the data was acquired on a monthly basis by a uniform methodology (Clarke et al. 2010). The data on precipitation, temperature and radiation were taken from continuous measurements. Their daily data were used and processed by the MetHyd model.

Soil properties such as the texture and basic chemical composition were measured in 2006. Soil characteristics in the table 'ecords' represent a soil layer of 40 centimetres measured from the surface. The data on slopes, aspects and altitudes were taken from the geographical map. Information on the values of 'TempC' and 'Theta' represent the annual averages of daily measurements in the period from 2005 to 2010. Parameters of the table 'DRpoint', such as concentrations of N, base cations, pH and alkalinity in the soil solution are observed in samples

Table CZ.1 Site characteristics of forest plots.

Site	Name	Trees	Annual average growth in kg ha^{-1} a^{-1}	Background rocks	Soil type	Soil texture
2015	Mísečky	Beech, spruce	1693.43	Biotitic slate	Podzols	Sandy loam
2161	Želivka	Spruce	3776.31	Paragneiss	Cambisols	Loam
2102	Březka	Oak and other deciduous	5254.66	Biotitic granodiorite with amphibole	Cambisols	Loam
2103	Všeteč	Beech	9506.05	Biotitic paragneiss	Cambisols	Sandy loam
2163	Lásenice	Spruce, beech, fir	6818.22	Dune sands	Podzols	Loamy sand
2251	Luisino údolí	Spruce	3716.73	Gneiss-migmatite	Podzols	Sandy loam
2361	Medlovice	Beech, oak, pine, larch	6542.20	Clay stone to sandstone glauconitic rocks	Cambisols	Sandy loam
2521	Lazy	Spruce	4034.95	Coarse-grained biotitic granite	Podzols	Sandy loam

collected under the soil organic layer in the given year. Values of Cpool, CNrat, bsat and Qle evaluate the top soil layer up to a depth of 10 cm.

Data on deposition measurements used for the elaboration of the table 'DRpoint' were assessed on the basis of bulk and throughfall samples and their analyses. Throughfall and bulk depositions have been measured since 1996 (1997) in four plots (Mísečky, Želivka, Medlovice and Lazy). Deposition data has been provided from the forest plot of Březka since 2000. The monitoring of the remaining forest plots began in 2003 or later (Luisino údolí in 2004). Stem flow samples were collected from the plots of the deciduous forests - in Medlovice, Všeteč, and Mísečky. Procedures for measurements in the forest plots are comparable with other deposition measurements within the ICP Forests and UNECE programmes. Total depositions for the forest ecosystem were calculated according to the methodology published in Draaijers et al. (1995, 1998). Total depositions of reduced N forms are derived from modelled dry depositions of ammonia in gaseous form (Zapletal 2013 in: Novotný et al. 2013).

The state of ground vegetation in the forest experimental plots (in the table 'Composition') is assessed using a semi-quantitative method of phytocenological snaps. The eight-member, modified, combined scale of abundance and dominance from Braun-Blanquet (1965) is used. The presence of all vegetation species in herb layers (used in this evaluation) was registered, and the coverage or respective number was visually estimated and classified within the following scale:

- r: very rare species, mostly only one or few individuals of negligible coverage
- +: rare species (at least two individuals in the plot) or few individuals of low coverage
- 1: frequent species, but of low coverage, or less frequent more dense coverage, 5% maximally (often individual bushes or rarer grasses)
- 2a: very frequent species (abundant) high number of small individuals of about 5% coverage, or lower number of bigger plants of 5-12.5% coverage
- 2b: same as 2a. Coverage always 12.5-25% of total area
- 3: coverage of species 25-50%
- 4: coverage of species 50-75%
- 5: coverage of species 75-100%

These items are considered for the average values of the coverage by the individual species of herbs in the given ranges. Items indicating very rare and rare species are interpreted as being 0.1% and 0.5% of the coverage, respectively. Item "1" represents 2.5% of the coverage in this report.

Biodiversity observations in forest plots were made in 2005 and 2009 in most cases. Some of the phytocenological snaps from localities were carried out earlier. For example, four sets of forest vegetation species snaps are available in the experimental plot of Medlovice (1998, 2001, 2005, and 2009). Similarly, biodiversity data were compiled for the years 1996, 2000, 2005 and 2009 in the forest plot of Želivka. The forest plot of Mísečky provides three phytocenological snaps from 1997, 2004 and 2009. Percentages of ground vegetation species coverage in the forest plots only represent herbs (herb forest layer). The composition of forest ground vegetation species in included in the table 'DRpoints' and its item 'DRpointID'. The table 'RefComposition' contains vegetation species occurring in all phenological observations in the forest plot and in the same density of coverage. They can be considered to be typical vegetation species of the site.

Results

Most of the data were compiled for the years of the phenological survey i.e. 2005 and 2009 with the exception of the plots of Medlovice and Želivka (observed four times), and Mísečky (observed three times). Atmospheric depositions of S and N for the given years were calculated from the measured data based on the average annual throughfall, as well as bulk and wet depositions. In addition to the data on atmospheric depositions, some measured parameters of soil properties and the soil solution of the soil horizon to a depth of 40 cm and the upper soil horizon to a depth of 10 cm, respectively, were also calculated. The forest ground vegetation with the most abundant vegetation types is represented by the herb layer.

This layer includes species sensitive to N as well as nitrophilous species. Some herbs are present only on a few less monitored plots and there is either a relatively small number of values for the evaluation or the species occur only sporadically. The maximum occurrence of herb species of vegetation (25-31) can be seen in the forest plot of Všeteč (site ID 2103) with an atmospheric N deposition of about 1280 eq ha^{-1} a^{-1}. Forest plots Želivka (site ID 2161) and Březka (site ID 2102) also show a high occurrence of vegetation species. The number of vegetation species in these plots was in the range of 22 to 26 in the period from 2005 to 2009, with atmospheric depositions of N in the range of 980 to 1230 eq ha^{-1} a^{-1}. On the contrary, the lowest number of ground vegetation species (7 species) was observed in the plot of Lásenice (site ID 2163) with atmospheric N depositions between 1170 and 1250 eq $ha^{-1}a^{-1}$. Ground vegetation species seem to be without a response to atmospheric deposition (both N and S). The relationship of total N depositions and total species coverage shows that vegetation coverage increases with an increase in atmospheric deposition of N (Figure CZ.2). Therefore, the influence of the site environment to dose-response relationships should also be included. If we select a site with a relatively long time series of measurements such as Želivka, for example, we observe a decrease in the number vegetation species at the site with an increase in atmospheric N deposition (Figure CZ.3).

Conclusions

There is an insufficient number of observations to exactly evaluate the extent of atmospheric N deposition. The relatively short time series of measurements and uncertainties in the current total

Figure CZ.2 Relationships between atmospheric N depositions and total coverage by ground vegetation species in the herb layer of forests (the item BIODIVINDEX in the table "DRpoint").

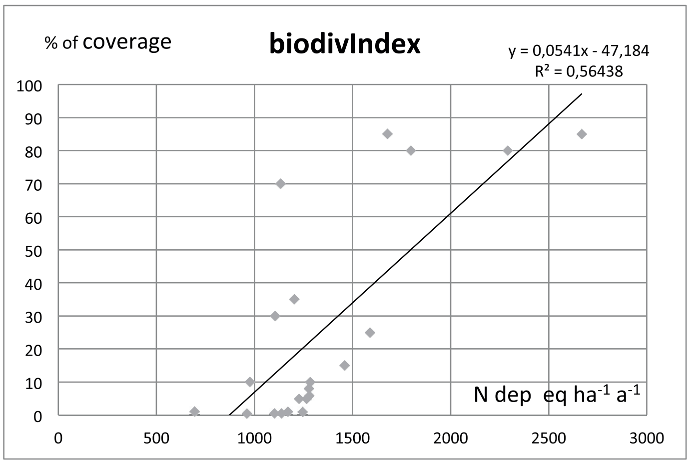
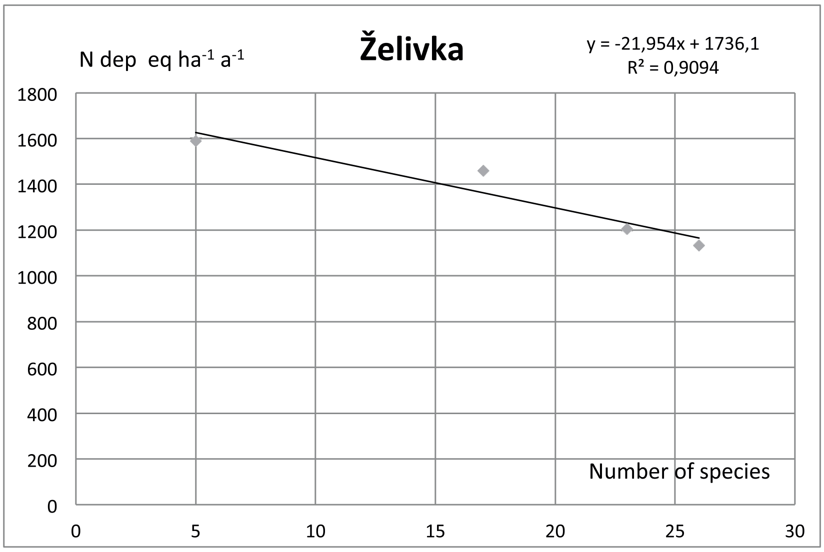


Figure CZ.3 Number of ground vegetation species in the forest plot of Želivka in relation to atmospheric N deposition (in 1996 » 2000 » 2005 » 2009).



atmospheric N depositions also create many obstacles to correct assessment. Biodiversity observations fall in the period with a relatively small gradient of atmospheric depositions of both N and S. The influence of delay in the effect of atmospheric deposition on ground vegetation species was not included in the evaluation. Ground vegetation species should be divided into species sensitive to N and N demanding species for future evaluation. Dose-response functions should also include the environment of the site summarised in the values of critical loads, for example.

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Summary

Finland receives comparatively low nitrogen (N) deposition and it is challenging to separate the impacts of air-borne N on vegetation and biodiversity from those of other concurrent drivers of change such as climate and land use. The long term monitoring results of the Finnish Forest Research Institute indicate that forest management is the most important factor changing forest floor vegetation. Although the development of a metric of "no net loss of biodiversity" on the European scale is important also from the Finnish perspective, Finland has not submitted data in response to this call. Finland participates, however, in the work on method development, or proof of concept, through the exercise led by ICP Integrated Monitoring to apply VSD+ and PROPS to selected IM sites in Europe. In response to an earlier call for data, empirical critical loads of nutrient N were assigned for 20 EUNIS habitat types in Finnish Natura 2000 sites, covering about 41,000 km^2. Although N deposition to Finland is considerably lower than to central or southern Europe, empirical critical loads of N were exceeded at 12% of the area of Finnish Natura 2000 sites with deposition estimates for the year 2000. The highest exceedance (AAE) values were obtained for surface water habitats. There is work in progress on updating the information in the

Finnish Natura 2000 database and after that task has been completed can the exceedance assessment be updated with new deposition scenarios.

Nitrogen effects on biological diversity in Finland

Finnish ecosystems belong primarily to the boreal biogeographical region, extending from 60° to 70° northern latitude and are characterized by comparatively low N deposition (Vuorenmaa et al. 2009) and observed and projected climate warming (Ruosteenoja et al. 2011; Tietaväinen et al. 2010). The Finnish Forest Research Institute surveyed the understorey vegetation on 443 mineral-soil sites in 1985-86, 1995 and 2006 (Tonteri et al. 2013). These sample plots are part of the 3000 permanent sample plots established in 1985-86 (Reinikainen et al. 2000) and they belong to the ICP Forests Level I network. Tonteri and co-workers conclude that the main causes of the observed vegetation changes were forest management practices and natural succession of the stands, although the accumulated N deposition and the long-term lack of forest fires may also have played a role (Tonteri et al. 2013). Although there are now detailed studies on N stocks in forest ecosystems (Merilä et al. 2014), the work in progress on assessing the role of air-borne N in vegetation changes in Finland is challenging because the comparatively low signal of N deposition is masked by concurrent climate warming, forest succession and forest management. Merilä and co-workers (Merilä et al. 2014) report N stocks in different compartments, including ground vegetation, of forest ecosystems in Finland (tree stand and soil, litter layer, ground vegetation and fine and small roots). They conclude that the understorey vegetation N stock was largest in northern spruce stands and smallest in southern spruce stands (Merilä et al. 2014).

In a recent study on the response on forest floor vegetation to N deposition in Europe, Dirnböck et al. (2014) found that the cover of plant species which prefer nutrient-poor soils decreased the more the measured N deposition exceeded the empirical critical load for eutrophication effects (CLempN). Four Finnish monitoring sites were included in the study. At these sites, the N deposition was considerably lower (0.6–1.9 kg N $ha^{-1}yr^{-1}$) than the deposition in Central Europe (10–20 kg N $ha^{-1}yr^{-1}$) or Italy (20–30 kg N $ha^{-1}yr^{-1}$). Although the N deposition levels in northern Europe are comparatively low, even a small increase in chronic N deposition may change the competitive relations of vascular plants by favouring the establishment and growth of eutrophic species or overstorey trees.

Pollution pressure reported for Habitats Directive

Air-borne N has been identified as a pressure for 18 habitat types in the reporting under Article 17 of the Habitats Directive of the EU, including many habitat types characterised by naturally low levels of N such as active raised bogs (7110), open rocky habitats and many coastal habitat types of the Baltic Sea. In most cases, air-borne N is just one component of human induced eutrophication that causes overgrowth of open habitats by saplings and bushes and changes species composition. Although air-borne N input was reported as a pressure only for one species (Pulsatilla patens), it is among the drivers of overgrowth for a number of species. The reported pressures for the Habitats Directive are primarily based on qualitative analysis. The options of utilizing quantitative indicators to support the evaluations for the reporting to the Habitats Directive have not yet been fully explored in Finland. For example the regional distribution of the exceedance of critical loads of eutrophication would contribute an additional source of information to the reporting of pressures on biodiversity.

Exceedance of empirical critical loads of N

In response to an earlier call for data, empirical critical loads of nutrient N were assigned for 20 EUNIS habitat types in Natura 2000 sites, covering about 41,000 km^2. The largest areas were covered by forest, mire and surface water habitats, extending to about 18,000, 16,000 and 6000 km^2, respectively. Empirical critical loads of N were exceeded at 12% (4776 km^2) of the area of Finnish Natura 2000 sites (Holmberg et al. 2011), with deposition estimates for the year 2000. Only the maximum feasible reductions scenario would protect all Natura 2000 sites in Finland. The highest average accumulated exceedance (AAE) (< 2 kg N ha^{-1} yr^{-1}) values were obtained for surface waters, which were assigned the lowest empirical critical loads (3 kg ha^{-1} yr^{-1}). In the Finnish Natura 2000 sites, most waters are oligothrophic (4 501 km^2), only a small number of protected lakes are naturally eutrophic (31 km^2), occurring mainly in clay soils in southern Finland. Although the naturally eutrophic lakes were not discussed by (Bobbink and Hettelingh, 2011), a low value (3 kg ha^{-1} yr^{-1}) was used for their critical load of N. This was motivated by the importance of the naturally eutrophic lakes in the nature protection areas and because of lack of evidence that they would sustain larger amounts of atmospheric N than other lakes. Of all habitat types in Finnish Natura 2000 sites, dystrophic lakes showed the highest percentage of area exceeded (82% or 1242 km^2) with deposition estimates for the year 2000 (Holmberg et al. 2011).

There is work in progress on updating the information in the Finnish Natura 2000 database, and after that task has been completed the exceedance assessment can be updated with new deposition scenarios.

Indicators of biological diversity in Finland

A recent report on metrics of ecosystem services was published in Finnish (Kniivilä et al. 2013). The authors summarize that indicators applicable for monitoring biological diversity have been developed since 2004 in Finland. The indicators have been closely related to monitoring the effects of policies of natural diversity and they have been used primarily for the evaluation of the national biodiversity strategy and the Finnish reporting to the CBD (Auvinen et al. 2010; Normander et al. 2012). The primary channel for publication of the Finnish biodiversity indicators is the website www.biodiversity.fi/en/, which provides a thematic overview of the indicators by main habitat type (forest, mires, Baltic Sea, inland waters, etc.) and with respect to climate change and invasive species.

TEEB Finland (2013–14) is a project that aims to initiate a systematic process to incorporate the value of ecosystem services into all levels of decision-making in Finland. The goal is to identify the key ecosystem services and propose methods to assess their current status and future trends. The project pays special attention to the regulating and cultural services that thus far have received limited attention. TEEB Finland is building on the TEEB Nordic scoping assessment (TEEB 2013) and it is implemented in close co-operation with a number of ongoing national projects, e.g. developing national ecosystem service indicators (FESSI) and Green Infrastructure projects (GreenFrame). Biological diversity and well-functioning ecosystems provide also essential services for human health and well-being. Within the scope of a recent project on Ecosystem Services and Human Health, the Finnish Forest Research Institute and the Finnish Environment Institute collaborate with the aim to improve multidisciplinary collaboration in the studies of ecosystem services with the focus on human health and well-being.

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Introduction

The 2012/14 Call for Data aimed to evaluate the 'no net loss of biodiversity' due to long-range transboundary air pollution. The objectives of the French NFC over these last two years were to model vegetation and soil response to nitrogen (N) atmospheric deposition. Since the last call for data, in order to integrate the "no net loss of biodiversity" in the simulation process, the French NFC focused on the following items: i) first, we continued to improve the biogeochemical-ecological coupled ForSAFE-Veg model by applying it on a variety of French forest reference sites, integrating, calibrating and validating new data; ii) second, we worked on an harmonization of the French forest ecosystem map using the EUNIS classification; iii) third, we evaluated the separated and combined impacts of atmospheric deposition scenarios, climate change scenarios and forest management on model outputs; iv) finally, we looked for a simple biodiversity index that let to quantify changes in vegetation biodiversity regarding these changing inputs. To reach these objectives, we used particularly input data from three very well documented forest sites belonging to the French ICP forest network (RENECOFOR, National network of forest health survey from the National Forest Office), which is part of the European network for forest health survey since 1992.

Sources and methods

Sites characteristics and input data

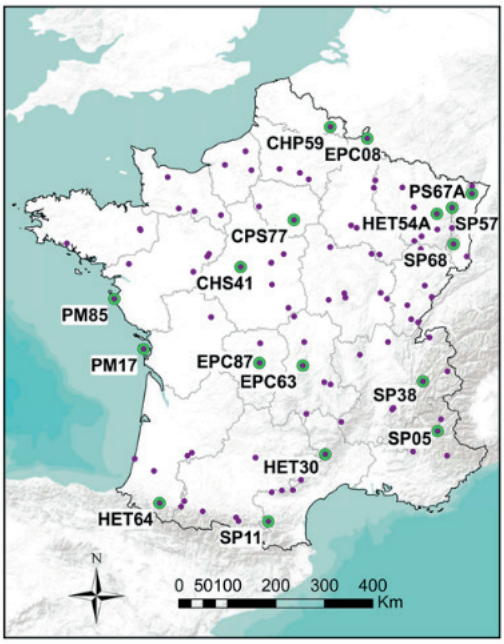
The French ICP forest network is a 102 sites network located over the whole territory (Figure FR.1). These 102 sites are regularly surveyed and sampled for numerous environmental variables, depending on their description level. The National Forest Office, in charge of this survey and on the forest management, uses three levels of description for the observed variables. The first level of description concerns the environmental characteristics of the sites such as site description, trees inventory. The most detailed description level concerns 17 reference sites that belong to the CATAENAT sub-network (Figure FR.1). The same data of the first level are described, but it also integrates data from atmospheric deposition and soil solutions (concentrations and fluxes). Several variables are observed in each level of description. The most important variables are listed in table Tab.FR1 with the number of sites where they are sampled (Ulrich et al. 1995).

All these data are available for modelling purpose, and they are compiled in a detailed database developed and managed by the French NFC. Indeed, the biogeochemical-ecological models used (ForSAFE-Veg and VSD+Veg, for details see Wallman et al. 2005; Belyazid et al. 2011; Bonten et al. 2009) require information on deposition and also concerning the chemical composition of soil solution, e.g., for output validation (see Probst et al. 2012). That is why we focused on the 17 reference forest sites (Figure FR.1) to continue our intensive work of model calibration and validation since they

Table FR.1 Number of sites and most important variables sampled.

Number of sites	Operation types
102	Site description
	Trees inventory and dendrometric measures
	Dendrochronology
	Observations: defoliation, pathological symptoms…
	Phenology
	Litter fall sampling
	Leaves analysis
	Soils description and analysis
	Inventories of vegetation ecology
	Meteorological data
	Phytoecological surveys, list of plants
17	Open field and throughfall deposition
(addition variables)	Fog analysis (punctually in foggy weather)
	Soil solution concentration and fluxes

Figure FR.1 Location of the 102 RENECOFOR forest sites and the 17 CATAENAT reference sites. Sites are identified by letters indicating the dominant tree species of forest stand. CHP = *Quercus robur* L., CHS = *Quercus petraea* Liebl., CPS = mixed *Q. robur*/*Q. petraea*, EPC = *Picea abies* (L.) Karst., HET = *Fagus sylvatica* L., PM = *Pinus* pinaster Aiton, PS = *Pinus sylvestris* L., SP = *Abies alba* Mill. Numbers correspond to the French department where the sites are located (Ponette et al. 1997).



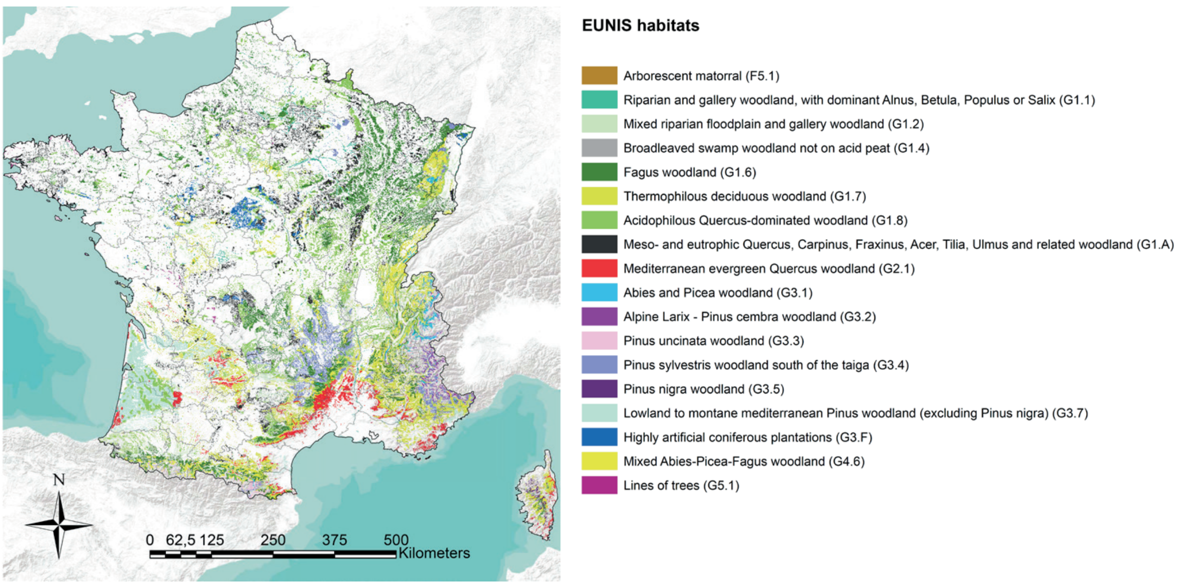
are representative of a variety of French forest conditions. Moreover, the information on the main tree species present or installed on each site allow to determine the forest stand type and the habitat type. In addition, exhaustive plants relevés are performed every five years on each of the 102 sites, which inform about plant associations and site conditions.

Update of the French ecosystems map using the EUNIS classification

The characteristics of the French forest sites were normalized by using the EUNIS European classification of habitats as a harmonized reference. This updated French forest map enables a better collaboration with other countries and a harmonization at the European scale, namely to extrapolate the modelisation process of soil solution and plant responses to various N and climate scenarios, and to produce critical loads maps. For that purpose, we applied two different methods using data from the French potential vegetation map, the Corine Land Cover database, the RENECOFOR database concerning the ICP forest sites and the EUNIS key determination of habitats.

The first method combined the potential vegetation map (Leguédois et al. 2011) and the Corine Land Cover database at a 1:1,000,000 scale. The

Figure FR.2 Updated map of French forest EUNIS habitats (described at level 3, based on the potential vegetation map see Leguédois et al. (2011) and the Corine Land Cover database (2006)

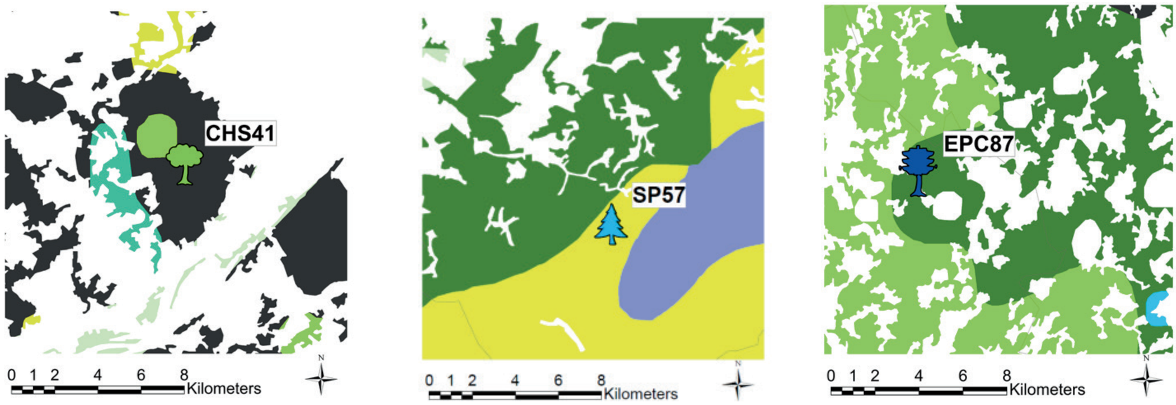


correspondences between mapping vegetation units and EUNIS habitats were determined considering the dominant potential vegetation. An updated map of French forest ecosystems characterized by their EUNIS class of habitat was produced (Figure FR.2). This map localized the French EUNIS habitats at a quite coarse scale (1:1,000,000) for the whole territory. Then, we attributed one class of habitat to each of the 102 RENECOFOR studied sites regarding the habitat classification of its belonging polygon. With this first method, we could classify all the studied sites into the EUNIS classification in relation to their localization and the potential vegetation characteristics of their geographical zone. This method gives good results at a national scale for large surface areas, but for some sites it is not efficient enough to classify habitats at the site scale. For example one of the studied and well documented sites dominated by Picea abies, was classified as Fagus woodland. This wrong designation can be related to a scale effect (too coarse to classify the site habitat), which do not take into consideration the fine scale field reality in the potential vegetation database (such as plantations, agricultural areas…). For these reasons, with this classification method, small surface areas of highly artificial plantation woodlands were considered like larger woodlands located nearby. Thus, this method gives as a whole good classification results, but it is not precise enough in few cases to point out field sites particularities.

As an alternative, a second method was used to encounter local scale and reflect field reality. The corresponding type of habitat was determined by using the environmental characteristics and namely the plant composition of twelve very well documented sites of the French ICP forest network RENECOFOR. We 'read' EUNIS habitat classification key using these input informations for the twelve selected sites. Through a dichotomy lecture of the key, we reached the third level of description and classified the selected sites into the EUNIS habitats classification. This method gave very good results in attributing the right habitat to each site. A routine will be develop to classify automatically the site habitats for the 102 sites, by 'reading' the EUNIS key using site plant relevés and topographical characteristics as input data.

Habitats differences that can be observed by using national or local classification scale are presented on Figure FR.3. Indeed, the two considered methods are complementary: (i) the national-scale map based on the potential vegetation gives continuous description of forest habitats for the whole national territory. This approach provides relevant information in regard to the habitat of forested areas everywhere in France, but it is not sufficient to classify the habitat at a site scale (25% error rate); (ii) on the opposite, the site habitats were classify precisely using field observations, but this method does not allow mapping French forest EUNIS habitats in a continuous way for large areas. This case-by-case classification method can be automatized, but the exhaustive list of present plants is always needed.

Figure FR.3 Illustration of differences between national and local scale EUNIS classification. Background map corresponds to the national scale. Tree symbols represent the local scale. See EUNIS legend on Fig FR.2.



Calculations of biodiversity indices

Several biodiversity indices (species richness, Shannon, Czekanowski…) have been considered to evaluate the impact of dominant tree species on understorey biodiversity, as well as the impact of several EUNIS habitats on the evolution of biodiversity. Here, we illustrate the results with two main biodiversity indices: number of species and Shannon index. Species richness was calculated from the phyto-ecological relevés done by the French National Forest Office on the 102 French ICP forest sites (RENECOFOR network). The evolution of species richness was evaluated for each type of habitat and of dominant tree species at the national scale. The Shannon index (H') was calculated using the relative cover of each plant species for some of well-known studied sites, according to:

(1) $H' = -\sum_{i=1}^{S} x_i . \ln x_i$

With *S* the number of species and x_i the proportion of the *i*-th species.

Selection of the studied sites for modelling purpose

To simulate soil and plant response to nitrogen atmospheric deposition from present day to 2100 and to test an indicator of the evolution of plant composition, we selected three well-documented sites among the 17 reference sites mentioned above, which represent a large gradient of environmental conditions (altitude, geographical conditions, dominant tree species…) and of three typical EUNIS habitats type (Table FR.2). Three different dominant tree species are concerned (sessile oak, silver fir and Norway spruce).

Deposition and climate scenarios

The impact of climate change and atmospheric N deposition on soil solution concentration, and its consequences on vegetation cover, was investigated by combining atmospheric deposition and climate change scenarios. It is indeed a key issue to model accurate critical loads in a context of climate change and forests evolution. Four atmospheric N deposition scenarios – natural background (BKG), Maximum Feasible Reductions (MFR), Gothenburg deposition scenario (GP) and Current Legislation (CLE) deposition scenario – and three climate scenarios have been tested (Figures FR.4 and FR.5), separately or in combination to evaluate their impacts on forest ecosystem response. Atmospheric N deposition and climate change scenarios were respectively provided by the CCE and by the IPCC (Nakicenovic and Swart 2000).
Since 2011, new climate change scenarios were elaborated (RCP 4.5, 6 and 8.5 scenarios, respectively replace SRES B1, A1B and A2 scenarios; Van Vuuren et al. 2011). Our tentative to access to these scenarios (via IPSL and INERIS) did not succeed for the moment. Hence, the simulations consider no change and the A2 and B1 SRES scenarios, which correspond to high and low global warming conditions (Figure FR.5). They were combined to the 4 atmospheric deposition scenarios.

Figure FR.4 Input atmospheric deposition scenarios (note: before 2008, the red line represents historic deposition)

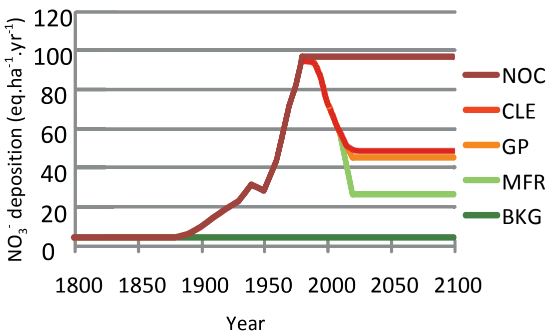
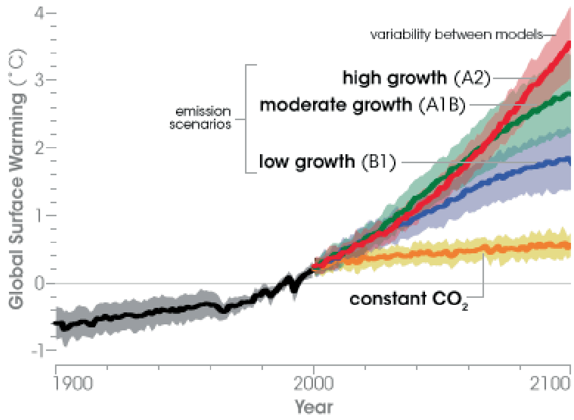


Table FR.2 Three typical EUNIS habitats.

Site	Location	Altitude	Tree dominant species	EUNIS habitat	level_3
CHS41	North-W	127 m	Sessile oak	Acidophilous Quercus dominated woodland	G1.8
EPC87	Center-W	650 m	Norway spruce	Highly artificial coniferous plantations	G3.F
SP57	North-E	400 m	Silver fir	Abies and Picea woodlands	G3.1

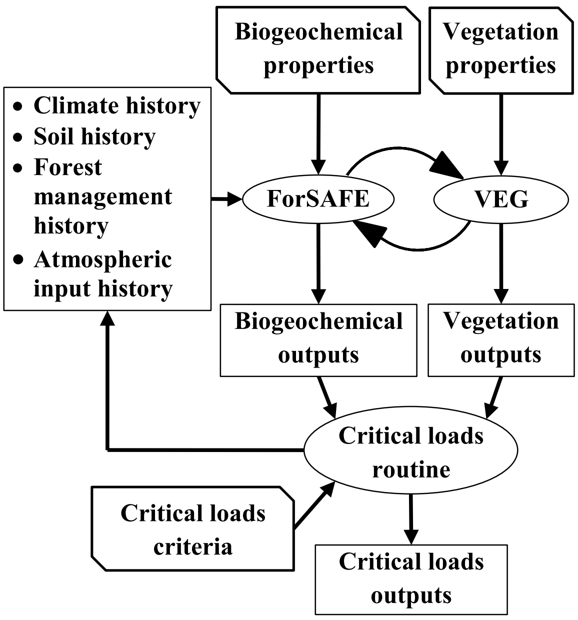
Figure FR.5 Emission Scenarios of the IPCC Special Report on Emission Scenarios (IPCC 2007).



Model description

The ForSAFE-Veg model is a dynamic coupled biogeochemical (ForSAFE) and ecological (Veg) model, particularly adapted for use at the site scale (Belyazid et al. 2011; Sverdrup et al. 2007) (Figure FR.6). The French NFC started working with the ForSAFE model a long time ago and had close interactions and fruitful exchanges with Swedish modellers (see Probst et al. 2012). During the last two years, hard work has been done on the improvement of ForSAFE-Veg to calibrate and validate data and add new laws, which lead to improve the model code and get robust and useful input and output data. For example, the biological retention of N by soil micro-organisms has been introduced as well as an improvement of the formula which simulates the organic matter decomposition (Gaudio et al. submitted). In the meantime, the French input database has been revised and updated, too.

Figure FR.6 The layout of the ForSAFE-Veg system. The biogeochemistry data, input histories and ground vegetation parameter files provide inputs to the model (Sverdrup et al. 2012).



Species richness and harmonized biodiversity index

The change in biodiversity was evaluated on the three selected sites by using two different methods: (i) the first one uses measured species abundance/ dominance. During the years 1995, 2000 and 2005, vegetation relevés with plant abundance were performed by the National Forest Office on each site. The presence/absence for each species allowed evaluating the change of the plant composition of a given site between 1995 and 2005. For each site, we considered all the species at least registered once. This method could not be extrapolated to other periods due to lack of measured data ; (ii) to simulate the plant composition until 2100, a second method aims at predicting the presence probability for around 470 plant species, in relation with the variations of some environmental parameters, such as pH, C/N, mean temperature, minimal temperature and soil water content. Outputs of the ForSAFE model were used to model and quantify the changes on those parameters until 2100. Then, for the entire list of 470 plant species, a routine calculate plants presence probability considering the growth optimum value for each parameter, and thus simulate the evolution of species presence/absence until 2100 for the sites.

Work on the Veg table

To evaluate the 'No net loss of biodiversity' due to the impact of atmospheric N deposition, the plants response and changes in biodiversity over time are estimated using coupled geochemical-ecological models. During the last two years, the French NFC worked on the calibration of the Veg module of the ForSAFE-Veg model, based on a list of reference plants characteristic of French forest ecosystems. In a first attempt, the European Veg database was fed by a large variety of French list of plants (230 species) described by around 20 environmental parameters. But this table was enriched by various expert opinions all over Europe for 415 plant species, which lead to a discrepancy to French ecological references and the list of representative species of French ecosystem. About 200 species observed in the RENCOFOR sites were not in the table. To run the

Table FR.3 Description of the input parameters in the Veg table.

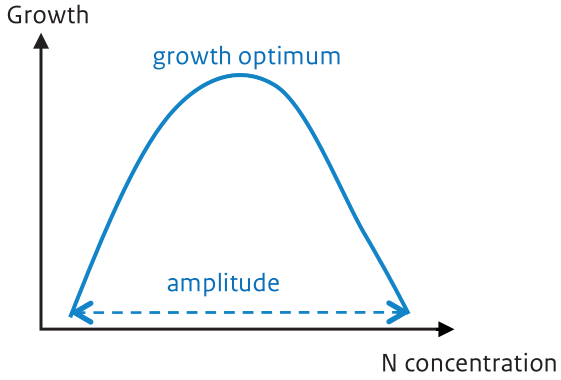
	Variable	Unit	Description
Nitrogen	K+	mg N/l	Nitrogen promotion factor
	K-	mg N/l	Nitrogen inhibition factor
	W	unitless	Slope of the nitrogen response curve
Calcium	kCa	mg Ca/l	Calcifuge inhibition factor
pH	pHhalf	pH	pH promotion factor
Soil moisture	Wmin	yearly average of % soil moisture saturation	Minimum water threshold
	Wtop	% soil moisture saturation	Optimal water threshold
	Wmax	% soil moisture saturation	Start of water inhibition
Temperature	Tmin	Yearly average air temperature in °C	Minimum temperature threshold
	Ttop	Yearly average air temperature in °C	Optimal temperature
	Tmax	Yearly average air temperature in °C	Upper temperature limit
Light	Lmin	Yearly average in µmol (photons)/ m^2,sec	Minimum PAR requirement
	Lmax	Yearly average in µmol (photons)/ m^2,sec	Optimal PAR threshold
Species characteristics	H	m	Plant shading height
	root_class	unitless	Root depth class
	Grazing	unitless	Palatability factor
	Years	years	Plant longevity
Species classification	Group code	not a factor	Plant group code
	Group	not a factor	Plant group name
	EUNIS Classes	not a factor	EUNIS class membership

Veg model on French sites, it was thus necessary to revise the table to improve the list and to harmonize the inputs parameters since for example they were described by 1, 2 or 3 variables (Table FR.3).

It was decided to keep two variables for parameters description so that plant response curve was characterized by amplitude and an optimum (Figure FR.7).

Including this kind of plants response curve is in progress for each of the 415 species of the Veg table. Nevertheless, the most important point remains to calibrate accurately the parameters of this table since they are the input data of the Veg model. For that purpose, we used quantified data, which origin are well known and well defined for French ecosystems, and mostly correspond to measured data instead of expert advices. The parameters must have ecological sense, and stay compatible with the Veg model input requirements. The EcoPlant database (Gégout 2001; Gégout et al. 2003) can be used, since it gathers thousands of phytoecological relevés with corresponding measured soil parameters. The available data must be adapted by developing extrapolation laws and combining variables in order to parameterize all the model input parameters into the right units.

Figure FR.7 Theoretical plants response to nitrogen concentration parameterized by two amplitude and optimum.



As an example, for light the percentage cover of tree dominant species was used to determine the response to light requirement in µmolphoton.m^{-2}. The cover percentage of each plant species from the 102 RENECOFOR sites was used to calculate the percentage of light beams that crosses the canopy and reaches the ground, using an adaptation of the Beer-Lambert formula (Anderson 1966; Nilson 1971).

(2) $I = I_o\, e^{-k \cdot rec}$

With I the intensity (power per unit area) of the transmitted radiation, I_o the intensity of the incident radiation, k the light extinction coefficient, and *rec* the cover percentage of dominant trees.

For temperature, we used two independent variables such as the mean annual temperature and the mean temperature of the coldest month of the year (January), which mimic benefit and inhibition effects of plants growth, respectively. Temperature data are from the EcoPlant database (Gegout et al. 2005).

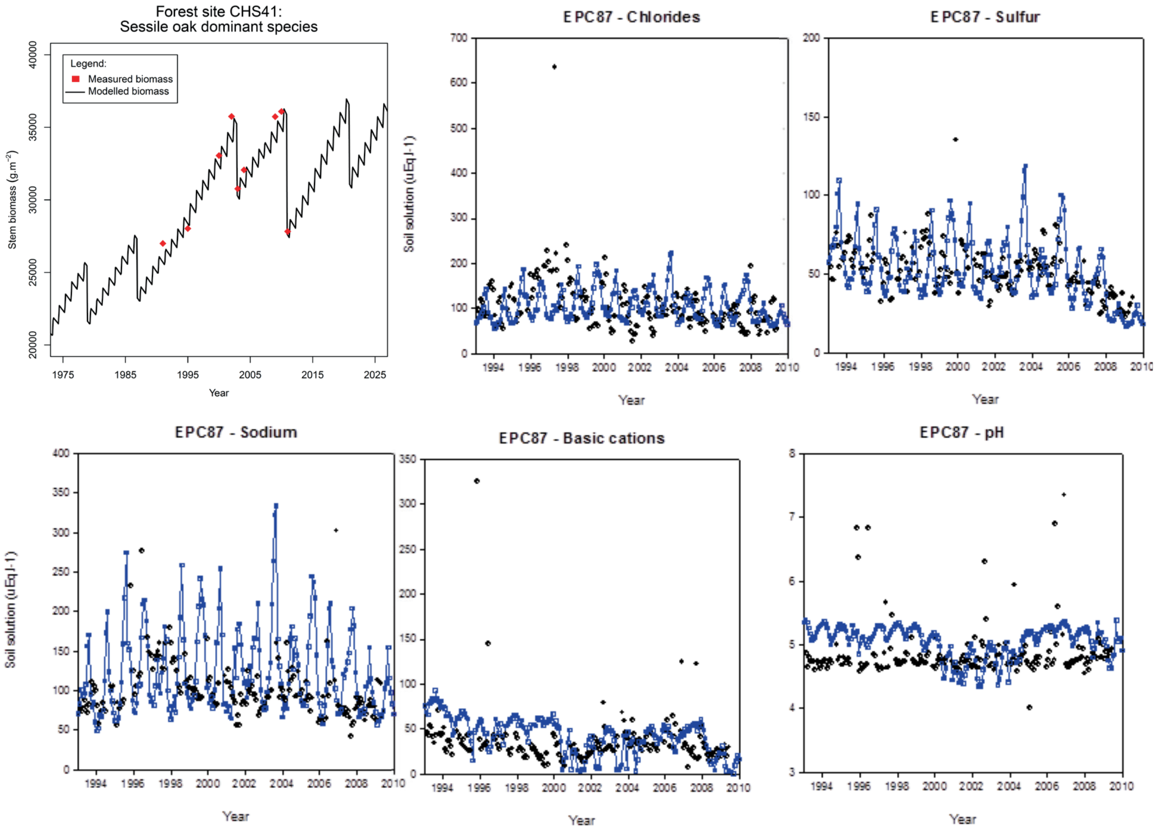
Modelling results

We present the results concerning the outputs of the biogeochemical model ForSAFE: first, the soil solution composition and the stem biomass as simulated by the model and the validation results measured on selected studied sites; second, the influence of climate, atmospheric deposition and forest management on changes in soil and soil solution chemistry.

Model validation: soil solution and biomass data

The soil solution composition in response to atmospheric deposition and climatic scenarios was simulated by ForSAFE until 2100 (Figure FR.8). The simulated data were compared with measured data for soil solution parameters (chloride, sulphur, sodium, pH, N and base cations), for soil base saturation, and for stem biomass considering the influence of storm events and forest management on clear-cutting.

Figure FR.8 Simulations of some soil solution parameters (site EPC87) and of stem biomass on the sessile oak dominated site (site CHS41). Blue lines and black or red points represent simulated and measured data, respectively.



Many ForSAFE runs were performed on various forest sites, allowing to evaluate the validation performance. Feedbacks were associated to these exercises, which allowed model improvements such as those described under model description. The simulated data and the observations are presented following the last improvements for the sites CHS41 (sessile oak) and EPC87 (Norway spruce) (Figure FR.8).

We obtained rather good correlations between simulated and measured data for stem biomass evolution and for soil solution parameters, particularly for conservative elements Cl^-, S^-, SO_4^{2-}, Na^+, which indicates an efficient hydrological module. The discrepancy between measured and simulated curves were evaluated according to a multiple tests method (Fromont and Laurent 2006; Fromont et al. 2011). Three statistical criteria were evaluated (NAE, "Normalized Average Error", RMSE, "Root Mean Square Error" and ME "the modelling efficiency"). A publication has been submitted (Gaudio et al., submitted).

The results indicate good accuracy between simulated and measured data, except for soil with low water retention capacity (for pH and base cations) and for nitrogen even if base line data are in the same range of magnitude (Figure FR.9). It appears that forest disturbance, which are not taken into account by the model, influences nitrogen outputs and need to be considered. Indeed, in 1999 a huge storm event occurred, which led to a large forest clear-cut. The nitrate leaching increased during the following year. Following these observations, model improvements are under progress to take into account the role of forest management like clear-cut done in the past and those planned by foresters, as well as storm event or the health status of the trees.

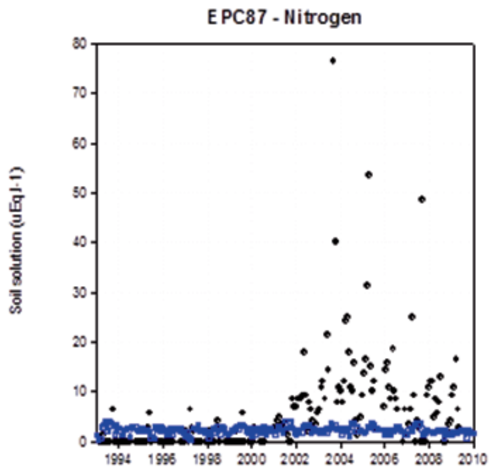
Long-term impact on soil solution: Atmospheric deposition and climate change scenarios

Four atmospheric deposition scenarios and three climate scenarios were used alone or in combination as input data of the ForSAFE model, leading to twelve combinations of possible atmospheric evolution scenarios and their impacts on soil solution composition and plant composition.

Impact of atmospheric deposition scenarios

For each of the three selected sites, we focused on the influence of N and sulphur deposition on soil solution composition. We tested the impact of the

Figure FR.9 Comparison between simulated (blue line) and measured (black dots) N concentration in soil solution on the Picea abies dominated site (EPC 87).



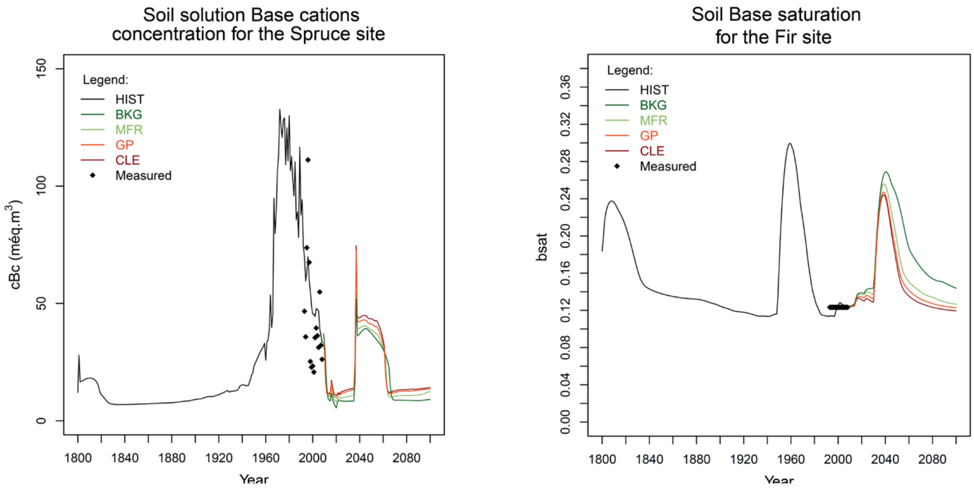
four atmospheric deposition scenarios on several soil solution parameters from nowadays to 2100.

The results were quite similar for the three selected sites with the same range of trends according to the deposition scenarios. To illustrate the results, the evolution of base cations concentrations in soil solution and of soil base saturation is shown for the spruce site (EPC 87) and for the fir site (SP 57), respectively (Figure FR.10).

We observed a general increasing trend for both base cations in the soil solution and soil base saturation during the 1980s (with a good agreement with measured data during the falling limb), and during the second part of the 21st century. Since the first increase of base cation concentration in soil solution corresponds to nitrogen atmospheric deposition increase observed in the 1980s (see Figure FR.4), the base saturation peak observed in 1960 on the Fir site does not match to the deposition one (Figure FR.10). Hence, other influencing factors have to be considered.

For the future, the simulations are consistent for the different scenarios and indicate a high increase for both parameters after 2040. Some differences between deposition scenarios are indeed observed by 2010. During the whole period from 2010 to 2100, CLE scenario has a higher impact on soil solution base cation concentration than GP, MFR and BGK scenarios, which is consistent with a desaturation of the soil exchange related to the acidity bound to N deposition. The CLE scenario has more impact than MFR (and all the soil parameters) and this difference

Figure FR.10 Evolution of base cation concentration in soil solution and base saturation in soil until 2100, in relation to the 4 atmospheric deposition scenarios (BGK, MFR, GP, CLE, with HIST representing the historical deposition). Black dots represent measured data.



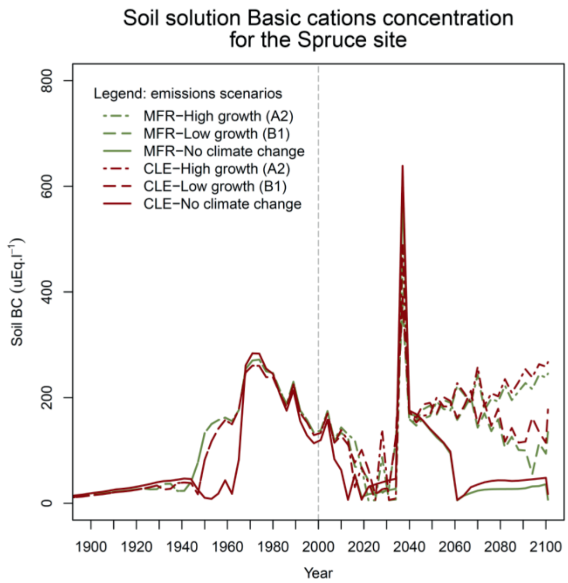
increases with time by 2100. The high increase in base cations concentration observed in 2040 for all scenarios is not related to a high increase of N deposition, consequently atmospheric deposition is not the only main parameter that influences soil solution base cations concentration and soil base saturation.

Impact of combined deposition and climatic scenarios

For the most probable nitrogen deposition scenarios (MFR and CLE), we combined the impact of three climate change scenarios (A2, B1 and no climate change). These combinations allow to discriminate the respective effects of each influencing factor on soil solution trends, as shown for base cation concentration until 2100 (Figure FR.11).

ForSAFE simulations indicate that the response of soil solution base cation concentration vary roughly in a same way from 1900 to 2040, and are highly influenced by climate and deposition trends during this period, nitrogen inputs having a stronger impact around the eighties. The CLE scenario has a stronger influence on base cations release than MFR. However, by 2040, climate change (A2 and B1 scenario) lead to significantly higher increase of base cation concentration in soil solution than CLE or MFR deposition. The A2 scenario (high growth) leads to ten times base cations concentrations release compared with 'No climate change', and two times compared with the B1 (low growth) (Gaudio et al. submitted). This stronger influence of climate (A2 representing the warmest conditions) may be linked to soil temperature increase, which accelerates mineralization process, contributes to a higher degradation rate of organic matter (Woodwell 1978; Jenkinson et al. 1991; Schimel et al. 1994; Kirschbaum 1995) and production of base cations in the soil solution.

Figure FR.11 Evolution of base cation concentration in soil solution of the spruce site (EPC 87), according to CLE and MFR deposition scenario combined with the three climate scenarios (A2, B1 and no change).



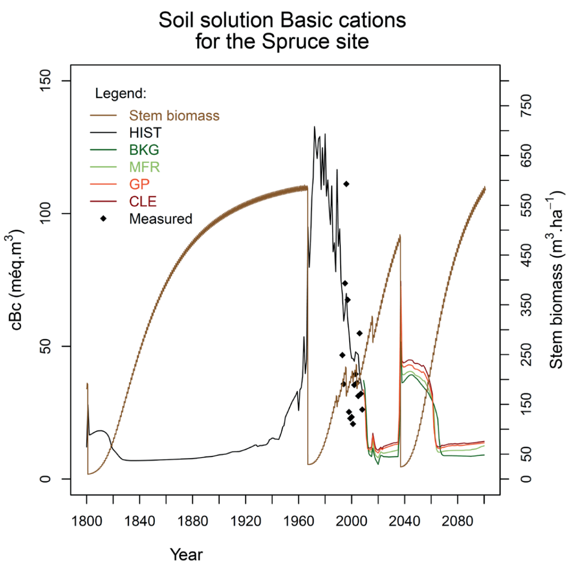
Short-term impact of forest management on soil solution

Climate change and atmospheric deposition scenarios have obviously a long-term impact on soil solution parameters. However, other anthropogenic activities and particularly forest management may also influence these parameters. Clear cuts and storms events are main events that strongly influence soil and vegetation response, by modifying biogeochemical cycle equilibriums.

The impacts of forest management on soil parameters can be evaluated in the case of highly artificial plantations. This kind of forest stand is dedicated to wood production and is thus managed through regular growth cycles that start with trees plantation and end with a clear cut of mature trees. To illustrate this purpose, the trends of stem biomass and of base cations in soil solutions were simulated under the influence of the four nitrogen deposition scenarios, focusing on the impact of clear cuts for the spruce site (Figure FR.12). Two clear cuts were performed during the considered period (1966 and 2036).

The results indicate that short-term high peaks of base cation concentrations in solution are strongly linked to stem biomass evolution, and namely to the changes due to clear cuts. In 1960 and 2035, the concentrations in soil solution increased suddenly in exceptional proportions, due the lack of uptake by trees, whatever the atmospheric deposition scenario. Stand clear cuts led to these high peaks due to leaching. However, the intensity of base cation release observed in the 1980s remains strongly influenced by N deposition: in 2040, the clear cut has a lower effect when N deposition is much lower. Thus, on a short-time scale, forest management and particularly clear cuts may have an important impact on base cation release, and can enhance the influence of an increase of atmospheric N deposition. In 2035, just before and after the forest cut, there is a slight difference according to deposition scenarios, whereas during the year of the clear cut, the base cations trends are the same, which indicate at this moment the major influence of forest management. In case of climate change scenarios, the base cation concentration trend is the same for all the scenarios during the time period of clear cut influence, leading to the same conclusions as above.

Figure FR.12 Evolution of the simulated stem biomass and base cations concentration in the soil solution of the EPC87 site under the influence of the four nitrogen deposition scenarios. Measured data are black dotted. Clear cut periods are indicated.



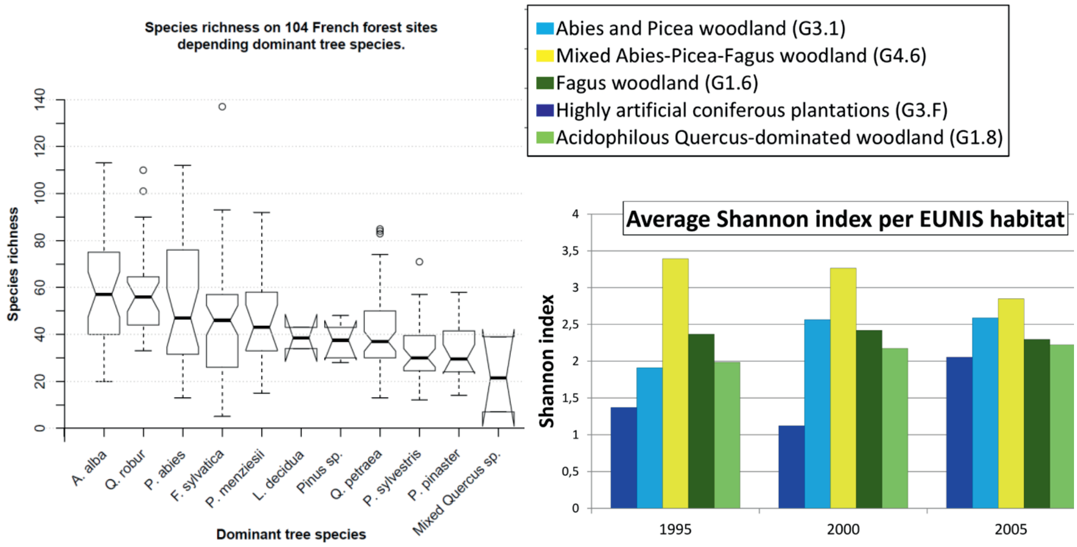
As a conclusion, climate change and atmospheric deposition have an important influence on soil solution composition, especially climate with an obvious impact on base cations by 2080. It is clear on the diagram FR.11 that these two factors impact soil solution on a long-term period.
Out of the long-term general trend of basic cations concentration, which is mainly driven by climate change, some punctual variations and peaks can be observed due to other factors. On a short time scale (around 25 years), at least one more factor, i.e. forest management, may influence base cation concentration in the soil solution together with climate change and atmospheric deposition.

Biodiversity evolution: measured and simulated data

Species richness and Shannon index evolution

The species richness is illustrated for each dominant tree species (Figure FR.13a) and the Shannon index for EUNIS habitat type (Figure FR.13b). Understory species richness was influenced by dominant tree species: Abies alba and Quercus robur woodlands have higher diversity species richness than Pinus ones, but with a higher site variability. Except for A. alba and Q. robur, the species richness is significantly different for all dominant tree species (95% family-wise confidence level Tukey's test). The Shannon

Figure FR.13 Species richness (a) and trends over 10 years of the Shannon index (b) under various dominant tree species and EUNIS habitats.

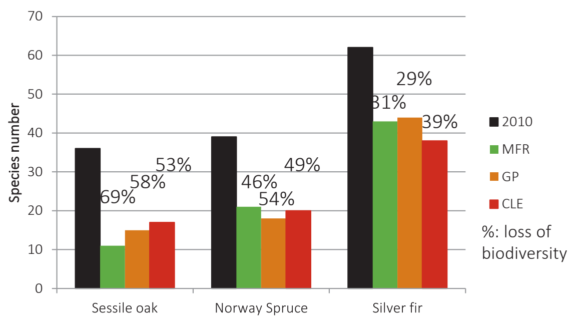


index highlighted the higher species diversity in mixed and Fagus woodlands. Mixed stands of Abies-Picea and Fagus provide a higher understorey diversity than pure stands.

Species richness simulation until 2100

The evolution of the relative percentage of plant species richness between 2010 and 2100, was calculated (Figure FR.14) on each forest site based on the survey done in 2010 by the ONF, and under the influence of three N deposition scenarios. C/N ratio and pH were the main parameters considered to estimate the evolution of species richness. Results are presented for the three studied sites.

Figure FR.14 Species richness (%) evolution between 2010 and 2100 under three atmospheric deposition scenarios.



As a mean, by 2100, the simulations indicate a loss a biodiversity of around 47%, but this loss depends on the site. It was more obvious for sessile oak, as a result of a higher pH increase for this site. Few differences were observed between the scenarios, except for the sessile oak site where MFR lead to a higher biodiversity loss probably due to a more important increase in pH from 5.8 to 6.4.
Indeed, C/N ratio and pH parameters may not be sensitive enough to predict accurately species richness evolution, since too tenuous differences were observed in response to the atmospheric deposition scenarios, particularly where initial species richness is high.

These data remain preliminary, since only three sites were considered and need to be precisely evaluated after model improvements that are still in progress. Moreover, the use of the new biodiversity index decided during the 24th CCE Workshop in Rome will let to estimate the species richness evolution by taking into account more environmental parameters.

Acknowledgements

The French NFC thanks Harald Sverdrup and Salim Belyazid for their collaborative work within our common project to adapt ForSAFE-VEG, the CCE for fruitful exchanges and the French experts mentioned in the collaborating institutions for the setup of the Veg-table and their helpful advices.
Our thanks go to the ADEME (Agence de l'Environnement et la Maitrise de l'Energie) for the financial support. This work has been done within the framework of the French-Swedish DYNAMO II project, the EXBD2C-2 project and the VALERIANE project. This latter was supported by the ANR PRIMEQUAL.

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Introduction

The German NFC responds to the Call for Data 2012–14 (CCE 2012) and submits effect indicator-values with the aim to assess 'no net loss of biodiversity'. Suitable biodiversity endpoints were tested to compile output variables of soil-vegetation models for different EUNIS classes. The calculation of biodiversity indicators for scenario assessment of changes in biodiversity was done by building a model chain of MetHyd, VSD+ and BERN.
Table DE.1 shows the different sites of the model chain application and the *historic* (1880), *highest* (1980) and *future* (2020) deposition derived by the CCE. The future deposition is based on the revised Gothenburg Protocol. The table shows that most of the plots are clearly in the lower region of the min-max range with respect to historic, highest and future deposition of sulphur and ammonia. The oxidized nitrogen on all plots is clearly above the average of 876 eq ha^{-1} yr^{-1} in the deposition year 1980.

Table DE.1 Selected sites and their past and future deposition in eq ha^{-1} yr^{-1}.

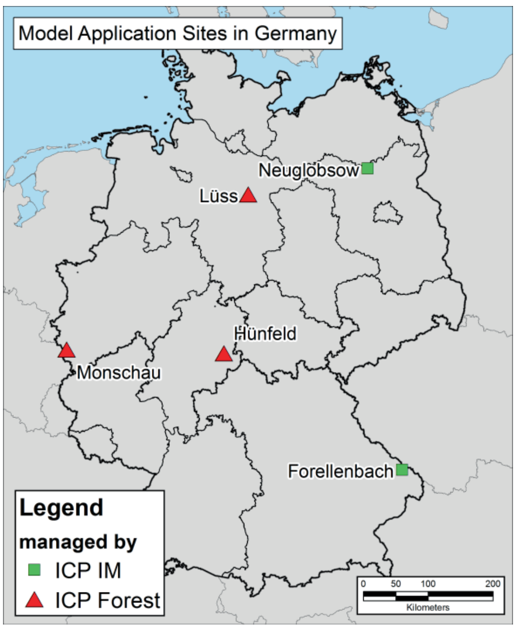
		SOx			NOx			NHy		
	EUNIS class	Historic (1880)	Highest (1980)	Future (2020)	Historic (1880)	Highest (1980)	Future (2020)	Historic (1880)	Highest (1980)	Future (2020)
Min-Max		113-912	1142-10396	126-1451	31-71	355-1396	185-1123	129-756	340-3455	381-2408
Forellenbach	G1.61	251	4363	203	57	1147	262	578	1094	967
Neuglobsow	G1.63	449	3253	232	54	943	269	361	887	677
Lüss	G1.63	341	3876	351	58	1060	501	446	1092	814
Monschau	G3.1D2	376	4535	296	69	1216	269	403	1237	677
Hünfeld	G1.61	384	4574	398	61	1179	419	423	1040	768

Site-specific soil and vegetation model runs at selected plots

Description of selected sites in Germany

For the assessment of biodiversity effects the German NFC applied the latest versions of the MetHyd (v1.5.1) and VSD+ (v5.0.1) model provided by the CCE. Some resulting parameters of the VSD+ model describe indicators of soil eutrophication (C:N ratio) and acidification (pH of soil solution). These parameters were used as input for the recent version of the ecological response model BERN (v3.3). This model is designed and developed by OEKO-DATA. The model chain MetHyd - VSD+ - BERN was applied to five selected sites in Germany with two different deposition scenarios. Two plots are sites of the ICP Integrated Monitoring and three are part of the ICP Forests Level II network. The chosen sites represent different EUNIS-classes and vegetation types. They are also located in quite different landscapes and climate regions (see Figure DE.1). The German sites for the application of the model combination represent not only different ecosystems but also different environmental and soil chemical conditions. The selected plots are also located in regions with different air pollution history and future perspective (see Table DE.1).

Figure DE.1 Selected sites for the application of the model combination in Germany.



Input parameters

Most input data for the VSD+ model were derived by the extended description and characterization of the sites by the different survey projects. The data set for base cations and chloride deposition was derived from the MAPESI project (MAPESI 2011). For this study the average of three years (2005, 2006 and 2007) was chosen as input for landuse specific base cation and chloride deposition. The data set for nitrogen and sulphur deposition was provided by the CCE. This data set includes historic deposition which starts in the year 1880 and ends in the year 2008. The data set also includes the predicted deposition of sulphur and nitrogen in the year 2020 assuming the full application of the revised Gothenburg Protocol (rGP). Another part of this database contains information about assumed non anthropogenic background deposition. This dataset was neglected in this study since it has large gaps (or zero values) for most areas in central Germany. No deposition of nitrogen might influence the soil chemical model too strongly. Therefore the deposition of the year 1880 was used as pre-industrial background deposition (BKG).
The uptake parameter was estimated assuming extensive land use. The values for litterfall (dry mass, carbon and nitrogen content) were derived from measurements on the plots. The input time series

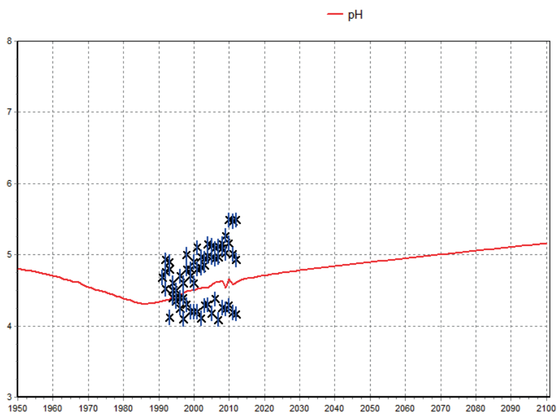
was adapted to reflect a lower litterfall flux during the forest maturing period (first 40 years). The water content of the soil, the percolation and reduction factors of the nitrification, denitrification and mineralization was derived, applying the 'MetHyd' (v1.5.1) tool provided by the CCE.

Application of the soil chemical and vegetation response models

The focuses in this study was the modelling of the soil chemistry (using VSD+) and link the results to a vegetation response model (BERN). The model output of VSD+ for pH and the C:N ratio was chosen to model trends of possibility for plant species and/or plant communities site potential. Figure DE.2 shows the results for pH and C:N ratio for the ICP IM plot "Forellenbach". This plot has measured pH values (soil solution in different soil depths) for more than two decades (blue X with standard deviation bars) and various measurements of soil carbon and nitrogen (in the year 1990 and 2010). These measured values are needed for the calibration and affect the model results directly (see the increasing oscillation in years of pH measurements).

The BERN model calculates the possibilities of plant species and communities by using fuzzy functions for 7 different site factors (soil water content, base saturation or pH, C:N ratio, climatic water balance, vegetation period, solar radiation and temperature). These functions represent the realized ecological niche under pristine or semi-natural conditions. Within this study the dynamic trends of parameters (pH and C:N ratio) and fixed parameters (all others) were used. The inclusion of the dynamic trends shall reflect the reaction of the vegetation to changes in the soil chemistry given by the VSD+ model. The fixed parameters were calibrated to the optimum of the recently found plant community. Figure DE.3 shows the pure number of species with different possibility thresholds in time. A possibility below 0.1 (vitality 10%) marks a high level of plant physiological stress and great risk of damage to the plant or dysfunctions for a plant community. Values above 0.5 (vitality 50%) indicate moderate and values above 0.8 (vitality 80%) full regeneration capabilities for plant species or plant communities. The decreasing trend in the 'rGP' scenario of pH (4.8 to 4.3) and C:N ratio (25 to 22) till 1990 is reflected by a decreasing number of species with moderate (0.5) possibility (140 to 126). The VSD+ modelled pH values react quite strong in the years between 1990 and 2010 while the C:N ratio shows only little fluctuation. The modelled possibility of plant species reacts to this alteration (the plants with low possibilities stronger than the plants with higher values). Figure DE.3 also illustrates the reaction of the biota to lower deposition of sulphur and nitrogen (background deposition). Generally the total number of possible species doesn't vary a lot between these scenarios of deposition. But the reaction of the plant species to the high deposition values in the 1980s is easily traceable in the 'rGP', while staying relatively stable in the 'BKG' scenario. Due to the N limitation less plant species are expected with background deposition. In addition to the analysis of the development of pure species numbers different sets of plant species and plant communities were analysed regarding their site potential. The set of plant species arises from the identification of the current plant community on the site. On the two sites of the ICP Integrated Modelling ('Forellenbach' and 'Neuglobsow') a plant survey and ecologic classification was done by the German NFC

Figure DE.2 pH value in soil solution (left) and C:N ratio in soil (right) modelled with the VSD+ model at the ICP IM plot "Forellenbach" based on the "rGP" scenario.



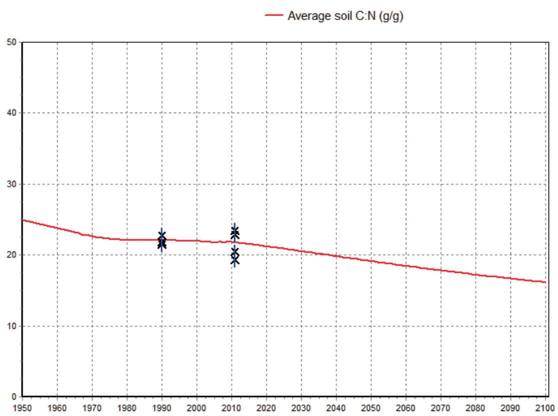
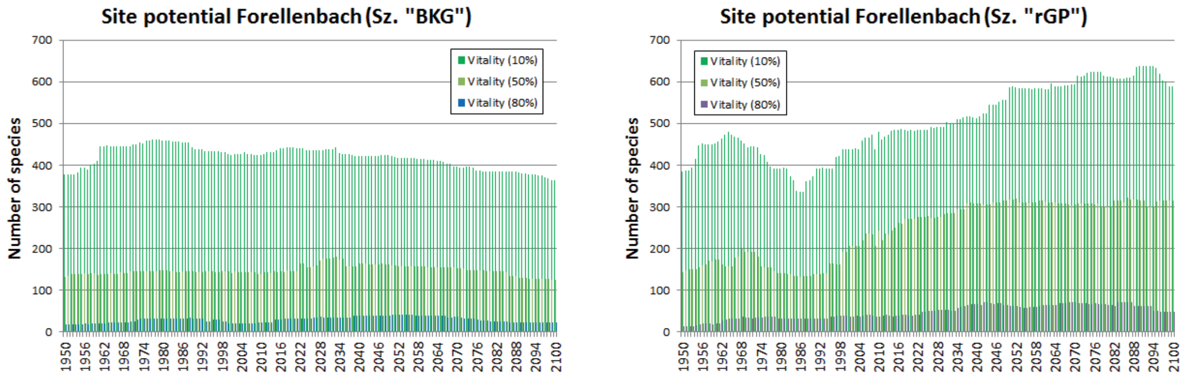


Figure DE.3 Number of plant species with possibility of 0.1, 0.5 and 0.8 at the ICP IM plot 'Forellenbach' for different deposition scenarios (BKG = background and rGP = revised Gothenburg Protocol).



for ICP Modelling & Mapping itself. On the ICP Forest plots the current (last available survey) plant composition and degree of coverage was derived from the database of the ICP Forest. Which plant species are expected to be constant members of a natural plant community is documented in the BERN model. Figure DE.4 shows the results for the ICP IM site 'Forellenbach' assuming *Luzulo-Abieto-Fagetum sylvatici (Vaccinio myrtillus-Subass.)* as current natural plant community. All the expected constant species of this plant community were analysed regarding their dynamic site potential. In addition, the Sørensen index as described in CCE Status Report, Annex 4A p.53 (CCE 2011) was calculated. The reference condition of the plant species was set to 1 in order to represent the best ecological condition. The Sørensen index can be used to indicate the general reaction of all plant species in one graph. Examining the reaction of the plant species indicates that the background (BKG) scenario is characterized by generally higher possibilities compared with the 'rGP' scenario and has no decrease in the 1990s. Also the outlook (2030–2100) seems to be better in the background scenario. Figure DE.5 shows the Sørensen index for the different deposition scenarios on the left side. The graph on the right side displays the site potential of the plot described by the number of species with three different levels of possibilities. By including the possibility of the plant species, the Sørensen index is altered not only by the presence and absence, but also by the vitality of the occurring species.

Figure DE.4 Possibility of plant species and Sørensen Index for VSD+ results on basis of background (left) and revised Gothenburg Protocol deposition (right).

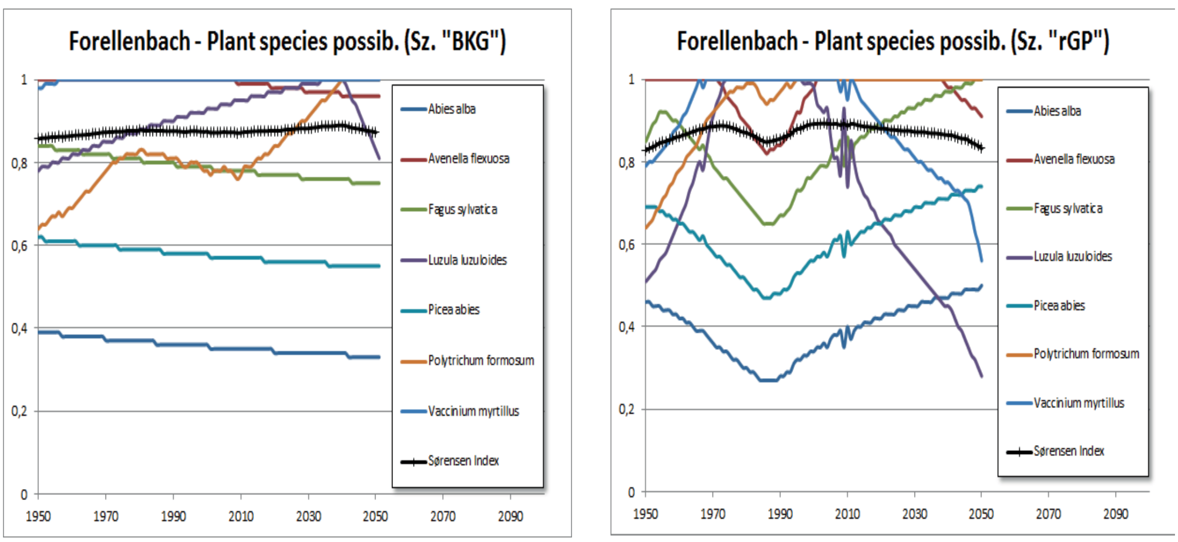
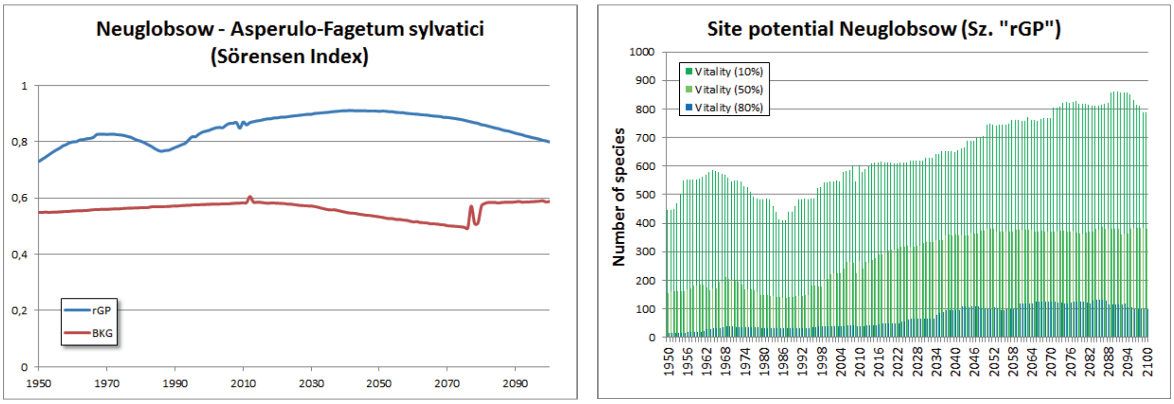
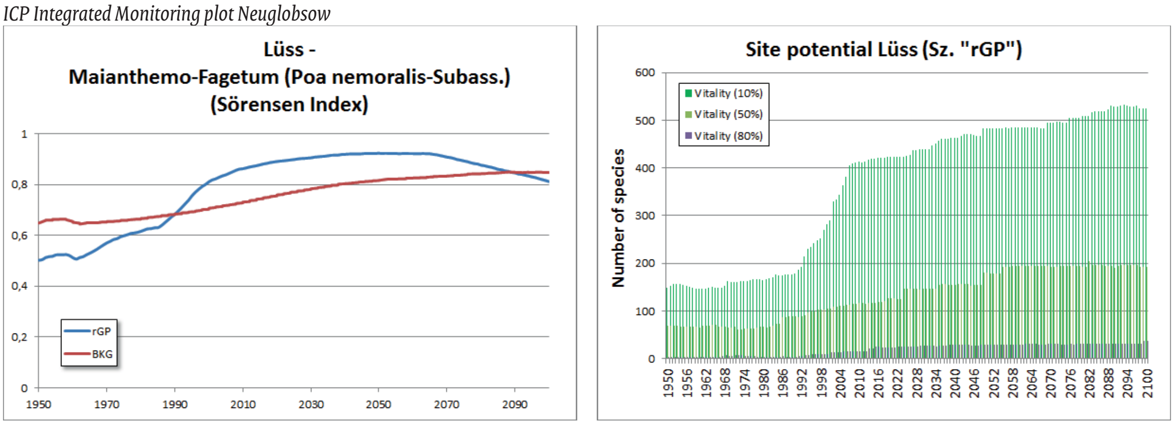


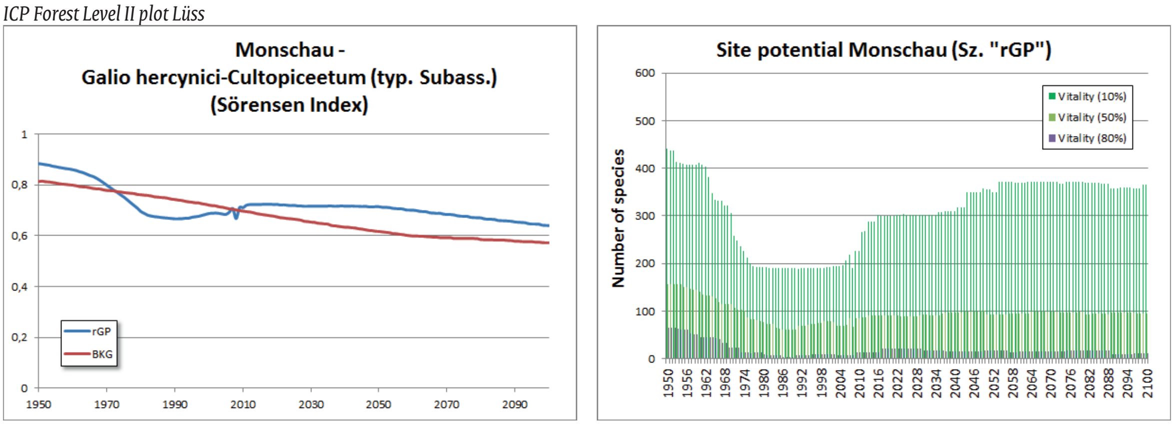
Figure DE.5 Similarity Index (left) and number of possible species (right) for Neuglobsow, Lüss, Monschau and Hünfeld.



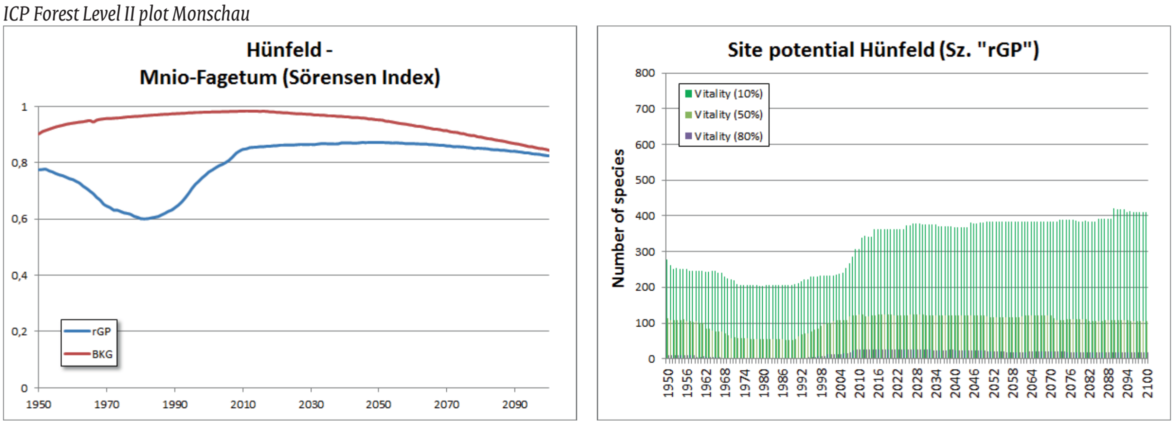
ICP Integrated Monitoring plot Neuglobsow



ICP Forest Level II plot Lüss



ICP Forest Level II plot Monschau



ICP Forest Level II plot Hünfeld

Discussion of modelling results

The comparison of the potential number of species (e.g. ICP IM site 'Forellenbach', see Figure DE.3) offers rough estimates of the site potential under different deposition scenarios. On the one hand the site potential in the background deposition run is rather stagnating and has no decrease in the 1980-1990ties. On the other hand the results on basis of higher deposition ('rGP' scenario) predict an increased site potential indicated by higher number of possible plant species on various health levels over large time spans.
From an ecological perspective the number of species alone cannot serve as protection objective to avoid loss of biodiversity. If a nutrient poor site, for example, will be changed to eutrophic conditions the number of species will increase, but rare species may be displaced. This shows that the analysis of the (potential) number of species might not be satisfying for the purpose. Therefore in addition the similarity analysis with the Sørensen index was done.

Two aspects of the similarity analysis determine the interpretation of the results for the Sørensen index crucially. The first aspect is the choice of the reference. The reference plant species composition may vary with different protection goals. For this study the currently existing plant relevés was analyzed regarding the plant species. This set of species was compared with the database of the BERN model and the constant members of the best fitting natural plant community were chosen as reference composition. Therefore the protection target can be described as the good ecological condition. The second aspect of the similarity analysis is the reaction of the single plant species to the predicted changes of soil chemistry. The aggregation of the possibilities of the single plant species might serve as indicator for future ecological developments on the site.
Looking at the results for the ICP IM plot 'Forellenbach' it seems that a few members of the desired plant community will not perform well in the future under the 'rGP' scenario. The results for the 'BKG' scenario show a more constant performance of the single plant species (see Figure DE.4).
The analyses of the potential number of species on all plots are shown in Figure DE.5 (right graphs). Comparing the numbers for the decade 1980-1990 it seems that the number of species will rise in future on all plots. The behaviors of the curves before the decade 1980–90 differ a bit. At the plots 'Neuglobsow' and 'Monschau' the numbers decrease while the plots 'Lüss' and 'Hünfeld' show generally low numbers especially for plant species with moderate and high potential. This analysis might be useful to get a first impression of the plot potential. It doesn't say anything about positive or negative trends in terms of sustainable ecological development or changes in biodiversity. The Sørensen index (see Figure DE.5, left graphs) taking into account the information about constant members of a natural plant community offers more information. Looking at the results for the 'rGP' scenario all figures have in common that the chosen similarity index decreases more or less beginning in the 2040s, but this is not true for the background scenario. Keeping in mind that our latest prediction of the deposition is made for the year 2020 the results far behind this year might be handled with great caution.

A comparison of the Sørensen indices for all plots and both deposition scenarios shows a different pattern. At the plots 'Forellenbach' and 'Monschau' the differences for the pre-industrial 'BKG' and the current 'rGP' scenario are quite minimal. The sites 'Lüss' and 'Hünfeld' show a better performance of the background deposition scenario, and the plot 'Neuglobsow' the opposite. The results at the site 'Neuglobsow' are interesting because it indicates that the current plant community is already adapted to the acidifying and/or eutrophying effects of the air borne deposition. On all plots (except 'Lüss') the difference between 'BKG' and 'rGP' decreases in the far future. This indicates that ecosystems will recover from acidifying and eutrophying effects of the deposition in the past if ambitious emission reduction policies are in force.

Acknowledgement

The exchange of information and expertise between the NFC M&M and the partners from the ICP IM and ICP Forests was very fruitful and constructive. Especially the excellent contact to Burkard Beudert (ICP IM Forellenbach) and Hubert Schulte-Bisping (ICP IM Neuglobsow) is gratefully acknowledged.

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Status

In response to the 2012/14 call for data, in order to test dynamic modeling on vegetation changes in selected sites, the dynamic model VSD+ was applied to four forest sites. These sites have been chosen because they are characterized by the presence of important plant communities for Italy, and are included in the Italian ICP Forests network (level II plots). Table IT.1 shows for each site the main environmental characteristics and representative tree species.

Table IT.1 Italian forest sites for the VSD+ application.

Site Info	EMI1	LAZ1	LOM1	PIE1
Name	Carrega	Monte Rufeno	Val Masino	Val Sessera
Latitude	44.7183	42.8306	46.2378	45.6819
Longitude	10.2017	11.9139	93.5211	80.6819
Altitude	200	690	1190	1150
No. of species	39	76	49	30
Prevalent tree species	oak forest	oak forest	spruce (and fir) forest	beech forest
Age	55	45	90	65
Protection	2	0	3	2
Eunis Class	G1.7	G1.7	G4.6	G4.6
PROPS vegetation type	Ligurian-middle Apennine downy oak forests	Middle Apennine mixed hop-hornbeam-downy oak forests	Central European Galium odoratum-	Galium odoratum-

Data sources

The data have been provided by Italian National Forest Service (Corpo Forestale dello Stato) and collected in the framework of the National Program for Forest Ecosystems Monitoring (ConEcoFor) as part of the collaboration between ICP M&M and ICP Forest.

The modeling chain has been applied without the use of the Access™ tools provided by CCE.

- MetHyd has been run to calculate mineralization/nitrification/denitrification modifying factors;
- VSDin file has been compiled to be uploaded by GrowUp module;
- GrowUp has been run to calculate uptake and compile VSDin file with uptake data;
- VSD+ model has been run and then PROPS module has been selected for vegetation analysis.

Table IT.2 shows the input data including the sources and the processing methodology.

Results and discussion

The biodiversity indices have been calculated by PROPS module, taking into consideration two options:

1) by considering the observed list species;
2) by considering the list of the species according to the site's EUNIS classification.

Biodiversity indices and the lists of the species observed and in according to the EUNIS Classes are reported in Figures IT.1-2 and Tables IT.3-4, respectively - for the indicated sites. It appears evident that the species hypothesized on the basis of the EUNIS classification are less than those really detected in field. This disagreement may be caused by lack of information about the Italian flora in the model PROPS database.

Table IT.2 Data, sources and processing methodology.

VARIABLE	UNITS	EMI1	LAZ1	LOM1	PIE1	SOURCES AND PROCESSING
Thick	m	0.600	0.531	0.527	0.312	European soil database
Bulkdens	g/cm^3	1.063	1.183	0.905	0.722	European soil database
Theta	m^3/m^3	File	File	File	File	MetHyd output
pCO2fac	atm	24.348	24.016	20.202	19.683	European soil database
Clay_ct	%	21	25	15	18	Daffinà et al. (2003)
CEC	meq/kg	125.175	178.814	197.535	155.043	Mapping Manual eqn. 5.2
Cpool_0	g/m^2	14791.48	2515.464	3033.45	2553.225	By VSD calibration process
CNrat0		10.0091	12.77778	38.0181	17.87879	By VSD calibration process
lgKAlBC	depending on exchange model	0.098003	0.8378	1.5988	1.503	By VSD calibration process
lgKHBC	depending on exchange model	6.148333	3.9702	1.8791	4.279	By VSD calibration process
expAl		3	3	3	3	Constant
lgKAlox		8	8	8	8	Constant
TempC	C°	File	File	File	File	MetHyd output
percol	m/yr	File	File	File	File	MetHyd output
Nadep	$eq/m^2/yr$	File	File	File	File	By ICP Forest measured
Cadep	$eq/m^2/yr$	File	File	File	File	By ICP Forest measured
Mgdep	$eq/m^2/yr$	File	File	File	File	By ICP Forest measured
Kdep	$eq/m^2/yr$	File	File	File	File	By ICP Forest measured
Cldep	$eq/m^2/yr$	File	File	File	File	By ICP Forest measured
NH3_dep	$eq/m^2/yr$	File	File	File	File	By ICP Forest scaled on GP scenario
NOx_dep	$eq/m^2/yr$	File	File	File	File	By ICP Forest scaled on GP scenario
SO2_dep	$eq/m^2/yr$	File	File	File	File	By ICP Forest scaled on GP scenario
EAlobs		8.5	4.12	4.9	7.2	By ICP Forest measured
EHobs		8.3	4.5	5	7	By ICP Forest measured
cAlobs	eq/m^3	-	0.248556	0.33		By ICP Forest measured
cBcobs	eq/m^3	-	0.36	0.0023		By ICP Forest measured
cHobs	eq/m^3	-	0.000624	-		By ICP Forest measured
pHobs		4.03	6.053	5.75		By ICP Forest measured
bsatobs	$eq/m^3/yr$	3.08	0.36			By ICP Forest measured
CNratobs	g/g	17.65	11.4838			By ICP Forest measured
Cpoolobs	g/m^2	3176	2773			By ICP Forest measured
Nawe	$eq/m^3/yr$	0.0241049	0.014048	0.0100498	0.003563	Mapping Manual eqn. 5.39
Kwe	$eq/m^3/yr$	0.0144629	0.008429	0.0060299	0.002138	Mapping Manual eqn. 5.40
Cawe	$eq/m^3/yr$	0.0554410	0.032310	0.0231144	0.008195	Mapping Manual eqn. 5.41
Mgwe	$eq/m^3/yr$	0.0216943	0.012643	0.0090448	0.003207	Mapping Manual eqn. 5.42
Ca_upt	$g/m^2/yr$	File	File	File	File	GrowUp output
Mg_upt	$g/m^2/yr$	File	File	File	File	GrowUp output
K_upt	$g/m^2/yr$	File	File	File	File	GrowUp output
N_gupt	$g/m^2/yr$	File	File	File	File	GrowUp output
Ni	eq/ha/yr	File	File	File	File	GrowUp output
Nfire	eq/ha/yr	File	File	File	File	GrowUp output
Nvol	eq/ha/yr	File	File	File	File	GrowUp output
Nfix	eq/ha/yr	File	File	File	File	GrowUp output
Clf	$g/m^2/yr$	File	File	File	File	GrowUp output
Nlf	g/m2/yr	File	File	File	File	GrowUp output
Nimobs	$eq/m^2/yr$	File	File	File	File	GrowUp output
Ndeobs	$eq/m^2/yr$	File	File	File	File	GrowUp output

Figure IT.1 EMI1 and LAZ1 plots - biodiversity indices elaborated by VSD+ PROPS with observed species (A; C) and EUNIS classes species' list (B; D).

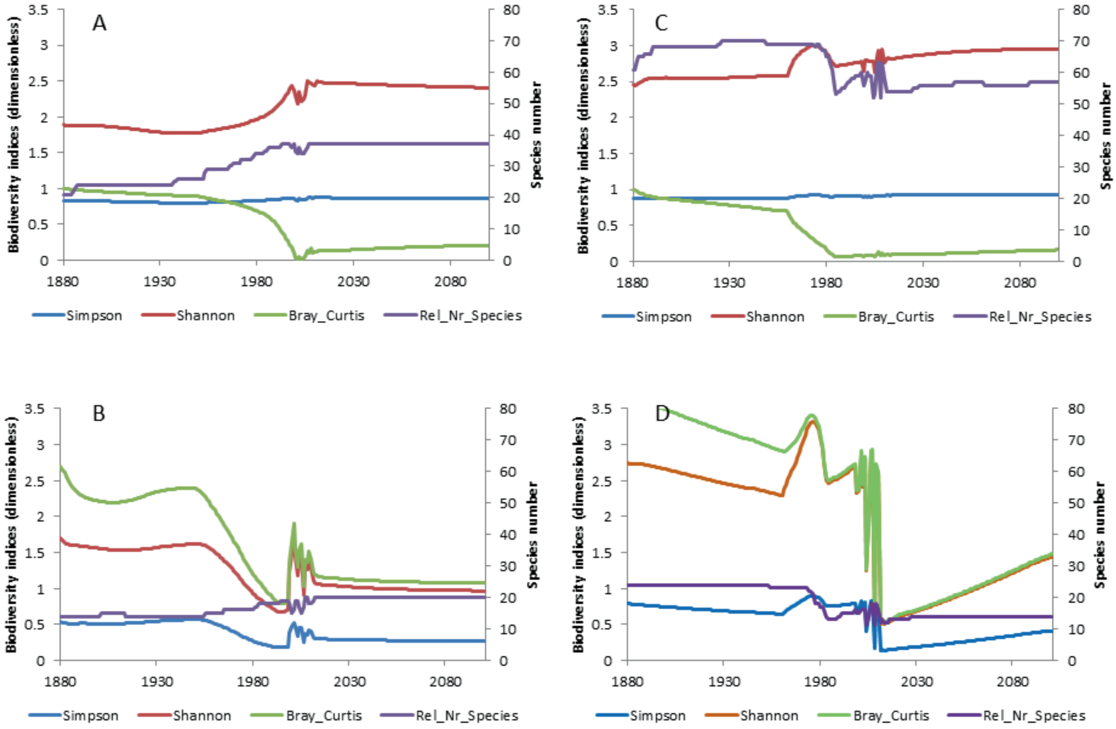

Figure IT.2 LOM1 and PIE1 plots - biodiversity indices elaborated by VSD+ PROPS with observed species (A; C) and EUNIS classes species' list (B; D).

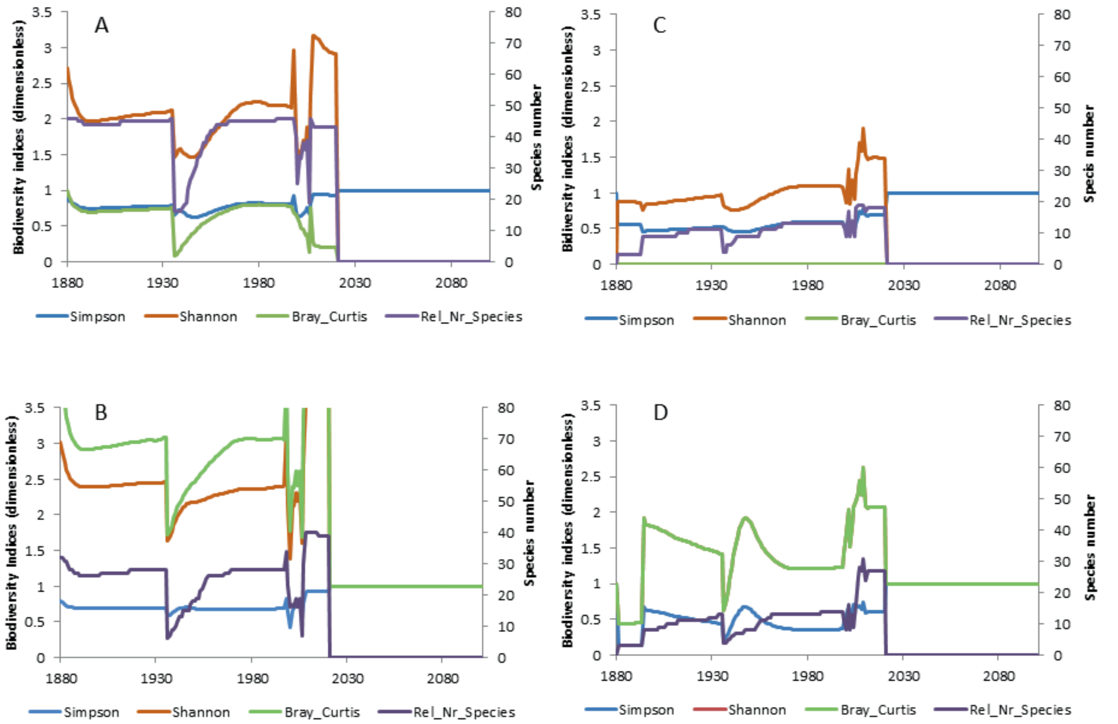

Table IT.3 EMI1 and LAZ1 observed species list and EUNIS class species list.

EMI1 Observed Species	EMI1 EUNIS Class Species	LAZ1 Observed Species	LAZ1 EUNIS Class Species
Acer_pseudoplatanus	Acer_campestre	Acer_campestre	Acer_campestre
Alliaria_petiolata	Buphthalmum_salicifolium	Agrimonia_eupatoria	Acer_monspessulanum
Aremonia_agrimonoides	Campanula_medium	Agrostis_capillaris	Buxus_sempervirens
Brachypodium_pinnatum	Cornus_mas	Ajuga_reptans	Campanula_trachelium
Calluna_vulgaris	Cornus_sanguinea	Anemone_nemorosa	Clematis_vitalba
Carex_flacca	Crataegus_monogyna	Anthericum_liliago	Cornus_mas
Carpinus_betulus	Cyclamen_repandum	Anthoxanthum_odoratum	Crataegus_monogyna
Castanea_sativa	Fraxinus_ornus	Brachypodium_sylvaticum	Daphne_laureola
Corylus_avellana	Hedera_helix	Buglossoides_purpurocaerulea	Euphorbia_amygdaloides
Cruciata_laevipes	Helleborus_foetidus	Carex_flacca	Euphorbia_dulcis
Dicranella_heteromalla	Knautia_drymeia	Carpinus_betulus	Fraxinus_ornus
Erica_arborea	Ligustrum_vulgare	Cephalanthera_longifolia	Helleborus_foetidus
Festuca_heterophylla	Melittis_melissophyllum	Clematis_vitalba	Hepatica_nobilis
Fraxinus_excelsior	Ostrya_carpinifolia	Clinopodium_vulgare	Knautia_drymeia
Fraxinus_ornus	Peucedanum_cervaria	Cornus_mas	Laburnum_anagyroides
Genista_germanica	Quercus_pubescens	Crataegus_laevigata	Ligustrum_vulgare
Genista_tinctoria	Rosa_sempervirens	Crataegus_monogyna	Lonicera_etrusca
Hedera_helix	Sorbus_domestica	Crocus_vernus	Melica_uniflora
Hieracium_racemosum	Sorbus_torminalis	Cruciata_glabra	Melittis_melissophyllum
Holcus_lanatus	Teucrium_chamaedrys	Cytisus_scoparius	Ostrya_carpinifolia
Hypericum_montanum	Viburnum_lantana	Dactylis_glomerata	Prunus_mahaleb
Hypnum_cupressiforme		Dicranum_scoparium	Quercus_cerris
Juglans_regia		Digitalis_lutea	Quercus_pubescens
Lathyrus_niger		Erica_arborea	Viola_reichenbachiana
Lilium_bulbiferum		Euphorbia_dulcis	
Lonicera_caprifolium		Eurhynchium_praelongum	
Luzula_forsteri		Festuca_heterophylla	
Mespilus_germanica		Fragaria_vesca	
Molinia_caerulea		Fraxinus_ornus	
Platanthera_bifolia		Genista_germanica	
Polygonatum_odoratum		Hedera_helix	
Prunus_avium		Hieracium_racemosum	
Pteridium_aquilinum		Holcus_mollis	
Quercus_cerris		Hypericum_perforatum	
Quercus_petraea		Hypnum_cupressiforme	
Rubus_caesius		Isothecium_alopecuroides	
Sorbus_domestica		Juniperus_communis	
Sorbus_torminalis		Lathyrus_montanus	
Vinca_minor		Lonicera_caprifolium	
		Luzula_campestris	
		Luzula_forsteri	
		Luzula_sylvatica	
		Malus_sylvestris	
		Melica_uniflora	
		Mespilus_germanica	
		Mycelis_muralis	
		Neottia_nidus-avis	
		Oenanthe_pimpinelloides	
		Pinus_pinaster	
		Pinus_strobus	
		Platanthera_chlorantha	

Table IT3 Continued

EMI1 Observed Species	EMI1 EUNIS Class Species	LAZ1 Observed Species	LAZ1 EUNIS Class Species
		Polytrichum_commune	
		Potentilla_micrantha	
		Primula_vulgaris	
		Prunus_spinosa	
		Pyrus_pyraster	
		Quercus_cerris	
		Quercus_ilex	
		Quercus_petraea	
		Quercus_pubescens	
		Ranunculus_lanuginosus	
		Rhinanthus_minor	
		Rosa_arvensis	
		Rubus_hirtus	
		Rubus_ulmifolius	
		Ruscus_aculeatus	
		Solidago_virgaurea	
		Sorbus_domestica	
		Sorbus_torminalis	
		Stachys_officinalis	
		Symphytum_tuberosum	
		Tamus_communis	
		Teucrium_scorodonia	
		Torilis_arvensis	
		Viola_alba	
		Viola_reichenbachiana	

Table IT.4 LOM1 and PIE1 observed species list and Eunis class species list.

LOM1 Observed Species	LOM1 EUNIS Class Species	PIE1 Observed Species	PIE1 EUNIS Class Species
Acer_pseudoplatanus	Acer_pseudoplatanus	Anemone nemorosa	Acer_pseudoplatanus
Ajuga_reptans	Actaea_spicata	Athyrium filix-foemina	Actaea_spicata
Anemone_nemorosa	Atrichum_undulatum	Atrichum undulatum	Atrichum_undulatum
Asplenium_trichomanes	Brachypodium_sylvaticum	Avenella flexuosa	Brachypodium_sylvaticum
Athyrium_filix-femina	Bromus_ramosus	Betula pendula	Bromus_ramosus
Betula_pendula	Calamagrostis_varia	Calamagrostis arundinacea	Calamagrostis_varia
Carex_caryophyllea	Campanula_trachelium	Calypogeia fissa	Campanula_trachelium
Carex_digitata	Carex_digitata	Carex pilulifera	Carex_digitata
Carex_pallescens	Carpinus_betulus	Chiloscyphus profundus	Carpinus_betulus
Corylus_avellana	Cirsium_erisithales	Dicranella heteromalla	Cirsium_erisithales
Dactylorhiza_majalis	Clematis_vitalba	Dryopteris affinis	Clematis_vitalba
Dryopteris_affinis	Corylus_avellana	Dryopteris carthusiana	Corylus_avellana
Dryopteris_dilatata	Ctenidium_molluscum	Fagus sylvatica	Ctenidium_molluscum
Dryopteris_filix-mas	Cyclamen_purpurascens	Galeopsis tetrahit	Cyclamen_purpurascens
Epipactis_helleborine	Daphne_mezereum	Gymnocarpium dryopteris	Daphne_mezereum
Euphorbia_dulcis	Euphorbia_amygdaloides	Hypnum cupressiforme	Euphorbia_amygdaloides
Fagus_sylvatica	Eurhynchium_striatum	Lophocolea heterophylla	Eurhynchium_striatum
Festuca_altissima	Fagus_sylvatica	Luzula nivea	Fagus_sylvatica
Festuca_heterophylla	Fissidens_taxifolius	Maianthemum bifolium	Fissidens_taxifolius

Table IT4 Continued

LOM1 Observed Species	LOM1 EUNIS Class Species	PIE1 Observed Species	PIE1 EUNIS Class Species
Fragaria_vesca	Fraxinus_excelsior	Phegopteris polypodioides	Fraxinus_excelsior
Fraxinus_excelsior	Gentiana_asclepiadea	Picea abies	Gentiana_asclepiadea
Geranium_phaeum	Hedera_helix	Plagiothecium laetum	Hedera_helix
Gymnocarpium_dryopteris	Hypnum_cupressiforme	Polygonatum verticillatum	Hypnum_cupressiforme
Hieracium_murorum	Knautia_drymeia	Polytrichum formosum	Knautia_drymeia
Homogyne_alpina	Lathyrus_vernus	Polytrichum formosum	Lathyrus_vernus
Laburnum_alpinum	Lonicera_xylosteum	Prenanthes purpurea	Lonicera_xylosteum
Lonicera_nigra	Mercurialis_perennis	Rhynchostegiella tenella	Mercurialis_perennis
Luzula_luzulina	Picea_abies	Sorbus aucuparia	Picea_abies
Luzula_nivea	Plagiochila_asplenioides	Vaccinium myrtillus	Plagiochila_asplenioides
Luzula_pilosa	Poa_nemoralis		Poa_nemoralis
Maianthemum_bifolium	Poa_stiriaca		Poa_stiriaca
Melampyrum_sylvaticum	Prenanthes_purpurea		Prenanthes_purpurea
Milium_effusum	Prunus_avium		Prunus_avium
Oxalis_acetosella	Salvia_glutinosa		Salvia_glutinosa
Phegopteris_connectilis	Sambucus_nigra		Sambucus_nigra
Picea_abies	Tilia_platyphyllos		Tilia_platyphyllos
Polypodium_vulgare	Tortella_tortuosa		Tortella_tortuosa
Potentilla_erecta	Ulmus_glabra		Ulmus_glabra
Prenanthes_purpurea	Veronica_urticifolia		Veronica_urticifolia
Pulsatilla_montana			
Ranunculus_montanus			
Rubus_idaeus			
Saxifraga_cuneifolia			
Solidago_virgaurea			
Sorbus_aria			
Sorbus_aucuparia			
Viola_biflora			
Viola_reichenbachiana			

Conclusions

More work must be done on the species that characterize a specific EUNIS class for the Italian territory before using on PROPS model application EUNIS class in place of the species detected.
Statistical analyses performed on the datasets coming from the VSD application highlighted some important problem deriving from the VSD outputs.
Direct calculation of the biodiversity indices on the basis of row data (name of species per layer and percentage of coverage) showed some inconsistency between measured and modeled data. This could be due to the forest plot management practices or to the consideration that VSD estimates the probability of occurrence and not the species coverage.
The VSD+/props model should be discussed and analysed to improve its performance in predicting biodiversity indices for Italian ecosystems.

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Introduction

In the CCE Call for Data of 2012-14 on 'no net loss of biodiversity' countries were asked to compile output variables of soil-vegetation models for every relevant EUNIS class (level 3). This output should enable CCE to calculate (country-specific) biodiversity indicators for (scenario) assessment of changes in biodiversity on a regional scale. This report describes which methods were used to deliver information on Dutch ecosystems.

Model selection

In the Netherlands there is a long history of using dynamic soil-vegetation models in making environmental assessments (Kros et al. 1998). The backbone of this modelling has long been the SMART2-MOVE model. The SMART2 model has been used to simulate the response of abiotic soil conditions due to different deposition scenarios, while MOVE was used to assess how the changes in the soils influenced plant species occurrences. These models have also been used to derive critical loads for Dutch vegetation types (Van Dobben et al. 2006) and nature targets types (Van Hinsberg and Kros 2001). In response to the Call for Data we have now used the PROPS model instead of MOVE, and VSD+ (Bonten et al. 2009) instead of SMART2. PROPS could be described as a new version of MOVE. PROPS is a plant response model based on regression of simultaneous measurements of abiotic soil conditions (e.g. pH, soil nitrogen concentrations) and plant species occurrences, whereas MOVE is based on regression of plant occurrences against (Ellenberg) indicators for abiotic conditions. By using

PROPS, it is no longer needed to translate Ellenberg indicator values into abiotic soil conditions, thus reducing the model's uncertainty. SMART2 and VSD+ are also very similar models. The main difference between VSD+ and SMART2 is the organic matter module. In SMART2, there is an 'inert' organic pool in the mineral layer and a decomposable organic pool in the litter layer. In contrast, VSD+ distinguishes four organic matter pools, allowing more differentiation in parameterization of C:N-ratios and decomposition rates. The use of VSD+ and PROPS for Dutch ecosystems has been described in the 2011 CCE Status Report.

Selection of modelled EUNIS classes

Realization of the targets of the European Birds and Habitat Directives is the major priority of Dutch nature policies. The directives aim to protect biodiversity in Europe. They require that Member States take measures to restore the natural habitats and species of community importance. Species and habitat should get a 'favourable conservation status'. Under the directives the Natura 2000 network of protected natural areas is established. The Natura 2000 network aims to assure the long-term survival of Europe's most valuable and threatened species and habitats. Nitrogen (N) deposition is one of the important threats for the protected habitats and species (Wamelink et al. 2013). From the 251 European habitat types 51 occur in the Netherlands. 45 of the Dutch habitat types are sensitive to N deposition and have critical load below 34 kg N/ha/yr (Dobben et al. 2014). The sensitive habitat types occur in a wide range of different EUNIS classes. In order to create a representative dataset for the CCE, we focused on the most occurring sensitive habitat types in the Dutch Natura 2000 sites. In addition, we looked at all major terrestrial EUNIS classes (i.e. bogs, dunes, forests, grasslands and heathland).

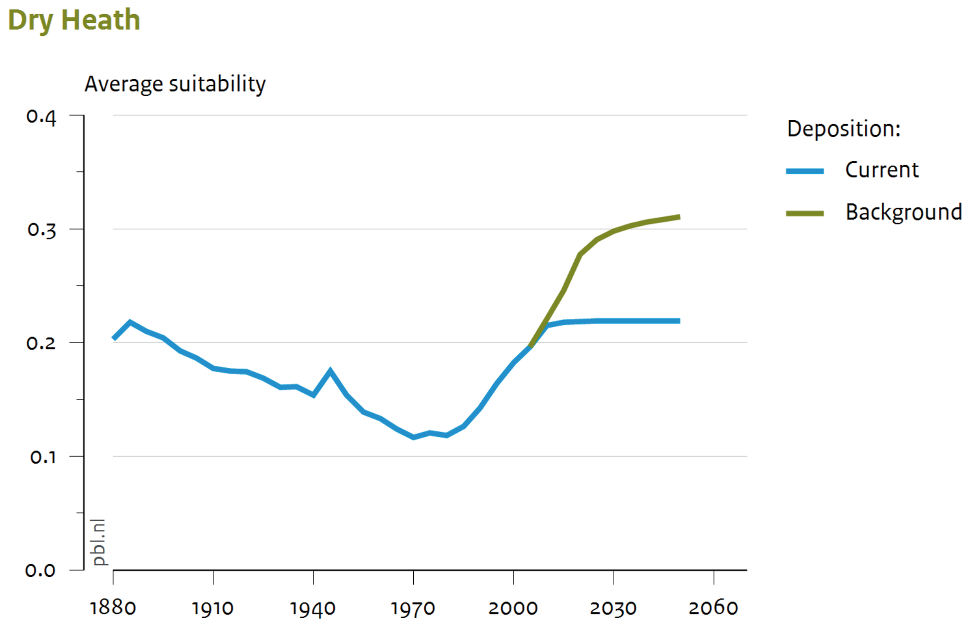
Biodiversity indicator

The Habitats Directive aims to achieve 'favourable conservation status' of habitats and species of community interest. During the implementation of the Habitat Directive in the Netherlands the Ministry of Economic Affairs has characterized the habitats in terms of typical species, plant associations and abiotic conditions (www.synbiosys.alterra.nl/natura2000). The list of typical species is used for monitoring and quantifying the habitat quality. The list contains species from a wide range of genera (e.g. birds, mammals, higher plants, butterflies). Species are often characteristic for a particular habitat type and often more or less restricted to a habitat type. These species are often the target species of the Dutch nature policy, which were selected because they were rare, had negative trends or were protected by national or international policies (Bal et al. 2001). Protection of these species largely depends on the protection of the habitat types. Most of the typical species are also Red List species. In addition, indicator species are added which indicate a good abiotic or biotic condition. For vegetation modelling this list of typical species has limited value because the rare species are often difficult to model. The relatively low number of mentioned plant species also limits the possibility to calculate robust biodiversity indicators. However, the link with the Dutch vegetation system offers another source of plant species which can be used to describe habitat quality. Each habitat type is characterized in terms of plant associations which should be present when conditions are favourable. The complete species compositions of plant associations are in turn described in the Dutch vegetation database (Hennekens and Schaminee 2001) and Synbiosys (www.synbiosys.alterra.nl). Based on this information we compiled a list of plant species for each of the selected habitat types. From this list we removed the invasive or undesired species, i.e. the species that are more abundant in less-developed forms of the given plant associations. PROPS was used to calculate the suitability for occurrence of the selected species at a particular site where the habitat type occurs. This suitability was calculated relative to the maximum suitability which occurs at optimal abiotic conditions. The average suitability over all species per habitat type was used as the indicator for 'good habitat quality' (see also Van Hinsberg et al. 2012).

Model runs

To deliver the desired output, VSD+ was parameterized for each of the selected habitat types using habitat specific soil and vegetation conditions (see also Van Hinsberg et al. 2011, 2012). The model was run for a grid in which the current critical load exceedance was equal to the average exceedance over all grids in which the habitat type was present. VSD+ was run for three different deposition scenarios; a scenario with current deposition level, a scenario with deposition according the Gothenburg protocol and a scenario in which background

Figure NL.1 Average suitability for occurrences of dry heath species at different deposition scenarios.



Source: Alterra, PBL 2014

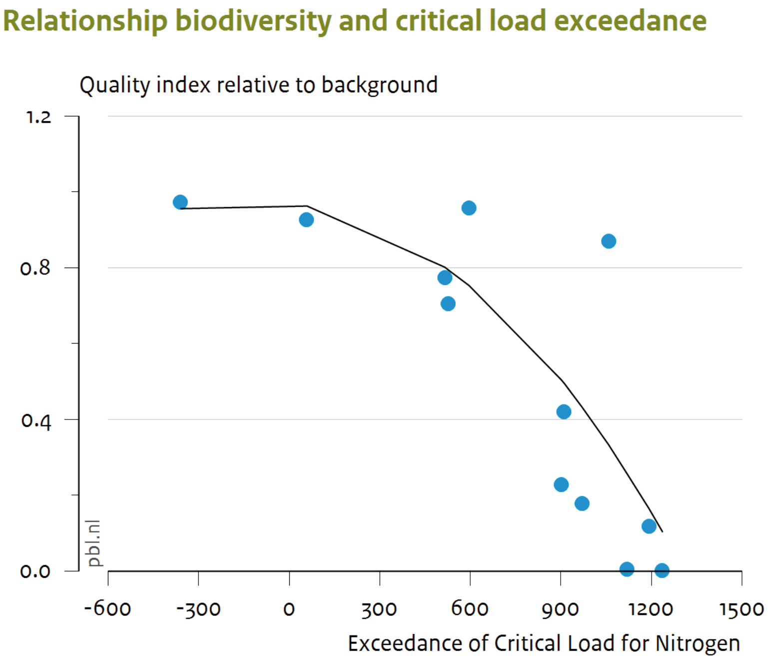
deposition levels were reached. Figure NL.1 shows an example of the model output for a dry heath site. The figure shows that the average suitability of the modelled plant species decreases from 1880 until the 1980s. During this period sulphur and N deposition increased at the site (data not shown). During the second period (from the 1980s till present) the average suitability increases, as deposition levels go down. In the background scenario the suitability increases even further. The individual plant species show often a similar response (data not shown). Surprisingly, the suitability in the background scenario exceeded the suitability calculated at low deposition levels around 1880.

Figure NL.2 shows how the habitat quality index of the different habitat types, relative to the quality index at background deposition levels in 2050, relates to the exceedances of critical loads for nitrogen in 2050. It suggests that the quality of the habitats sharply decreases with increasing deposition.

Discussion and conclusions

- Based on descriptions of protected habitat types and available soil-vegetation models it was possible to deliver the desired information for different relevant EUNIS classes in the Netherlands to the CCE. With PROPS it was possible to calculate information on most (80%) of the selected species and VSD+ could be run for different habitat types. Delivering information on both diversity between and within habitat types is very relevant for biodiversity policy.
- The average suitability of selected species seems a useful policy relevant indicator. Results show that this indicator in also (very) sensitive to deposition changes.
- In order to deliver a dataset for all habitat types occurring in The Netherlands more work is needed. More habitat types need to be included and models should be improved. Parameterization and testing of model runs for habitats from wet, calcareous or salt conditions needs special attention.
- The current vegetation model delivers information on suitability for occurrences. Biological recovery itself is not modelled, since information on aspects such as dispersal is missing.

Figure NL.2 Habitat quality index (average suitability of a particular habitat type in 2050 divided by the average suitability of that habitat type in 2050 at background deposition) plotted against the exceedance of the N critical load in 2050. Critical loads of habitat types are based on Van Dobben et al. (2014).



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Summary

In September 2012, a Call for Data was adopted by the Working Group on Effects at its 31st session (Geneva, 20-21 September 2012) and later issued by the CCCE of the ICP Modelling & Mapping with a delivery deadline of March 2014. The aim of the call is to assess to what extent 'no net loss of biodiversity' has been achieved using suitable regional-scale biodiversity endpoints, and to work towards supporting European environmental policies with information on adverse effects to biodiversity caused by air pollution, including the effects of climate change. This report describes empirical critical loads for nitrogen (N) as a nutrient established at Swedish Natura 2000 sites, and revised critical loads for acidity of surface waters. A database with the results of the new calculations is submitted simultaneously.

Historically most of the Swedish work related to critical loads has been based on calculations for forest soils or for lakes. Calculations have been made for both critical loads of acidity and critical loads of N as a nutrient. In contrast to previous submissions, here we focus on the establishment of critical loads for N as a nutrient at Natura 2000 areas. There are three reasons behind this shift in focus: (i) the call expressed direct encouragement to work specifically

with Natura 2000 areas, (ii) the increasing importance of forestry practices on element cycling in managed forests which makes critical loads more dependent on the way forestry is reflected in the calculations and (iii) the fact that protected areas in general are more sensitive and critical loads established at these are likely to guarantee protection from harmful effects in less sensitive parts of the landscape, such as managed forests.

The habitats of protected areas in general and Natura 2000 areas in particular are well documented. The National Focal Centre (NFC) has in co-operation with national experts reviewed habitats represented in 4071 Swedish Natura 2000 sites and established empirical critical loads of N as a nutrient. This was done either by assigning empirical critical loads values from Bobbink and Hettelingh (2011) according to habitats present at each Natura 2000 site, or by modifying the values in Bobbink and Hettelingh (2011) for Swedish conditions, or by developing new critical loads values for habitats not specified in Bobbink and Hettelingh (2011). The latter evaluation was performed by habitat experts at the Swedish Species Information Centre (ArtDatabanken).

On average, empirical critical loads for N as a nutrient were 4.3 kg N/ha/yr at the Natura 2000 sites. This is marginally lower than the average critical loads of 4.7 kg N/ha/yr estimated with the PROFILE model at managed forests close to Natura 2000 sites. The average Natura 2000 sites critical load estimate is, however, significantly lower than the previously established empirical critical load of 7.1 kg N/ha/yr (Posch et al. 2011) for the nearest forest, wetland, mountainous area or lake. Expressed as percentage of the Natura 2000 sites, the critical load of N was exceeded at 50% of Natura 2000 sites in the year 2010, at 44% sites in nearby managed forests based on PROFILE calculations and 19% of the 5 types of ecosystems in or near to Natura 2000 sites with previously assigned empirical critical loads. Thus, the non-exceedance of critical loads of N as a nutrient will call for the highest reduction in N deposition if based on Natura 2000 calculations, marginally lower reduction if based on PROFILE calculations, and significantly more N deposition will be tolerated if the non-exceedance calculations are based on previously submitted empirical critical loads.

The Call for Data encouraged further work on exploring modelled biodiversity change at protected areas for setting critical loads. The potential to perform these calculations in Sweden is limited due to lack of soils data from Natura 2000 sites. The lack of soils data limits the possibility to perform biogeochemical modelling of soil and soil water chemistry needed for modelling of biodiversity. This situation is not likely to change in the foreseeable future since no soil sampling program is in place at Swedish Natura 2000 sites.

The second part of the submission is a revision of previously (2012) submitted critical load calculations of acidity for lakes. In the current (2014) submission the critical loads calculations are based on roughly twice as many lakes compared to previous submission. Furthermore, forestry in the lake catchments accounted for in the critical load calculation is based on stem harvest at 2010 levels. Previously, forestry effects also included the expected increase in whole tree harvest which effectively resulted in lower critical load and therefore higher critical loads exceedance, for a given deposition level. For example the CLE deposition scenario resulted in exceedance of critical loads for acidity at 17.4% of country's area in year 2010. According to 2012 calculations, the exceedance would decrease to 15.5% by 2030. The decline in exceedance is relatively modest since effects of declining deposition were in part outweighed by increasing forest harvest intensity causing increased loss of base cations from catchment soils. With the revised methodology the same CLE scenario results in exceedances of 10.5% in 2030, which is more in line with the magnitude of the projected deposition decrease. Furthermore, the interpolation routine used in 2012 to calculate critical loads for grid cells in between those with actual lakes did not function properly. This has now been corrected. Compared to critical loads submitted in 2012, the new calculations follow the same geographical pattern, with most critical loads exceedances in southwest Sweden.

Introduction

From the Swedish perspective the ecosystem and health effects of air pollution and effects of climate change are high on the scientific and political agenda. Despite declining emissions of S and N in the last two decades, their impact on ecosystems is still of major concern, both with respect to acidification and eutrophication of soils and waters, together with ground level ozone concentrations and biodiversity changes. Therefore, Sweden welcomed the Call for Contribution issued by the CCE in September 2012. The Swedish NFC response to the 2012 call consists of two parts: a presentation of work on critical loads of N as a nutrient at Swedish Natura 2000 sites and revised critical loads for acidity on lakes.

Critical loads of N as a nutrient at Natura 2000 areas in Sweden

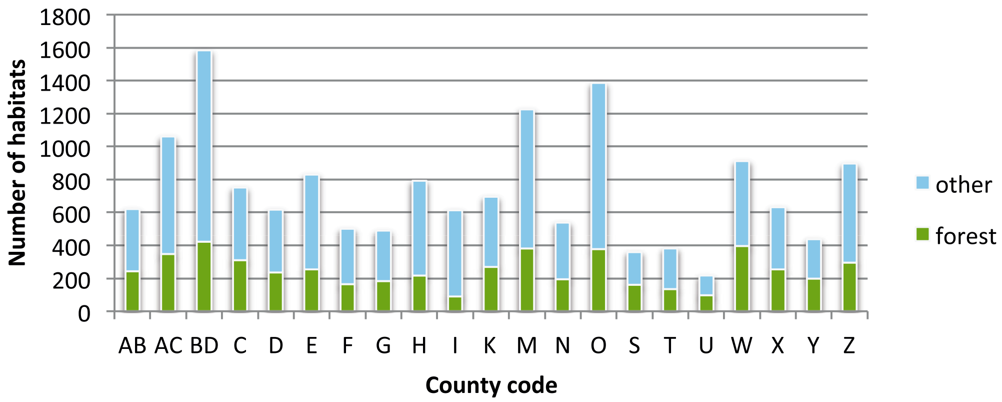
Historically, most critical loads related work has been based on calculations for forest soils and for lakes. Swedish NFC welcomed the direct encouragement to focus efforts on protected areas in general and on Natura 2000 areas specifically. The relative importance of forestry practices on soil base cations has been increasing due to both decreasing acidifying deposition and increasing intensity of harvesting (harvesting of thinning residues and of branches, tops and stumps for energy production). At managed forests, critical load estimates are increasingly dependent on how forestry is handled in the critical load calculations. This holds true both for critical loads based on BC/Al ratio in the root zone soil water and critical loads based on the acceptable levels of change in plant species. Protected areas often are not managed. A further advantage of working with protected areas is that they often are more sensitive, especially to nitrogen loads, than managed forest ecosystems. Therefore, protection of these areas (i.e. non-exceedance of critical loads) implies that even managed forests in the same area are protected. However, one disadvantage is that geochemical data, in particular on soils, are much scarcer compared to regularly sampled forest soils. The lack of soils data is problematic both for geochemical modelling of soil water chemistry to establish BC/Al ration for critical loads of acidity and for modelling of soil water nitrate concentrations for biodiversity modelling. Without soils data, any modelling would be speculative as it would not be possible to verify the geochemical model outcomes or the critical loads based on the modelled values. On the other hand, the habitats of protected areas are well documented. NFC has in co-operation with national experts reviewed habitats represented in 4071 Swedish Natura 2000 sites and established the empirical critical loads of N as a nutrient either by using values from Bobbink and Hettelingh (2011), or by modifying these values for Swedish conditions and complemented the values for habitats not presented in Bobbink and Hettelingh (2011).

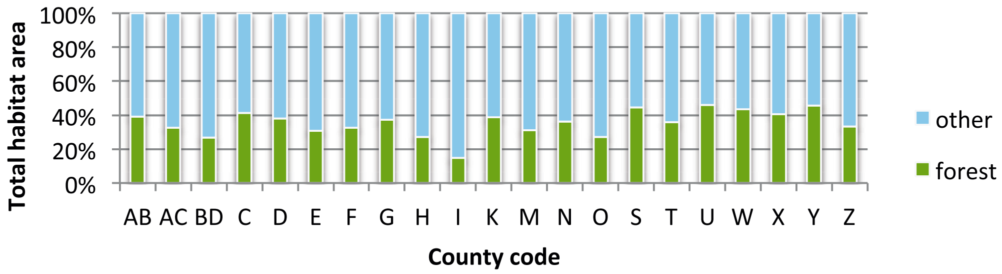
The 4071 Natura 2000 protected areas in Sweden cover an area of approximately 6.5 million ha, which constitutes 15 % of the total area of Sweden. About 60 % of the Natura 2000 sites overlap with protected areas such as national parks and reserves. The Swedish Environmental Protection Agency has the overarching responsibility for Natura 2000-related work in Sweden. The county administrative boards act as regulatory authorities together with the Swedish Forest Agency which handles forestry practices. Species and habitat data together with auxiliary information for the Swedish Natura 2000 sites was downloaded from the European Environment Agency (www.eea.europa.eu/data-and-maps/data/natura-4#tab-european-datahttp://www.eea.europa.eu/data-and-maps/data/natura-4#tab-european-data, data downloaded 2013-09-10). These data are based on the standard data form (SDF) that every member state uses to report to the European Commission. The latest update was carried out in 2012. More information regarding the SDF is available at: http://bd.eionet.europa.eu/activities/Natura_2000/reference_portal.
At Swedish Natura 2000 sites the number forest habitats are less than half of the total number of habitats and the total area of forest habitats is small compared to the total habitat area (Figure SE.1).

Empirical critical loads habitats

There are a total of 89 habitats included in the Swedish Natura 2000-sites. Our aim was to set empirical critical loads for nutrient N for each of these habitats with a starting point in the tables for empirical critical loads in Bobbink and Hettelingh (2011). After consulting the tables about 1/3 of the habitats lacked empirical critical loads. Experts from the Swedish Species Information Centre (ArtDatabanken) went through the material and set empirical critical loads for 82 habitats (also changing some set from Bobbink and Hettelingh (2011) to suit Swedish conditions) and 7 habitats were excluded (Table SE.1).

Figure SE.1. Top: Total number of habitats for all Natura 2000-sites in each county divided in forest habitats (classified G according to EUNIS level 1) and non-forest habitats. Bottom: percentage of forest habitat areas (classified G according to EUNIS level 1) and other habitat areas of the total area of habitats in the Swedish Natura 2000-sites for each county.





Comparisons with previous reporting

To see what impact the new derived empirical critical loads for the Natura 2000-sites could have, the exceedance was calculated and compared with earlier calculations from the Swedish reporting (Posch et al. 2011). In the 2011 reporting, critical loads of nutrient N were based on:

- PROFILE (Sverdrup and Warfvinge 1993) modelled concentrations of nitrate (critical limit of 0.3 mg N/l) in the water leaching from the root zone. This was done for 17,333 sites within the National Forest inventory.
- Empirical critical loads from Bobbink and Hettelingh (2011) for the following land use classes: coniferous forest, deciduous forest, wetlands, lakes and mountain areas using a satellite-derived land use map (Mahlander et al. 2004).

The exceedance was calculated with the new empirical critical loads (and the critical loads reported for Sweden 2011) and the deposition downloaded from EMEP (www.emep.int/mscw/index_mscw.html, the 2010-v2013 version). GIS-software was used to match the deposition to the Natura 2000 sites, the sites used for PROFILE and the previously established empirical critical loads sites. If more than one EMEP square overlapped a site, the square with highest deposition was used to represent the deposition for the entire Natura 2000 site. In the same manner, the habitat most sensitive to deposition of N was also chosen to determine the critical load for the entire Natura 2000 site.

The sensitivity to deposition of N is highest if calculations are based on Natura 2000 areas both on average and for the majority of individual sites (Figure SE.2). The difference is, however, not large compared to critical loads for forests soils in geographical proximity to Natura 2000 sites (c.f. green and blue lines Figure SE.2). The 5 types of ecosystems for which empirical critical loads of N were previously established are much less sensitive to N deposition than Natura 2000 sites. Non-exceedance of critical loads at these areas leaves a significant part of Natura 2000 sites unprotected (c.f. blue and red lines, Figure SE.2).

Empirical critical loads of N as nutrient established at 82 habitat types present at Swedish Natura 2000 sites are summarized in Table SE.1.

Figure SE.2 Exceedance of critical loads calculated empirically for Natura 2000-sites (blue), empirically from 2011 reporting (red) and from soil water using PROFILE 2011 (green).

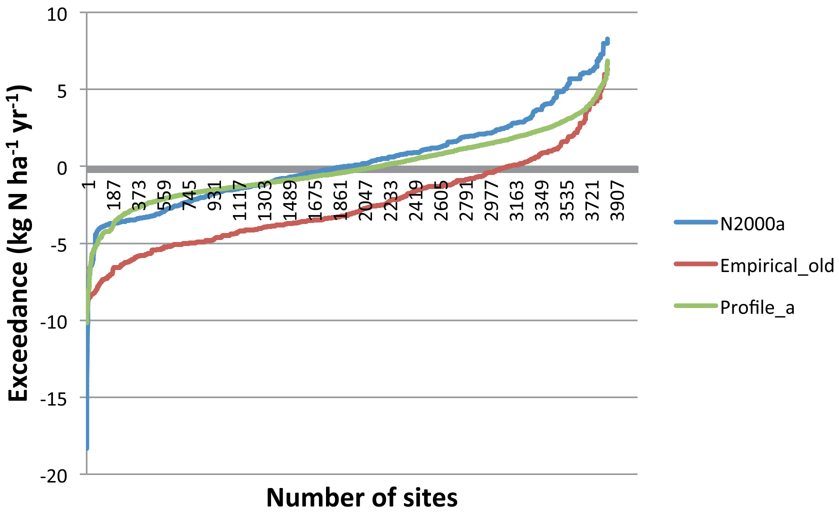


Table SE.1 Empirical critical loads of nutrient N.

HABITAT CODE	CL range (kg N/ha^{-1}/yr^{-1})	Swedish description	English description	Source	EUNIS
1130	20-30	Estuarier	Estuaries	Bobbink & Hettelingh, 2011	X01
1140	20-30	Blottade ler- och sandbottnar	Mudflats and sandflats not covered by seawater at low tide	Swedish expert judgement-Lowest/ Highest	A2.2
1150	20-30	Laguner	Coastal lagoons	Bobbink & Hettelingh, 2011	X02/X03
1160	20-30	Stora vikar och sund	Large shallow inlets and bays	Swedish expert judgement-Lowest/ Highest	
1220	8-15	Sten- och grusvallar	Perennial vegetation of stony banks	Bobbink & Hettelingh, 2011	B2.2
1230	3-5	Vegetationsklädda havsklippor	Vegetated sea cliffs of the Atlantic and Baltic Coasts	Swedish expert judgement-Lowest/ Highest	B3.3
1310	20-30	Glasörtstränder	Salicornia and other annuals colonizing mud and sand	Bobbink & Hettelingh, 2011	A2.548
1330	20-30	Salta strandängar	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)	Bobbink & Hettelingh, 2011	A2.5
1610	5-10	Rullstensåsöar i Östersjön	Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation	Swedish expert judgement-Lowest/ Highest	
1620	5-10	Skär och små öar i Östersjön	Boreal Baltic islets and small islands	Swedish expert judgement-Lowest/ Highest	
1630	10-20	Strandängar vid Östersjön	Boreal Baltic coastal meadows	Swedish expert judgement-Lowest/ Highest	A2.5
1640	8-15	Sandstränder vid Östersjön	Boreal Baltic sandy beaches with perennial vegetation	Swedish expert judgement-Lowest/ Highest	B1.2

Table SE.1 continued.

HABITAT CODE	CL range (kg N/ha^{-1}/yr^{-1})	Swedish description	English description	Source	EUNIS
1650	10-15	Smala Östersjövikar	Boreal Baltic narrow inlets	Swedish expert judgement-Lowest/ Highest	A5.3112
2110	8-15	Fördyner	Embryonic shifting dunes	Swedish expert judgement-Lowest/ Highest	B1.31
2120	5-10	Vita dyner	Shifting dunes along the shoreline with Ammophila arenaria ("white dunes")	Swedish expert judgement-Lowest/ Highest	B1.3
2130	5-10	Grå dyner	Fixed coastal dunes with herbaceous vegetation ("grey dunes")	Swedish expert judgement-Lowest/ Highest	B1.4
2140	5-10	Risdyner	Decalcified fixed dunes with Empetrum nigrum	Swedish expert judgement-Lowest/ Highest	B1.5
2170	5-10	Sandvidedyner	Dunes with Salix repens ssp. argentea (Salicion arenariae)	Swedish expert judgement-Lowest/ Highest	B1.62
2180	5-10	Trädklädda dyner	Wooded dunes of the Atlantic, Continental and Boreal region	Swedish expert judgement-Lowest/ Highest	B1.7
2190	5-10	Dynvåtmarker	Humid dune slacks	Swedish expert judgement-Lowest/ Highest	B1.8
2320	5-10	Rissandhedar	Dry sand heaths with Calluna and Empetrum nigrum	Swedish expert judgement-Lowest/ Highest	F4.2/E1.9
2330	5-10	Grässandhedar	Inland dunes with open Corynephorus and Agrostis grasslands	Swedish expert judgement-Lowest/ Highest	E1.9
3110	3-5	Näringsfattiga slättsjöar	Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)	Swedish expert judgement-Highest	C1.1/C1.12
3130	3-5	Ävjestrandsjöar	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea	Swedish expert judgement-Highest	C1.2/C3.5
3140	3-10	Kransalgsjöar	Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.	Swedish expert judgement-Lowest/ Highest	C1.2
3150	5-10	Naturligt näringsrika sjöar	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation	Swedish expert judgement-Lowest/ Highest	C1.3
3160	3-10	Myrsjöar	Natural dystrophic lakes and ponds	Bobbink & Hettelingh, 2011	C1.4
3210	5-10	Större vattendrag	Fennoscandian natural rivers	Swedish expert judgement-Lowest/ Highest	C2.2/C2.3
3220	3-5	Alpina vattendrag	Alpine rivers and the herbaceous vegetation along their banks	Swedish expert judgement-Lowest/ Highest	C2.2/C2.3

Table SE.1 continued.

HABITAT CODE	CL range (kg N/ha⁻¹/yr⁻¹)	Swedish description	English description	Source	EUNIS
3260	5-10	Mindre vattendrag	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation	Swedish expert judgement-Lowest/ Highest	C2.2/C2.3
4010	5-10	Fukthedar	Northern Atlantic wet heaths with Erica tetralix	Swedish expert judgement-Lowest/ Highest	F4.1
4030	5-10	Torra hedar	European dry heaths	Swedish expert judgement-Lowest/ Highest	F4.2
4060	5-10	Alpina rishedar	Alpine and Boreal heaths	Swedish expert judgement-Highest	F2.2/F3.2
4080	5-15	Alpina videbuskmarker	Sub-Arctic Salix spp. scrub	Bobbink & Hettelingh, 2011	F2.321
5130	5-10	Enbuskmarker	Juniperus communis formations on heaths or calcareous grasslands	Swedish expert judgement-Lowest/ Highest	F3.1
6110	3-5	Basiska berghällar	Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi	Swedish expert judgement-Lowest/ Highest	E1.11
6120	3-5	Sandstäpp	Xeric sand calcareous grasslands	Swedish expert judgement-Lowest/ Highest	E1.12
6150	5-10	Alpina silikatgräsmarker	Siliceous alpine and boreal grasslands	Bobbink & Hettelingh, 2011	E4.3
6170	5-10	Alpina kalkgräsmarker	Alpine and subalpine calcareous grasslands	Bobbink & Hettelingh, 2011	E4.4
6210	5-10	Kalkgräsmarker	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)	Swedish expert judgement-Lowest/ Highest	E1.2
6230	5-10	Stagg-gräsmarker	Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)	Swedish expert judgement-Lowest/ Highest	E1.71
6270	5-10	Silikatgräsmarker	Fennoscandian lowland species-rich dry to mesic grasslands	Swedish expert judgement-Lowest/ Highest	E2.2
6280	3-5	Alvar	Nordic alvar and precambrian calcareous flatrocks	Swedish expert judgement-Lowest/ Highest	E1.2/E1.25
6410	8-15	Fuktängar	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)	Swedish expert judgement-Lowest/ Highest	E3.5
6430	8-15	Högörtängar	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	Swedish expert judgement-Lowest/ Highest	E5.5/E5.4
6450	10-20	Svämängar	Northern boreal alluvial meadows	Swedish expert judgement-Lowest/ Highest	E3.47
6510	8-15	Slåtterängar i låglandet	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)	Swedish expert judgement-Lowest/ Highest	E2.2

Table SE.1 continued.

HABITAT CODE	CL range (kg N/ha⁻¹/yr⁻¹)	Swedish description	English description	Source	EUNIS
6520	8-15	Högländta slåtterängar	Mountain hay meadows	Swedish expert judgement-Lowest/ Highest	E2.3
6530	8-15	Lövängar	Fennoscandian wooded meadows	Swedish expert judgement-Lowest/ Highest	X09
7110	5-10	Högmossar	Active raised bogs	Bobbink & Hettelingh, 2011	D1.11
7120	5-10	Skadade högmossar	Degraded raised bogs still capable of natural regeneration	Bobbink & Hettelingh, 2011	D1.12
7130	5-10	Terrängtäckande mossar	Blanket bogs (* if active bog)	Bobbink & Hettelingh, 2011	D1.2
7140	5-10	Öppna mossar och kärr	Transition mires and quaking bogs	Bobbink & Hettelingh, 2011	D2.3
7160	5-10	Källor och källkärr	Fennoscandian mineral-rich springs and springfens	Swedish expert judgement-Lowest/ Highest	C2.11/C2.18 /C2.1A
7210	5-10	Agkärr	Calcareous fens with Cladium mariscus and species of the Caricion davallianae	Swedish expert judgement-Lowest/ Highest	D5.24
7220	5-10	Kalktuffkällor	Petrifying springs with tufa formation (Cratoneurion)	Swedish expert judgement-Lowest/ Highest	C2.12
7230	5-10	Rikkärr	Alkaline fens	Swedish expert judgement-Lowest/ Highest	D4.1
7240	5-10	Alpina översilningskärr	Alpine pioneer formations of the Caricion bicoloris-atrofuscae	Swedish expert judgement-Lowest/ Highest	D4.2
7310	5-10	Aapamyrar	Aapa mires	Swedish expert judgement-Highest	D3.2
7320	5-10	Palsmyrar	Palsa mires	Swedish expert judgement-Lowest/ Highest	D3.1
8110	5-10	Silikatrasmarker	Siliceous scree of the montane to snow levels (Androsacetalia alpinae and Galeopsietalia ladani)	Swedish expert judgement-Lowest/ Highest	
8120	5-10	Kalkrasmarker	Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)	Swedish expert judgement-Lowest/ Highest	
8210	3-5	Kalkbranter	Calcareous rocky slopes with chasmophytic vegetation	Swedish expert judgement-Lowest/ Highest	
8220	3-5	Silikatbranter	Siliceous rocky slopes with chasmophytic vegetation	Swedish expert judgement-Lowest/ Highest	
8230	3-5	Hällmarkstorräng	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo albi-Veronicion dillenii	Swedish expert judgement-Lowest/ Highest	
8240	3-5	Karsthällmarker	Limestone pavements	Swedish expert judgement-Lowest/ Highest	
9010	5-10	Taiga	Western Taïga	Bobbink & Hettelingh, 2011	G3.A/G3.B/ G3.D5/G4.2

Table SE.1 continued.

HABITAT CODE	CL range (kg N/ha^{-1}/yr^{-1})	Swedish description	English description	Source	EUNIS
9020	3-5	Nordlig ädellövskog	Fennoscandian hemiboreal natural old broad-leaved deciduous forests (Quercus, Tilia, Acer, Fraxinus or Ulmus) rich in epiphytes	Swedish expert judgement-Lowest/ Highest	G1.A
9030	5-10	Landhöjningsskog	Natural forests of primary succession stages of land upheaval coast	Swedish expert judgement-Lowest/ Highest	
9040	5-10	Fjällbjörkskog	Nordic subalpine/subarctic forests with Betula pubescens ssp. czerepanovii	Swedish expert judgement-Lowest/ Highest	F2.3
9050	5-10	Näringsrik granskog	Fennoscandian herb-rich forests with Picea abies	Bobbink & Hettelingh, 2011	G3.A3/G3.A4
9060	5-10	Åsbarrskog	Coniferous forests on, or connected to, glaciofluvial eskers	Swedish expert judgement-Lowest/ Highest	G3.A3/G3.B3
9070	5-10	Trädbeklädd betesmark	Fennoscandian wooded pastures	Swedish expert judgement-Lowest/ Highest	X09
9080	5-10	Lövsumpskog	Fennoscandian deciduous swamp woods	Swedish expert judgement-Lowest/ Highest	G1.4/G1.B
9110	3-5	Näringsfattig bokskog	Luzulo-Fagetum beech forests	Swedish expert judgement-Lowest/ Highest	G1.6
9130	3-5	Näringsrik bokskog	Asperulo-Fagetum beech forests	Swedish expert judgement-Lowest/ Highest	G1.6
9160	3-5	Näringsrik ekskog	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli	Swedish expert judgement-Lowest/ Highest	G1.A1
9180	3-5	Ädellövskog i branter	Tilio-Acerion forests of slopes, screes and ravines	Swedish expert judgement-Lowest/ Highest	G1.A
9190	3-5	Näringsfattig ekskog	Old acidophilous oak woods with Quercus robur on sandy plains	Swedish expert judgement-Lowest/ Highest	G1.8
91D0	5-10	Skogsbevuxen myr	Bog woodland	Swedish expert judgement-Lowest/ Highest	G3.D/G1.5/ G3.E
91E0	10-20	Svämlövskog	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)	Swedish expert judgement-Highest	G1.21
91F0	10-20	Svämädellövskog	Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)	Swedish expert judgement-Lowest/ Highest	G1.22
Excluded:					
1110	N/A	Sandbankar	Sandbanks which are slightly covered by sea water all the time		A2.5

Table SE.1 continued.

HABITAT CODE	CL range (kg N/ha^{-1}/yr^{-1})	Swedish description	English description	Source	EUNIS
1170	N/A	Rev	Reefs		A2.7/A5.6
1210	N/A	Driftvallar	Annual vegetation of drift lines		B1.1
1180	N/A	Undervattensstrukturer bildade av utläckande gas	Submarine structures made by leaking gases		
8310	N/A	Grottor	Caves not open to the public		
8330	N/A	Marina grottor, helt eller delvis under vattenytan	Submerged or partially submerged sea caves		
8340	N/A	Permanenta glaciärer	Permanent glaciers		

Critical loads of acidity for lakes

Sweden has revised calculations of critical loads of acidity for surface waters submitted to CCE as a response to the 2011 Call for Data (Posch et al. 2012). In the current (2014) submission the critical loads calculations are based on roughly twice as many lakes compared to 2011/12, and there have been some changes in calculation methodology (see below). Furthermore, the interpolation routine to calculate critical loads for grid cells in between those with actual lakes has been improved. Critical loads calculations based on forest soils were not revised since the 2011/12 submission and are therefore not included in this response to the call.
Compared to critical loads submitted in 2012, the new calculations follow the same geographical pattern but are in general slightly higher, which also means that exceedance of critical loads is lower (Table SE.2). This result is due to a combination of several factors including the fact that in the 2012 submission, a higher impact of forestry practices (more intensive forestry) was accounted for in the critical loads calculation.

The critical loads were calculated for 5084 lakes within the national lake survey program where approximately 850 lakes were sampled each year 2007-2012. The lakes were selected by a stratified random selection of lakes > 1 ha from the national lake register by SMHI (SVAR). The stratification was based on lake size class in SVAR and the 150×150 km^2 grid by EMEP (Grandin 2007). Limed lake chemistry was corrected by the ratio of Ca/Mg from non-limed references either up-stream within the catchment or outside the catchment within a 20 km distance (Fölster et al. 2011). Magnesium concentration of the liming agent was also corrected for.

The critical loads were calculated using the FAB model (Henriksen and Posch 2001) with modifications as described below. The chemical threshold, ANC_{limit}, was calculated individually for each lake to a value corresponding to a change in pH of 0.4 units from reference conditions (1860) calculated by MAGIC (Moldan et al. 2004). This criterion is used in Sweden, and is derived from empirical data for sensitive fish populations and littoral invertebrates (Fölster et al. 2007). A delta-pH > 0.4 is considered 'unacceptable biological damage' and is used for classification of ecological status in

Table SE.2 Exceedence of critical loads for acidification in lakes. Lakes are assumed to represent the whole surface of Sweden minus the area of the 9 largest lakes, i.e. 437,000 km^2. Deposition in 2030 according to CLE was used for the exceedance calculations.

	% Exceeded area	Exceeded area km^2*1000
Year 2010	17,4	76
Year 2030 (2012-submission)	15,5	68
Year 2030 (2014-submission)	10,5	46

Sweden (Naturvårdsverket 2007). Delta-pH was calculated from delta-ANC by using the model of Hruska et al. (2003) for organic acids and assuming that total organic carbon (TOC) has been constant over time. The partial pressure of CO_2 was calculated by a linear relationship to TOC (Sobek et al. 2011). This flexible value of ANC_{limit} takes better account of the large TOC gradient in Swedish lakes with 5 and 95 percentiles of 1, 5 and 26 mg C/l. These TOC-concentrations corresponds to pH values of 6.0 and 4.1 when ANC is 20 µg/l, which was the previous fixed value of ANC_{limit}. The criteria of delta-pH = 0.4 is appropriate for naturally acidic lakes in which the biological community was controlled by acidity even during the preindustrial period.

Instead of assuming a fixed N immobilisation by the soil ecosystem, calculations of N immobilisation were based on Gundersen et al (1998). Excess N deposition was calculated as deposition minus forest N uptake. N immobilisation was set to 100% for excess deposition up to 2 kg N/ha, 50% for the fraction between 2 and 10 kg N/ha and 0 % for the excess deposition above 10 kg N/ha. In addition to this, leaching of organic N calculated from the lake concentration of Total Organic Nitrogen (TON) was regarded as non-acidifying.

The leaching of base cations (BCle) used in the FAB-model was the calculated BC concentration 2100 according to MAGIC simulations using the CLE scenario. Thus the F-factor for estimating the weathering rate was not used. The year 2100 was used instead of 1860 for steady state since modelling indicated that the BC concentration of 1860 will not be possible to reach even with a total reduction of acidifying deposition.

For each lake, data for BC2100 and delta-ANC is obtained from the most similar lake with a MAGIC simulation within the tool '$MAGIC_{library}$' (Moldan et al. 2013). ANC_{1860} is calculated as $ANC_t + \Delta ANC_{MAGIClibrary}$ and pH_{1860} is calculated from ANC_{1860} and TOC in the lake as described above. ANC_{limit} is finally calculated from $pH_{1860} - 0.4$ according to the criteria for acidification.

The results from the 5084 lakes can be used to estimate the state for all Swedish c. 96,000 lakes with an area greater than 1 hectare by destratification. A weight factor, $w_{i,j}$, is calculated for each lake as the ratio between the number of lakes in the lake register (SVAR) within a stratum of size class *i* and EMEP-square *j* and the number of monitored lakes within that strata according to:

$$(1) \quad w_{i,j} = \frac{N_{SVAR,i,j}}{N_{survey,i,j}}$$

This weight factor tells how many lakes each monitored lake represents. The total area of Sweden is regarded as the ecoarea for lakes, since the lake water quality is a result of processes in the catchment. The nine largest, and in all cases well-buffered lakes, are excluded from the total area. The ecoarea for a lake of size class *i* within EMEP-square *j* is computed as:

$$(2) \quad ecoarea_{i,j} = Area_j \frac{w_{i,j}}{\sum_j w_{i,j}}$$

where $Area_j$ is the area of the square within the total area. The calculation does not take into account that lakes have different catchment area and that the catchments may overlap, since the catchments of all Swedish lakes are not known. The % of exceeded area is calculated as the ratio between the sums of ecoareas of exceeded lakes and total ecoarea according to:

$$(3) \quad \%\ exceedence = 100 \frac{\sum ecoarea_{i,j\ exceeded}}{ecoarea_{total}}$$

The geographical distribution of exceedance can be visualised by maps showing a value for each EMEP50-square. In this report the 'Average Accumulated Exeedance' (AAE) is calculated for each square according to the Mapping manual for critical load (CLRTAP 2004) by the formula:

$$(4) \quad AAE = \frac{\sum_{i=1}^{n} ecoarea_i Ex_i}{\sum_{i=1}^{n} ecoarea_i}$$

where Ex_i is the total exceedance of sulphur and N for each lake. Lakes without an exceedance are included in the calculations with an exceedance of zero.

Interpolation to the 5 km ×5 km grid

Sweden contains approximately 18,000 5×5 km² squares. Provided that there are close to 100,000 lakes in Sweden there are on average close to 5 lakes in each 5×5 km² square. The 5084 sampled lakes were distributed over 3781 of the 5×5 km² squares. In most cases there was one modelled lake per 5×5 km² square. The ecoarea was then set to the area of the square covering the area of Sweden, the nine largest lakes excluded. For lakes within squares with more than one lake, an average value was calculated for the square. For the approximately 14,500 squares with no modelled lakes inside, the CL data were calculated by an interpolation between the squares with calculated CLs, using inverse distance weighted interpolation. For each square the interpolated value for the centre of the square was selected.

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Overview

This document summarizes the data sources, the methods applied and the results of the Swiss contribution to the CCE Call for Data 2012-14. The National Focal Centre of Switzerland, together with three collaborating institutions, followed two approaches to address the question of deriving exposure-response relationships between nitrogen (N) deposition and effects on biodiversity on a regional scale for sites within specific EUNIS classes:

1. Observation based exposure-response relationships between N deposition and species richness for 133 mountain hay meadows sites (EUNIS E2.3) and 37 (sub-)alpine scrub habitats sites (EUNIS F2.2) on the basis of modelled N deposition data and data from the Swiss Biodiversity Monitoring network;

2. Dynamic Modelling at 32 selected forest monitoring sites (EUNIS G1, G3 and G4) by applying the VSD+PROPS studio version made available by the CCE.

Figure CH.1 Location of forest monitoring sites used for dynamic modelling with VSD+PROPS and location of mountain hay meadows (EUNIS E2.3) and (sub-)alpine scrub habitats (EUNIS F2.2) sites used for deriving observation based exposure-response relationships between N deposition and changes in species richness.

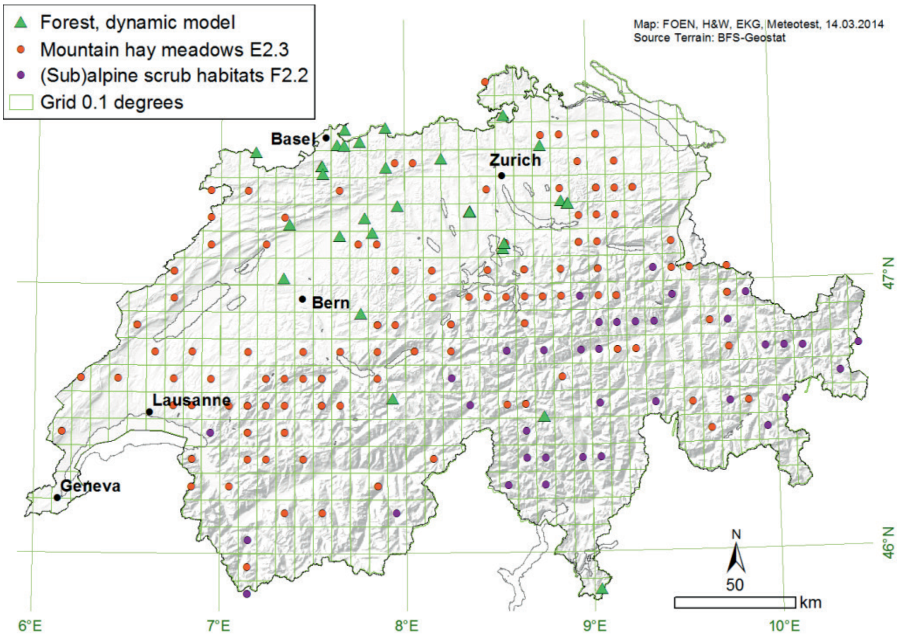


Figure CH.1 gives an overview of the sites being used for the analysis mentioned under (1) and (2). The forest sites are part of the Inter-cantonal Forest Monitoring Network pursued by the Institute for Applied Plant Biology (IAP), the mountain hay meadows and the (sub-)alpine scrub habitats sites represent a selection from the approximately 1500 plots of 10 m² of the Swiss Biodiversity Monitoring Network (BDM) established for monitoring species diversity in habitats. Since the BDM avoids publishing the exact positions of the plots, longitude and latitude were allocated to the centroid points of the new EMEP grid (0.1° × 0.1°).

In addition, some of the results were used to discuss potentially needed revisions of current empirical critical loads of N on the basis of the recent findings with respect to changes of species richness in mountain hay meadows and (sub-)alpine scrub habitats induced by N deposition.

1. Observation based exposure-response relationships between N deposition and species richness for montane and alpine habitats

Introduction

Nitrogen deposition is a major threat to biodiversity of many habitats in the lowlands (Stevens et al. 2010, Southon et al. 2013, Dirnböck et al. 2014). In alpine habitats, however, the effect of N deposition on biodiversity is not sufficiently well explored and available data seem to be difficult to interpret. Switzerland has a large proportion of alpine habitats. Correspondingly, it has a high responsibility for the protection of these habitats in Central Europe.

During the last two years possible relationships between N deposition at high spatial resolution (100 m × 100 m grid) in Switzerland and site-specific data available from the Biodiversity Monitoring in Switzerland (BDM, www.biodiversitymonitoring.ch) were analysed. So far the analysis has led to quantitative exposure-response relationships for species-rich mountain hay meadows (EUNIS class E2.3; Roth et al. 2013) and for alpine and subalpine scrub habitats (EUNIS class F2.2). Specifically, we tested (i) whether N deposition is negatively related to plant species richness and (ii) whether N deposition is related to species richness of oligotrophic species.

Material and methods

Biodiversity Monitoring Data

We analysed data of vascular plants that have been collected as part of the BDM from 2008 to 2012. Fieldwork was highly standardized and was carried out by qualified botanists who recorded all vascular plants on a surveyed plot. For more details on the field methods see Roth et al. (2013).

During each survey the botanists identified in the field the type of biotope according to the definition developed for Switzerland (Delarze and Gonseth 2008). The habitats of the survey plots were assigned to the EUNIS habitats (level-3 classification, Davies et al. 2004). For the current analyses, we selected mountain hay meadows (EUNIS class E2.3, n=133) and Arctic, alpine and subalpine scrub habitats (EUNIS class F2.2, n=37).

Measures of Plant Diversity

- Species richness (i.e. the total number of plants identified on species level) [indicator 8 of the CCE call for data]
- Number of oligotrophic species that are typically found on nutrient poor sites (i.e., species with N-values of one or two according to Landolt et al. 2010) [indicator 9 of the CCE call for data].

Nitrogen deposition

Atmospheric N deposition was estimated using a pragmatic approach that combines monitoring data, spatial interpolation methods, emission inventories, statistical dispersion models and inferential deposition models (Rihm and Kurz 2001, Roth et al. 2013). The model provided deposition rates at a resolution of 100 m × 100 m. Model predictions were made for two time steps:

- N deposition for the year 2010 (Figure CH.2) corresponding to the period of the BDM survey
- N deposition in 2100 based on Gothenburg Protocol (GP) conditions

Figure CH.2 Total N deposition in Switzerland modelled for the year 2010.

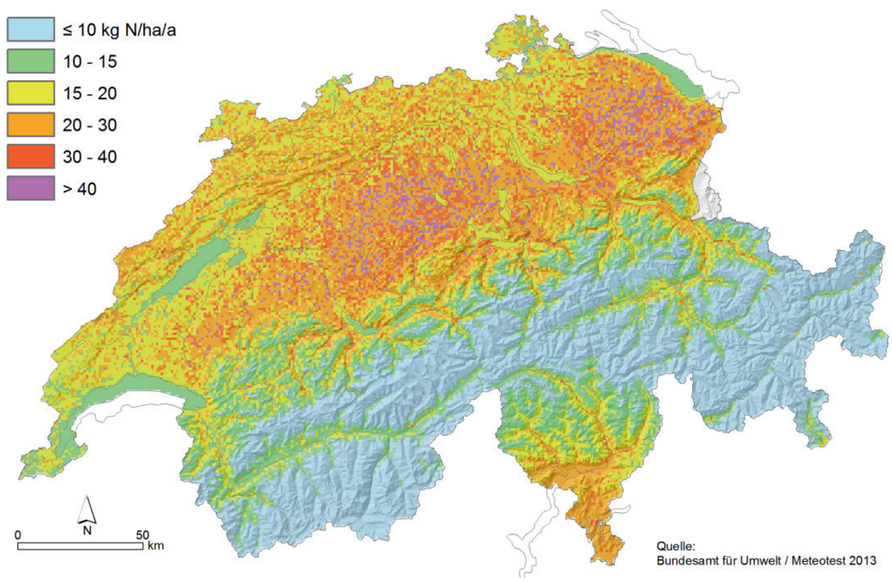


Table CH.1 Summary of environmental factors used in the statistical models.

Name	Description	Mean±SD; min, max	Source
Altitude	Meter above see level of sample plot (m)	1304±540; 377, 2439	Wohlgemuth et al. (2008)
Inclination	Inclination (degrees)	17±9; 0, 42	Wohlgemuth et al. (2008)
Precipitation	Annual precipitation (mm)	1494±297; 802, 2276	Wohlgemuth et al. (2008)
Soil reaction (R-value)	Mean Indicator value of soil reaction	3±0.5; 1.5, 3.9	Landolt et al. (2010)
Humidity (F-value)	Mean indicator value of soil humidity	3±0.2: 2.1, 3.5	Landolt et al. (2010)
Expositions	Exposition (360°; 0=N)	180±108; -1, 358	Wohlgemuth et al. (2008)

Other environmental factors considered
In addition to the explanatory variable 'N deposition' we accounted for additional environmental factors being known to influence plant diversity from earlier studies (Wohlgemuth et al. 2008, Roth et al. 2013).

Since within the sample of sites, altitude and mean light indicator values were strongly correlated (r=0.84), we decided not to use mean light indicator values in our analysis. Thus, for all statistical models we accounted for the confounding variables listed in Table CH.1.

Statistical analyses

To test for the effect of the independent variables we were interested in (e.g. N deposition) on the different response variables (e.g. species richness), we used generalized additive models (GAM; Zuur et al. 2009). All GAM analyses were done with the software R (R Development Core Team 2013) using the package 'mgcv'. For more details on the statistical methods see Roth et al. (2013).

Results

Mountain hay meadows
In mountain hay meadows mean ±SD species richness was 38.3±7.45 whereof 9.58 ± 9.71 oligotrophic species. Species richness and species richness of oligotrophic species were negatively related to N deposition. After adjusting for confounding effects of the environmental factors listed in Table CH.1, the exposure-response relationship between N deposition and total species richness was $58.935e^{-0.018x}$, $R^2 = 0.55$ (Figure CH.3); and between N deposition and species richness of oligotrophic species it was $51.186e^{-0.114x}$, $R^2 = 0.71$ (Figure CH.4). As expected, the response of oligotrophic species to N deposition was more pronounced than the response of overall species richness.

Figure CH.3. Predicted species richness in mountain hay meadows as function of N deposition, after adjusting for effects of variables listed in Table CH.1.

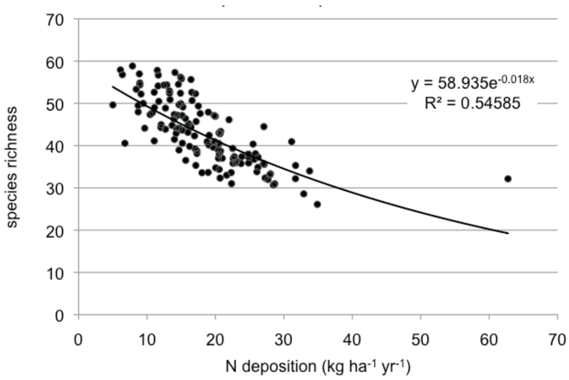
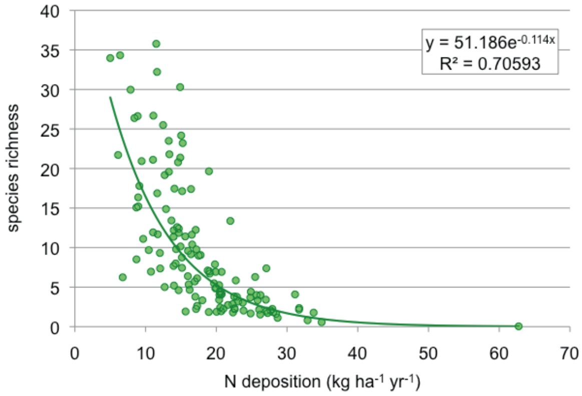


Figure CH.4. Predicted species richness of oligotrophic species in mountain hay meadows as function of N deposition, after adjusting for effects of variables listed in Table CH.1.



Alpine and subalpine scrub habitats

In alpine and subalpine scrub habitats the mean ± SD species richness was 28.05 ± 12.29, whereof 22.19 ± 9.26 oligotrophic species. Species richness and species richness of oligotrophic species were slightly negatively related to N deposition. After adjusting for confounding effects of the environmental factors listed in Table CH.1, the exposure-response relationship between N deposition and total species richness was $43.69e^{-0.05x}$, R^2= 0.27 (Figure CH.5); and between N deposition and species richness of oligotrophic species it was $43.75e^{-0.076x}$, R^2= 0.42 (Figure CH.6). As expected, the response of oligotrophic species to N deposition was more pronounced than the response of overall species richness.

Discussion and conclusions

To analyse the effect of N deposition on plant species richness, the number of plots of habitats on the level-3-classification used in this analysis is small and it is also smaller than in most other studies (e.g. Stevens et al. 2010). Furthermore, in the BDM scheme, plots are situated on a systematic grid with random origin irrespective of the distribution of the different habitats. Thus, single plots may comprise two or more different level-3 habitats. This is contrary to other studies (e.g. Stevens et al. 2010) where plots are arranged on a gradient of N deposition. Given the random BDM sample and the high heterogeneity of species richness, we argue that the pattern we found in mountain hay meadows must be very general.

Figure CH.5 Predicted species richness in alpine and subalpine scrub habitat (F2.2) as function of N deposition, after adjusting for effects of variables listed in Table CH.1.

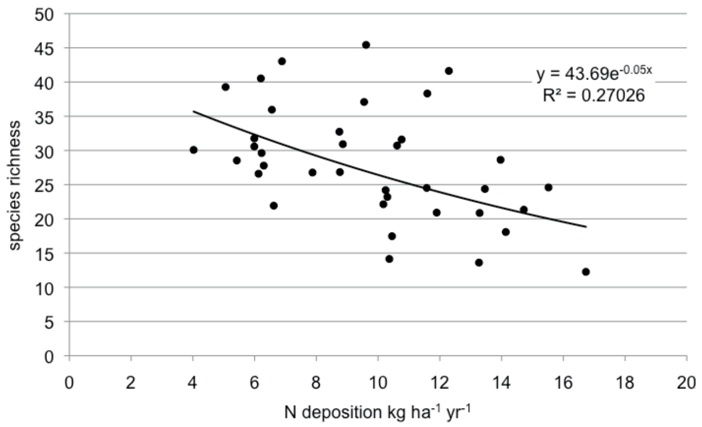
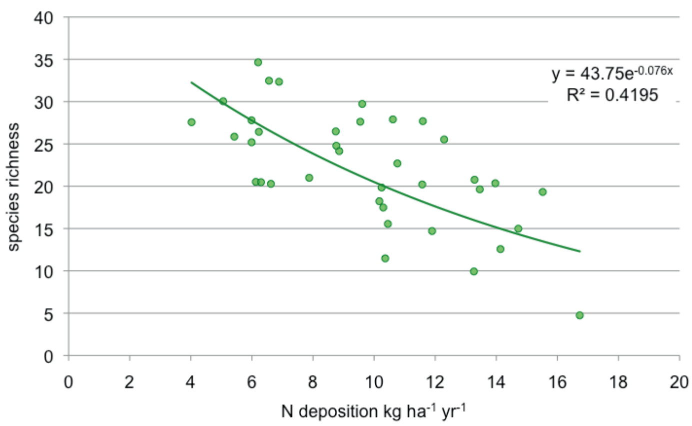


Figure CH.6 Species richness of oligotrophic species in alpine and subalpine scrub habitat (F2.2) as function of N deposition, after adjusting for effects of variables listed in Table CH.1.



After adjusting for confounding effects of different environmental factors, the exposure-response relationship between N deposition and species richness found in mountain hay meadows (E2.3) is more pronounced than the relationship found in acidic grassland (Stevens et al. 2010, $24.39e^{-0.0244x}$. In our model species richness is underestimated for plots with very high biodiversity (> 60 species per 10 m^2).

The current empirical critical load of N for mountain hay meadows is set at 10-20 kg N $ha^{-1}yr^{-1}$ with a reliability based on expert judgement (UNECE 2010, Bobbink and Hettelingh 2011). If the exposure-response relationship between N deposition and total species richness from our analysis is considered (Figure CH.3), we conclude that the range of the empirical critical load should be lowered to 10-15 kg N $ha^{-1}yr^{-1}$ in order to guarantee a sufficient protection of the ecosystem from biodiversity losses. And if the focus would mainly be on the protection of oligotrophic species (see Figure CH.4), one could even argue for an empirical critical load range of 5-10 kg N $ha^{-1}yr^{-1}$.

In alpine and subalpine scrub habitats (F2.2) the exposure-response relationships for total species richness and for species richness of oligotrophic species are very similar (Figures CH.5 and CH.6). This is not surprising, since on average 79 ± 13% of all species belong to the oligotrophic species. In alpine and subalpine scrub habitats the points discussed before, are even more pronounced and in addition the gradient of N deposition is small (4–17 kg $ha^{-1}yr^{-1}$). The effect of relatively small doses, especially on oligotrophic species, is in accordance with recent studies in other alpine habitats, where the proportional biomass of functional groups changed by the addition of 5 kg N $ha^{-1}yr^{-1}$ (Bassin et al. 2013). Thus, on the basis of the observation-based exposure-response relationships we conclude that the currently set range of the empirical critical load of N for (sub)alpine scrub habitats (5-15 kg N $ha^{-1}yr^{-1}$, qualified as quite reliable; UNECE 2010, Bobbink and Hettelingh 2011) could be lowered to 5-10 kg N $ha^{-1}yr^{-1}$.

Following Stevens et al. (2010), we fitted exposure-response relationship with an exponential function. However, in the range of N deposition observed in Switzerland a linear function would fit the data as well ($y=35.21–1.337x$, $R^2=0.43$).

The applicability of the derived observation-based exposure-response relationships for mountain hay meadows and for (sub-)alpine scrub habitats is restricted to montane and (sub-)alpine areas. For grassland ecosystems in Switzerland in regions below 800 m a.s.l. we recommend to use the exposure-response relationship according to Stevens et al. (2010).

High N deposition has already led to substantial losses of biodiversity. If reducing N deposition in the future, as settled in the Gothenburg protocol, we cannot be sure if species richness turns upward following the quantitative exposure-response curve. We have to assume that, only after a probably long delay time, ecosystems will reach a status allowing rare species with a need for nutrient poor soil conditions to reappear.

Specifications of submitted data according to the requirements of the CCE Call for Data 2012-14

The biodiversity indices for each plot were calculated using the adjusted species richness data and equations f shown in Figures CH.3 to CH.6 as follows:

$$\text{biodivindex} = \min(BDM_{max}, \text{species richness} * f(N_{dep,\,scenario}) / f(N_{dep,\,2010}))$$

where:
BDM_{max} = maximum number of species recorded; E2.3 = 78 and F2.2 = 64,
scenario = Gothenburg Protocol (GP), Background (BG)

Background deposition was assigned to the minimum value of correspondent plots in 2010 (5 kg N ha^{1} yr^{-1} for E2.3 and 4 kg N ha^{-1} yr^{-1} for F2.2) and the species number per plot was limited to BDM_{max}. Thus, the dose-response functions are only applied within the value ranges they were derived from. The resulting average species richness increases from 39.8 in 2010 to 41.2 and 53.7 for the GP- and BG-scenario, respectively.

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2. Dynamic modelling

Methods and models

VSD+PROPS (Studio, version 5.1 of 24 Feb 2014) was applied to 32 forest monitoring sites in Switzerland in compliance with the Call for Data 2012-14 of the CCE. Model input was basically extracted from the national database and adapted to the particular needs of VSD+PROPS. Time series input of deposition was modeled with MakeDep (Alveteg et al., 2002) using revised EMEP gridded historical and scenario (Gothenburg Protocol (GP), Background (BG)) as well as site-specific present deposition data. Historic deposition trends were considered until 2000 and were linked to the scenarios starting in 2020 by linear interpolation. Canopy scaling of dry deposition allowed by MakeDep was deactivated. Fluxes of macronutrients and carbon required by the VSD+ model were simulated by means of GrowUp (Bonten et al., 2012). GrowUp allows using tree species- and site index-specific Michaelis-Menten growth functions, the parameters for which were derived from Swiss yield tables of unmanaged spruce and beech stands. Tree species composition of the stands (up to three dominant species allowed), site index of the dominant tree species and site-specific forest management already were input to MakeDep and could be adapted for use with GrowUp. Additional tree species related data required by GrowUp, i.e. biomass expansion factors time-series, turnover of tree compartments time-series and nutrient contents of tree compartments (nitrogen (N) including min and max for leafage; calcium, magnesium, potassium for stem and branches only) were drawn from GrowUp's internal database. A stand-alone variant of MetHyd (version 21 Nov 2013) was used to model climate and hydrological time-series data required by VSD+. As input to MetHyd we have used national meteorological and climate data provided by Meteotest and soil properties were taken from the national database.

Time series of deposition, climate, hydrology and biomass

Prior to the VSD+ model runs, the simulated flux input was graphically examined with regards to consistency and plausibility. Compared to earlier simulated deposition (e.g. Call for Data 2011/12), current simulations returned higher chloride and sodium, lower base cation and comparable oxidized sulphur and N deposition (Figure CH.7). The current regional deposition pattern (defined by the ensemble of the 32 sites) of reduced N compounds is considered to be more plausible both regarding historic and future evolution. Historic trends include a recent systematic compilation of anthropogenic N emissions during the Holocene (Kopácek and Posch, 2011), which allowed modeling oxidized and reduced N deposition to Swiss EMEP grids for the period prior to 1900 with an EMEP emission-deposition model variant. Canopy scaling was omitted in the current runs having led to less noise and a lower spread in the data as well as time-invariant trends form 2020 onwards. Considering the A1B climate scenario for the simulation caused a distinct increase of temperatures and a small decrease of precipitation (Figure CH.8). As a result of temperature-dependent elevated evapotranspiration rates, both percolation and soil water contents moderately decreased in the second half of the simulation period. There was some concern about annual runoff approaching zero in periods with low precipitation input, which would point to a potential overestimation of evapotranspiration. However, a comparison of MetHyd output with earlier independently produced runoff rates gave no indication of a methodological bias. Since both temperature and soil moisture can be highly variable within a year, the reduction factors required by the carbon and nitrogen routines in VSD+ (mineralization (*mi*R), nitrification (*nit*) and denitrification (*denit*)) were calculated from daily rather than from annual mean input. Unlike earlier, the model now consistently outputs time-series with annual resolution including annual average reduction factors. GrowUp required a calibration of the maximum growth parameter (g_{max}) of the growth functions to get better convergence of modeled and monitored present stem biomass. Despite using default expansion factors, other simulated tree compartment masses fitted reasonably well with monitoring data after g_{max} calibration. The regional biomass trends reflected primarily the impact of management, which was much more intensive in past than in present times. Consequently, biomasses were up to 2 to 3 times higher in the second half of the simulation period and dependent fluxes such as litterfall and uptake exhibited the same feature (Figure CH.9). A peculiarity of GrowUp was only understood after having calibrated VSD+ runs and analyzed the calibration results. Growth in GrowUp is not limited by the availability of nutrients, which may lead to negative nutrient balances (e.g. N_{in}>N_{out}). It is understood that in e.g. the absence of an additional N_{in} flux such as N fixation, mineralization of the pools was enforced for prolonged periods to balance the missing N, which in turn may have led to conflicts in the calibration procedure.

Calibration of VSD+ runs

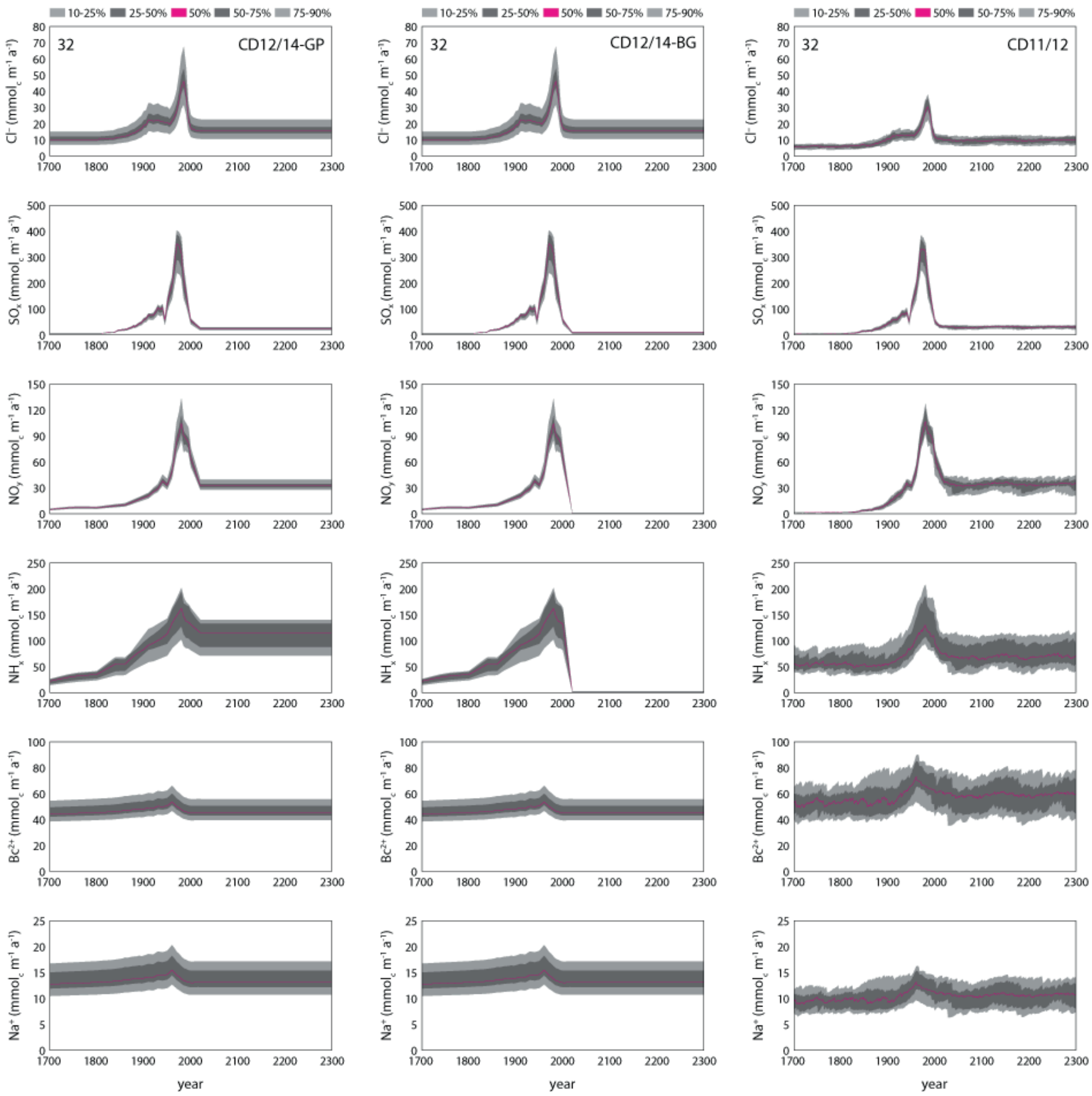
VSD+ runs were essentially calibrated regarding Gapon exchange coefficients (*lgKAlBc*, *lgKHBc*) and initial pools of carbon (C) and N in the topsoil (*Cpool_0*, *CNrat_0*) using current base saturation and C and N pools as reference. Initial distribution of the parameters was set to normal applying reasonable means and standard deviations. While Gapon selectivity coefficients were largely within the ranges found in the literature, the model still tended, compared to reference values, to often overestimate current C pool and to produce quite strongly scattering N pools (Figure CH.10). Among the reasons for the performance deficit, setting the initial distribution of C pool and C/N ratio to normal and aforementioned negative N balance in periods with low deposition input were identified.

Results

Modelled chemical parameters and fluxes in the soil compartment

In consequence of the current settings, both pools, C and N, tended to decrease in the initial phase of the simulation, even if calibration was started in 1850 (Figure CH.11). C pool decreased by 13% on average until 1933 and N pool by 3% on average. With

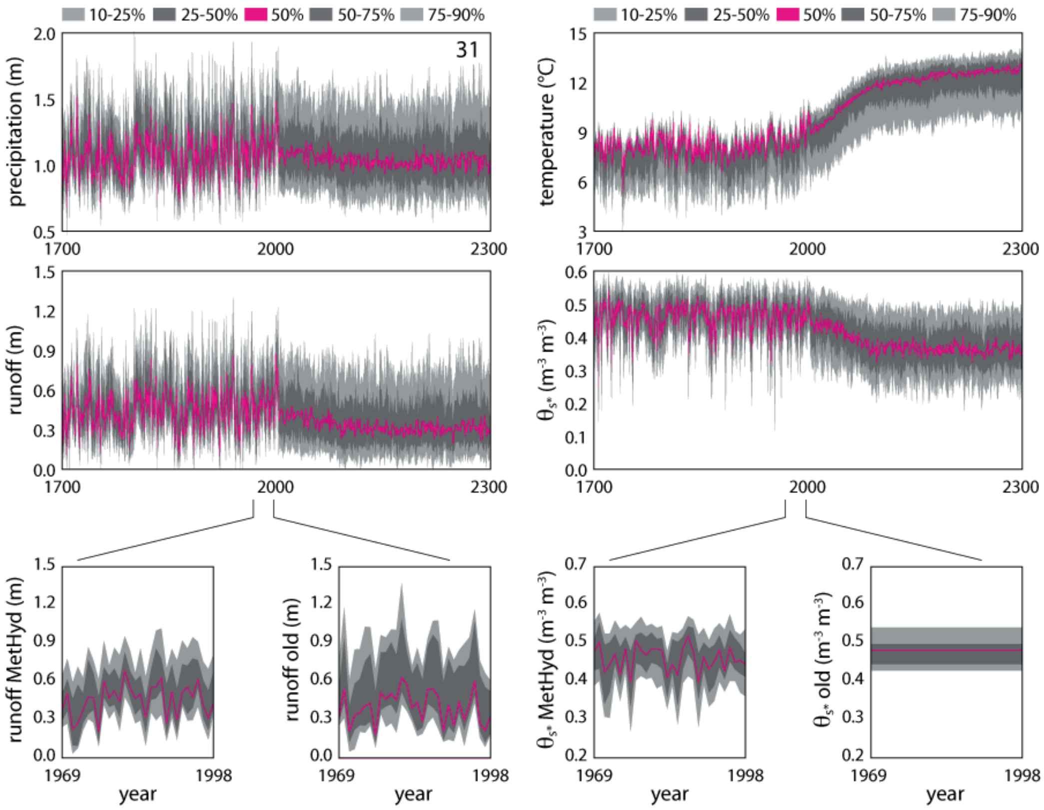
Figure CH.7 Trends and scatter of deposition input to 32 sites based on earlier (graphs in the 3rd column to the right: Call for Data 11/12) and updated trend data and present deposition (graphs in the 1st (Gothenburg Protocol: GP) and 2nd column (background: BG) to the left: Call for Data 12-14).



increasing higher deposition input and improved growth due to less intense management, both pools steadily increased. The BG deposition scenario only affected the N pool, which declined after the peak in the early 2000's. Regional C/N ratio obtained from applying the GP deposition scenario remained reasonably stable throughout the whole modeling period within a spread of roughly 10 to 25 (80% of the value population). In accordance with shrinking N pool under the BG deposition scenario, regional C/N ratio increased. Regional base saturation revealed the expected pattern with moderately lower values in the wake of the peak of acidification and rising values as the result of reduced acidifying input. Base saturation was on average roughly 7% (relative) higher by the end of the simulation, if BG was used instead of the GP deposition scenario.

Modeled and observed current tracer ion such as chloride and sulphate solution concentrations fell within ±1 order of magnitude (grey shaded area in the plots) independent of deposition scenario and model used (Figure CH.12A). VSD+ appears to have slightly overestimated chloride and sodium and underestimated sulfate concentrations. Base cation and nitrate concentrations (Figure CH.12B), both influenced by biological processes, showed larger scatter and patterns tended to be stretched along the y-axis. Base cation concentrations appear to have been underestimated by VSD+. The model

Figure CH.8 Summary of 31 sites' MetHyd simulations of climate and hydrology parameters based on national data and A1B climate scenario (simulation period 1700 to 2300). Small graphs compare current (MetHyd) input/output with formerly used annual or constant data (old).



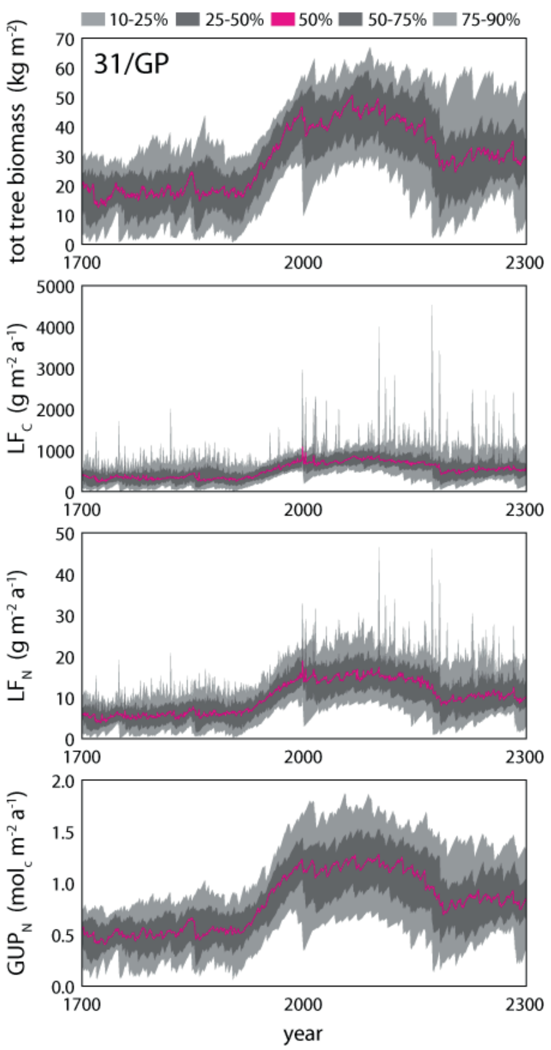
tended to return higher hydrogen ion concentrations than observed, most likely as a result of the underestimation of base cations. Part of the modeled and measured aluminium concentrations and molar aluminium to base cation ratios were of the same order of magnitude and fell along the 1:1 line, but a number of outliers were observed as also in the hydrogen ion patterns.

Regional trend patterns (Figure CH.13) generally show features, which have to be expected from the run settings such as lower sulphate concentrations in the second half of the modeling period, particularly if BG deposition was used as input, increasing sodium concentrations as a result of increased weathering due to higher temperatures, decreasing hydrogen ion and aluminium concentrations as well as molar aluminium to base cation ratios as function of decreasing acidification pressure. Compared to regional patterns of monitoring data (small plots in Figure CH.13), VSD+ has somewhat overestimated chloride, sodium, hydrogen ion and aluminum concentrations and underestimated to some extent sulfate and base cation concentrations. An exception regarding peculiarities is the regional nitrate solution concentration pattern obtained from using VSD+, which showed virtually no correlation with increasing and decreasing total N deposition. It has to be kept in mind that BG deposition reduces N deposition input to close to zero while VSD+ returned a regional N concentration pattern, which is almost indistinguishable from the pattern obtained from having used the GP deposition scenario. The insensitivity of VSD+ to N deposition input is also related to the N uptake efficiency parameter, which was set to 0.98 in the current runs. VSD+ reduces the transfer of N to the humified organic matter (*HUM*) pool in case the C turnover releases insufficient N for plant uptake, i.e.

$$(1) \quad N_D - N_I - \frac{N_U}{N_{upeff}} < 0$$

where N_D is N deposition, N_I is immobilization of N, N_U is uptake of N by the vegetation (all fluxes in mol $m^{-2}\ a^{-1}$) and N_{upeff} is the fraction of available N that plants can take up. If N_{upeff} <1 and conditions of eq.1 prevail, then the fraction of N flux, which is not

Figure CH.9 Biomass evolution (top) and carbon and nitrogen fluxes at 31 sites as obtained from GrowUp runs after calibration of gmax with regard to currently observed stem mass.



consumed by uptake, is forwarded to the soil solution and results in a base N concentration (linearly) dependent on uptake and not on deposition. Figure CH.14 demonstrates the effect of varied N_{upeff} on the modeled N concentration in the soil solution of five sites in a plot against the monitoring data. If the N fluxes were not disturbed by management, the N concentration was lowered by more than one order of magnitude, if N_{upeff} = 0.99 instead of 0.90 was used. Logically, the setting of N_{upeff} also affects the concentration of the other ions, particularly systematically of the hydrogen and aluminum ions, less systematically of the base cations. Figure CH.14 also implies that a N_{upeff} close to but not 1 would generally improve the convergence of modeled and measured solution chemistries.

However, in combination with the tendency to prevailing negative N balances particularly also under the BG deposition scenario, applying N_{upeff} close to 1 may (has) hamper(ed) the modeling of the ground vegetation with PROPS, since PROPS apparently requires the soil solution N concentration not to fall below certain thresholds, if the number of species considered in the simulation of the ground vegetation is being limited (see below).

Modelled ground vegetation composition

The ground vegetation composition in terms of probabilities of occurrence of plant species was modelled using PROPS (e.g. Wamelink et al. 2007). The database of PROPS currently contains 2900 plant species. To limit the number of species to be considered in the simulation of the ground vegetation of each site, the interface of PROPS has implemented the classification of the ecosystems according to the Map of Natural Vegetation of Europe 1:2.500.000 (MNVE; www.floraweb.de/vegetation/dnld_eurovegmap.html). Each vegetation type in the MNVE is characterized by its natural potentially occurring (ground) vegetation, which was matched with the plant species available in PROPS. The classification of the Swiss sites within this framework was obtained by overlaying the downloadable shapes of the MNVE with the sites in ArcGIS.

19 of the 32 sites ran through the whole modeling procedure including the application of the two deposition scenarios GP and BG. Plots of the site output of PROPS reveal the prevalence of generally low species occurrence probabilities for most of the simulation time only interrupted by the impact of management actions, which lead to higher N concentrations in the soil solution and increased species diversity and occurrence probabilities. Differences in the ground vegetation composition resulting from applying the two deposition scenarios were not easily detectable from the occurrence probability patterns but became evident using a similarity index (Bray-Curtis similarity index (BCS[1]);

[1] After Posch et al. (2010): Let xi and yi (i=1,...,n) denote two sets of (plant) abundances (xi, yi ≥ 0, but at least one > 0), either at two different points in time or from two different model outputs (at the same time). The similarity of the two sets xi and yi can be characterised with the so-called Bray-Curtis (earlier called Czekanowski) similarity index defined as:

$$BCS = 1 - \sum_{i=1}^{n} \left| x_i - y_i \right| \Big/ \sum_{i=1}^{n} \left(x_i + y_i \right)$$

Figure CH.10 Correlation of modelled and observed C and N pools after calibration using Gothenburg Protocol deposition scenario and start in 1850.

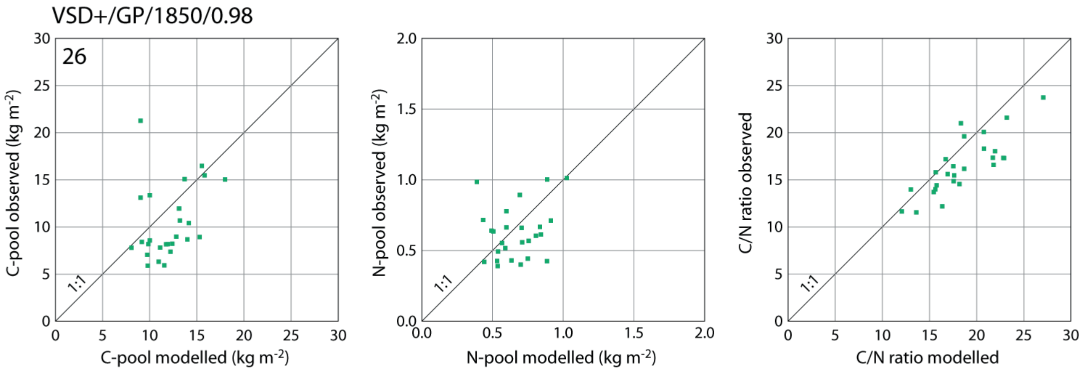
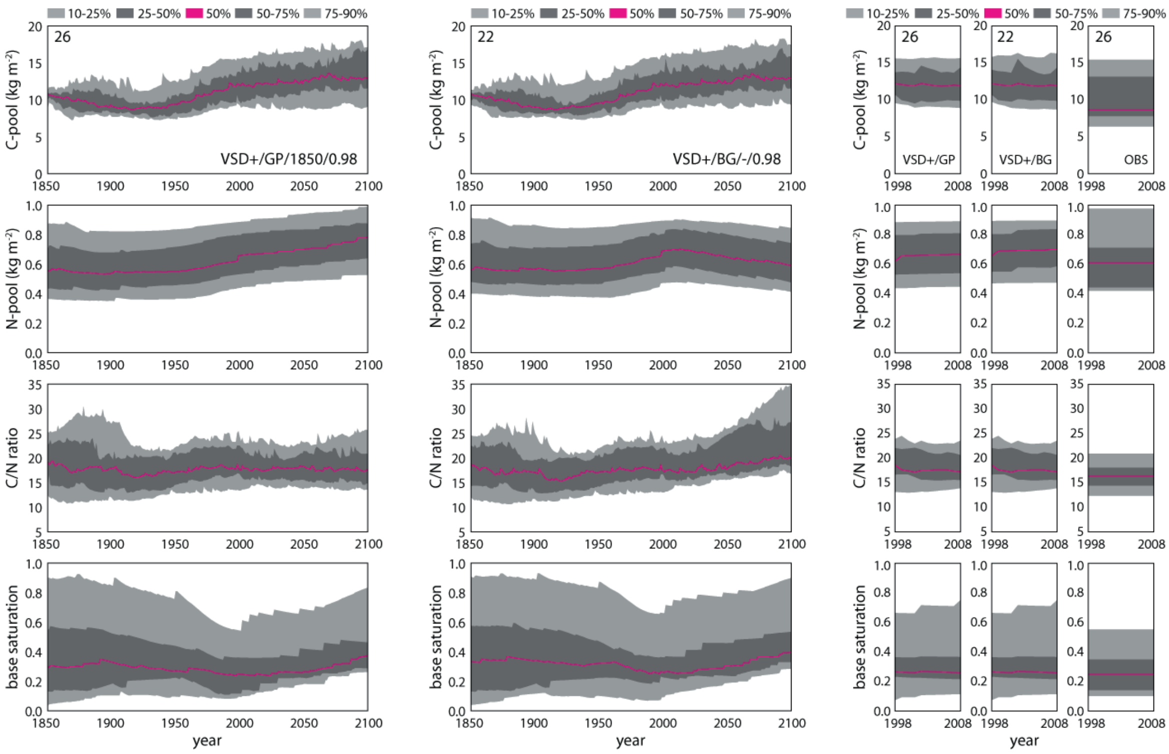


Figure CH.11 Regional trends of soil solid phase chemical parameters. Runs calibrated from 1850 onwards. Deposition scenarios beyond 2020 are Gothenburg Protocol (GP) and background (BG). Small numbers in the top left corner of the plots refer to the number of calibrated sites running with the respective deposition scenario.



Bray & Curtis 1957, Posch et al. 2010). The median BCS of the two scenario outputs fell to 0.84 until 2020 and leveled out around 0.75 towards the end of the simulation period (Figure CH.15). Despite BCS on regional scales appeared to be systematically lower, if BG deposition was used, Figure CH.16 exemplifies that this is not necessarily the case if the focus is on single sites. At these two sites, BCS resulting from applying BG deposition was in the course of time above and below the BCS obtained from using GP deposition, although BG total N concentration in the soil solution was consistently lower. This potentially erratic behavior of indices under the given circumstances (model and data setting) makes the choice of a key year for extraction of parameter values regarding the calculation of a harmonized

Figure CH.12A Solution chemistry obtained from VSD+ and VSD compared with monitoring data. Log-log scale, median (dot) and 10th and 90th percentile (line) of site-specific observation period (maximum 1998 to 2008). Grey shaded area covers ±1 order of magnitude.

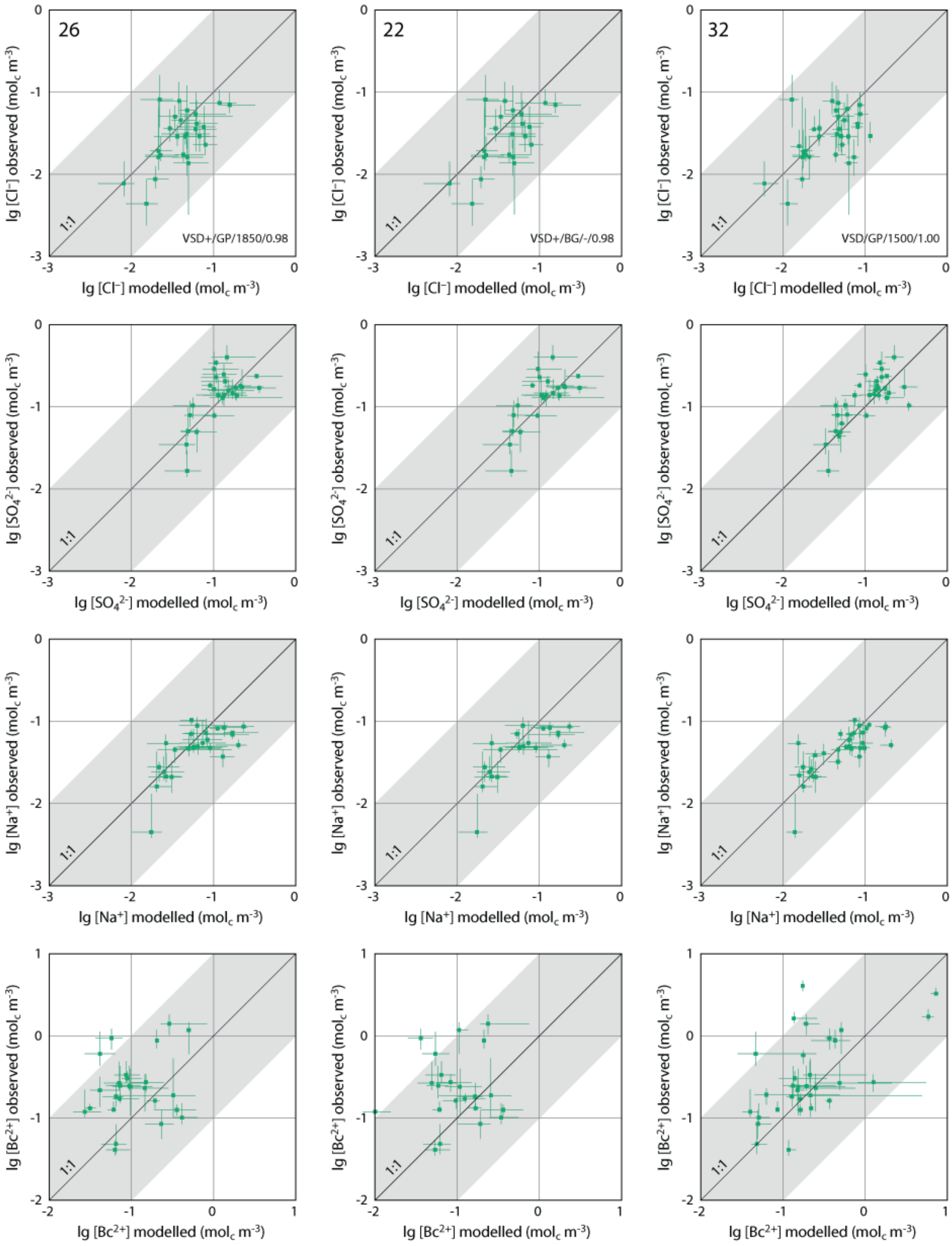


Figure CH.12B Continued from Figure CH.12A.

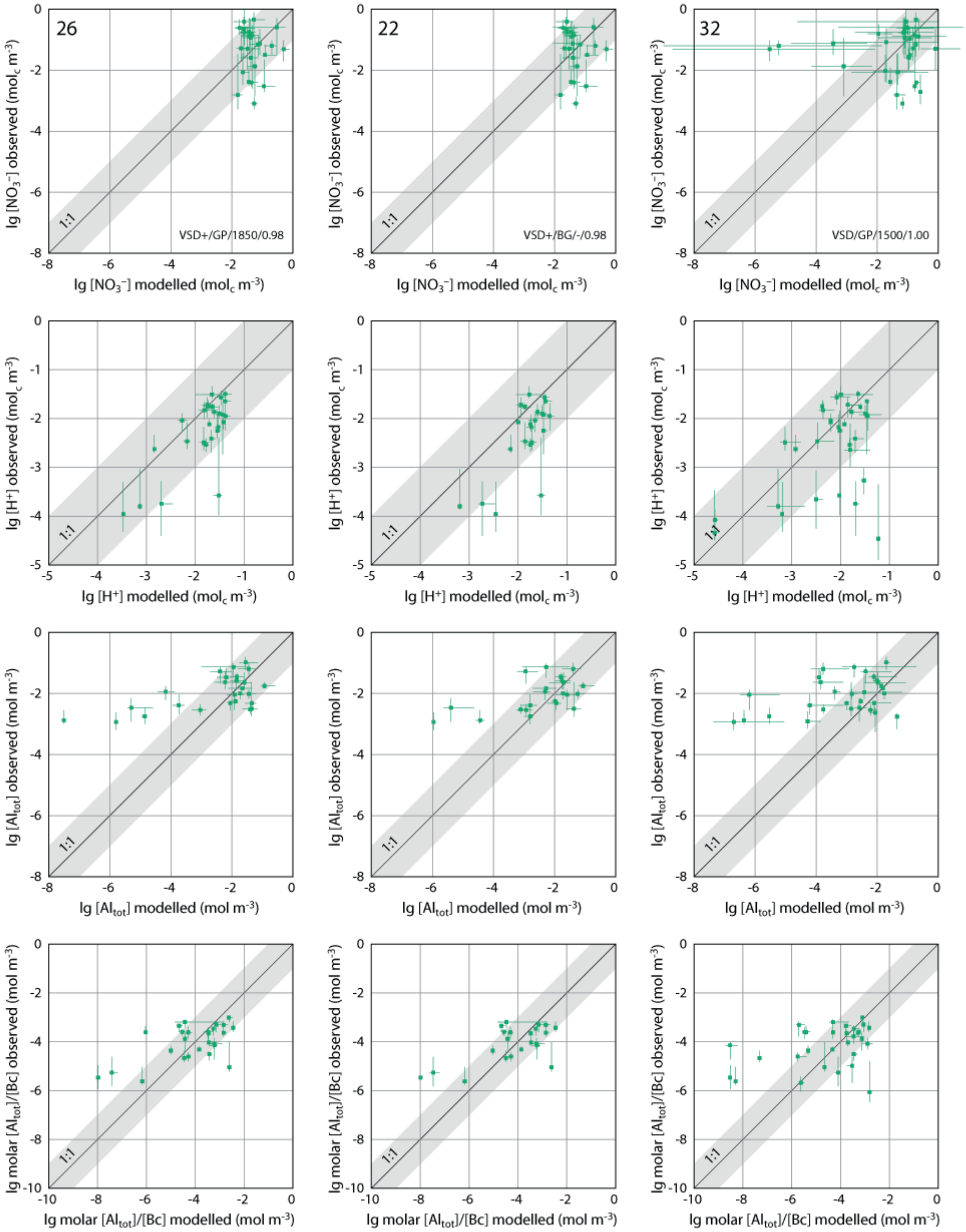


Figure CH.13 Regional trends of soil solution chemistry. Runs with VSD+ calibrated from 1850 onwards with Gothenburg Protocol (GP) deposition scenario. Small plots compare model predictions with observations for the period 1998 to 2008.

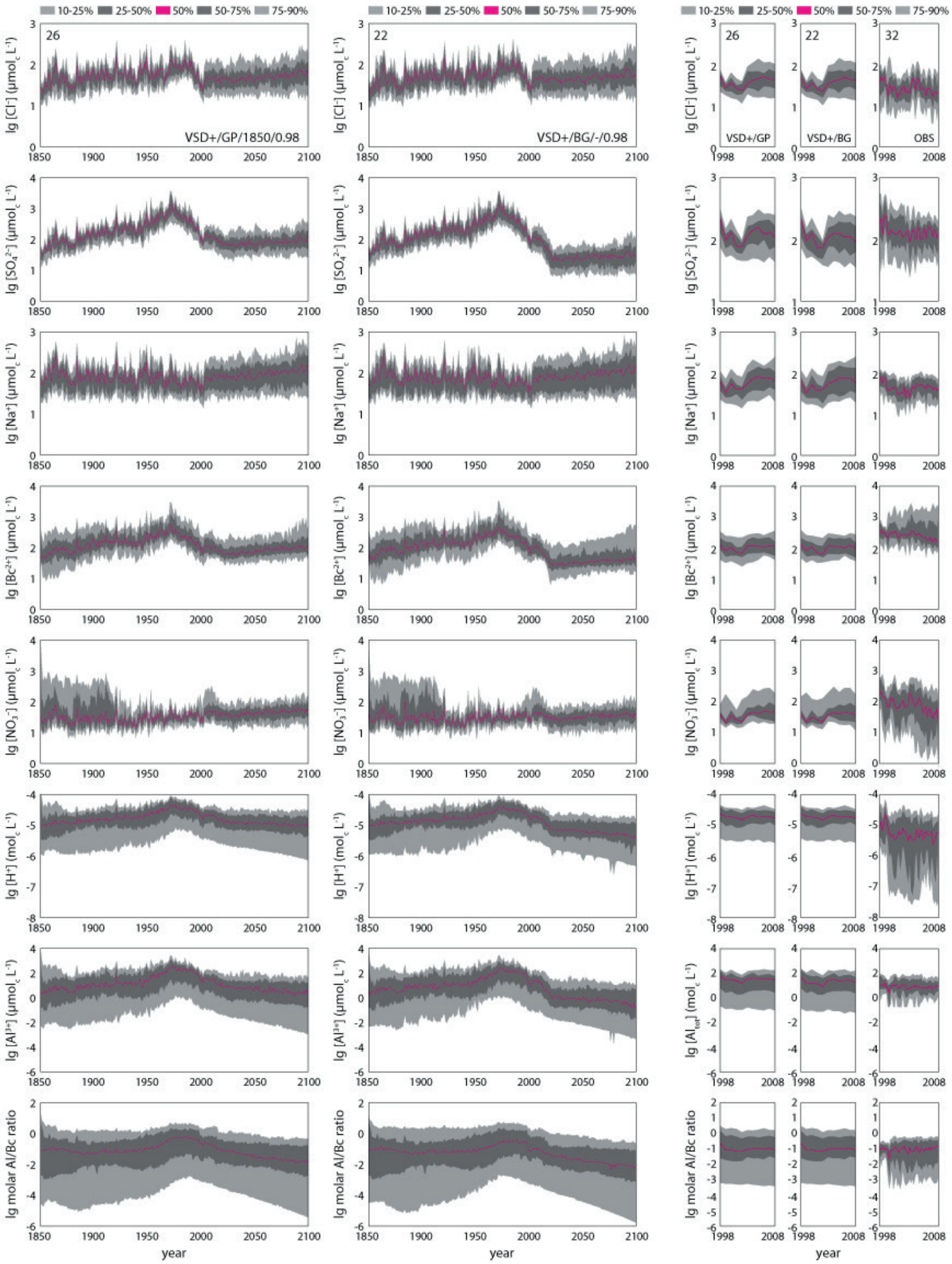


Figure CH.14 Impact of varied N_{upeff} settings on the concentration of N and other relevant ions in the soil solution at 5 sites. VSD+ was calibrated for each N_{upeff} setting individually from 1850 onwards using Gothenburg Protocol (GP) deposition scenario from 2020 onwards.

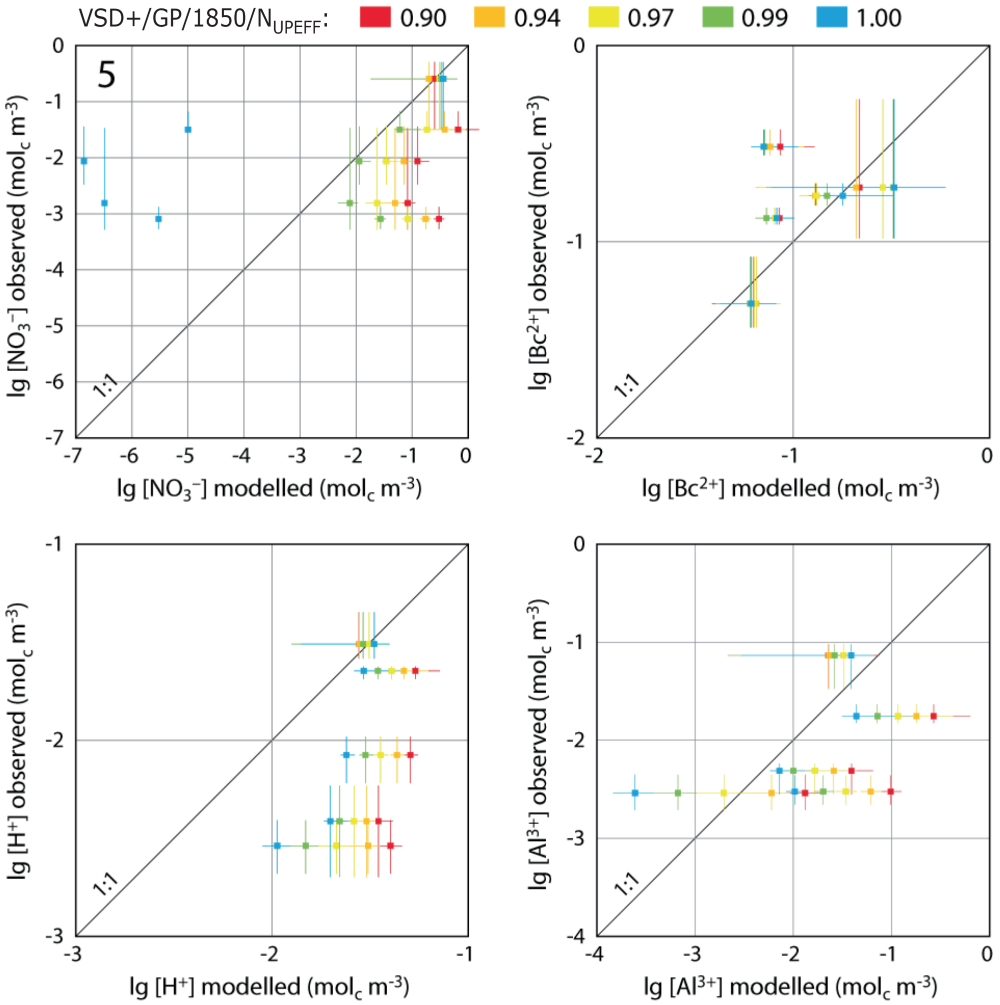


Figure CH.15 Differences in the ground vegetation composition expressed as ratio of Bray-Curtis similarity index of PROPS species occurrence probabilities obtained from applying Gothenburg Protocol (GP) and background (BG) deposition scenarios.

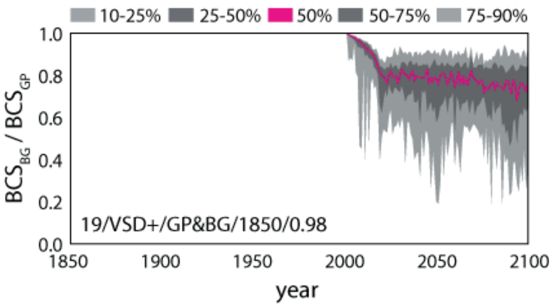
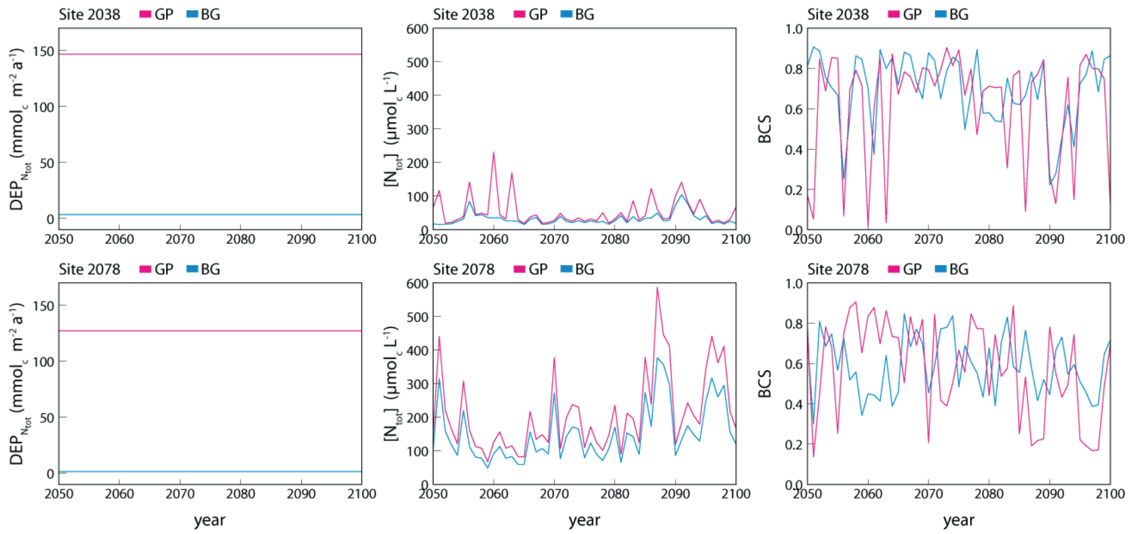


Figure CH.16 Relation among deposition of N, N concentration in the soil solution and ground vegetation composition expressed as BCS with reference year 2000 at two sites. GP is Gothenburg Protocol (pink) and BG background (blue) deposition scenario.

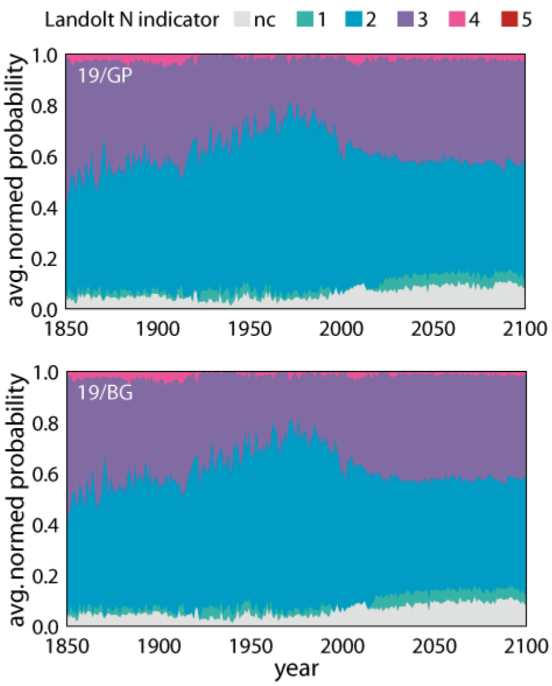


metric (as requested by the Call for Data) quite meaningless.

Currently output ‘default’ indices, such as BCS, are merely statistical figures and do not contain significant quality information. To analyze the changes in the ground vegetation composition with respect to N related trophic state of the forests, the selected species were classified using Landolt’s N indicator (Landolt 2010). The indicator has 5 values between 1 and 5, 1 and 2 being addressed as oligotrophic, 3 as mesotrophic and 4 and 5 as eutrophic. As mentioned earlier, the number of species considered in the current PROPS runs was limited to 175. The majority of selected species fell into class 2 and 3, 50 (29%) and 85 (49%), respectively, 4 (2%) fell into class 1, 19 (11%) into class 4, none into class 5 and 17 (10%) of the selected species were not found in the Flora Indicativa tables (n.c., i.e. not classified). Since relative shifts among the N classes were of interest, modeled plant occurrence probabilities at each site were added up group-wise and then normalized to one[2]. Regional Landolt N indicator group patterns were attained by averaging the site patterns and are plotted in Figure CH.17. N indicator group 2 and 3 dominated the patterns with consistently more than 80% of the normalized probability. There was quite an amount – up to 10% – of occurring plants which fell into group 0 and minor occurrence probabilities of group 1 and 4 plants. Not classified and group 1 plant occurrence probabilities slightly increased in the course of time, while group 4 plant occurrence probabilities slightly decreased. The change in the relation among group 2 and 3 plant occurrence probabilities i.e. peaking group 2 occurrence probability in the peak of N deposition input, is a counterintuitive finding and would be difficult to communicate. It simplified means that current model runs indicated that a reduction of N deposition input would lead to a loss in probability of oligotrophic plant occurrence. This is not substantiated by field evidence (e.g. Roth et al. 2013, Dirnböck et al. 2014) and has until further insights to be rated as model feature.

[2] $p_{LN} = \sum_{i=1}^{l} p_{i,LN} \Big/ \sum_{i=1}^{n} p_i$ where p_i is the probability of occurrence of species *i*, *l* is the number of species in the particular Landolt N indicator (subscript *LN*) group (0 (i.e. not classified) to 5) and *n* is the number of all species considered on the site.

Figure CH.17 Regional normalized Landolt N indicator group probability trends calculated from PROPS plant occurrence probabilities at 19 sites.



Discussion

The current output of the VSD+PROPS application to Swiss forest sites has to be interpreted in the context of the operational shortcomings met on different levels of the modeling procedure. The Call for Data 2012-14 requested a particular key year's output without explicitly specifying the state of the ecosystem. Considering the dynamics of climate and forest management, as done in the present model application, apparently produced ambiguous relations among deposition of N, N concentration in soil solution and plant occurrence response usually expressed as similarity index. Assuming that the Call for Data implicitly wanted steady-state conditions by the end of the simulation period, a series of technical and conceptual issues were insufficiently cleared. It is i.e. undecided what the steady-state climate should be in 2100, how it should be derived from/related to current climate modeling results and from when on a steady-state climate should be applied. Steady-state nutrient fluxes, which would result from continuous management, are also difficult to model with the available tools. GrowUp currently limits the management actions to 98, which is far from allowing to model typical current rotation periods and sufficient lead-times.

With the given setting, GrowUp returned nutrient fluxes which resulted in negative nutrient, particularly N, balances in periods with low N deposition input. The N deficit is offset by (enforced) mineralization of the C and N pools during the VSD+ simulation. If prolonged periods of mineralization are considered unlikely to happen in the selected forest ecosystems, GrowUp has to be revised either by making growth dependent on N-availability and/or lowering N contents of the tree tissues and/or allowing an additional N_{in} flux such as N fixation. Since N uptake demands and the potential for N immobilization in the current runs were mostly larger than the supply of N, N concentration in the soil solution became essentially dependent on the setting of the N uptake efficiency parameter (N_{upeff}). N_{upeff} linked the N supply to the soil solution linearly to N uptake, thereby fixing the N concentration and affecting via the charge balance the concentration of other relevant ions in the soil solution. The extensive uncoupling of N deposition and N concentration in soil solution features negative N balances; the relation of N_{upeff} to real processes needs further substantiation.

PROPS results could not be checked against monitored ground vegetation composition, since only roughly 10% of the observed species are found in the PROPS output. Although it is generally agreed that an ecosystem related selection of plant species should be taken prior to PROPS model runs, the disaccord of modelled and monitored species raises doubts whether the Map of Natural Vegetation of Europe is the appropriate tool to carry out the selection. The obtained plant occurrence probabilities were frequently very low, often also zero, and at some sites PROPS refused to return any output at all. It is not fully clear whether this is a technical problem or whether the selected plants are particularly susceptible to (very) low N concentrations in the soil solution. In consequence of the various shortcomings, the regional index patterns are not very conclusive, even counterintuitive, and cannot be substantiated by field evidences.

Finally, the current version of VSD+ with interface (Studio) is perfectly suited for test runs with a small number of sites, running a larger number of sites, however, became pretty inefficient. Despite the CCE offers a multi-site Access version of the model chain, having recurring tests and regional and national model applications in mind, there still is vital interest in the development of a standalone multi-site VSD+PROPS/Veg model.

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1. Introduction

In response to the "CCE Call for Data 2012-14: Modelling and Mapping regional 'no net loss of biodiversity'", the UK NFC has developed biodiversity metrics that summarise the outputs of soil-vegetation models. Here we describe the methods used to consult habitat specialists from the UK Statutory Nature Conservation Bodies (SNCBs), and the habitat-specific metrics that were developed following this consultation. The use of these metrics is illustrated by application to a set of designated nature conservation sites, including representatives of EUNIS classes D (mires, bog and fen habitats), E (grassland and tall forb habitats) and F (heathland, scrub and tundra). Values for the metric were calculated for each site under two pollution scenarios, using the MADOC-MultiMOVE model chain.

Nitrogen (N) tends to accumulate in ecosystems and cause delayed and cumulative effects. The time-course of many of these effects can be predicted using models of soil and vegetation chemistry, and by coupling these to niche models effects on habitat suitability for individual plant and lichen species can also be predicted. However, the use of such predictions in scenario analysis and to inform policy development has hitherto been limited, since changes in individual species or sets of species have not been clearly related to biodiversity targets. This report describes the calculation of biodiversity metrics to summarise the predicted floristic changes on a set of example sites, under different N pollution scenarios.

In November 2012, the Coordination Centre for Effects (CCE) issued a Call for Data, which was aimed at enabling the calculation of country-specific biodiversity indicators for assessing changes in biodiversity driven by atmospheric deposition. The ultimate aim of the CCE is to assess the extent to which 'no net loss of biodiversity' is achieved, under air pollution scenarios, using suitable biodiversity endpoints as a measure. The requirement is for metrics defined for each EUNIS (Level 2 or 3) habitat, which vary between a high value for the biodiversity endpoint, i.e. the target, and a low value for a damaged or degraded example of the habitat.

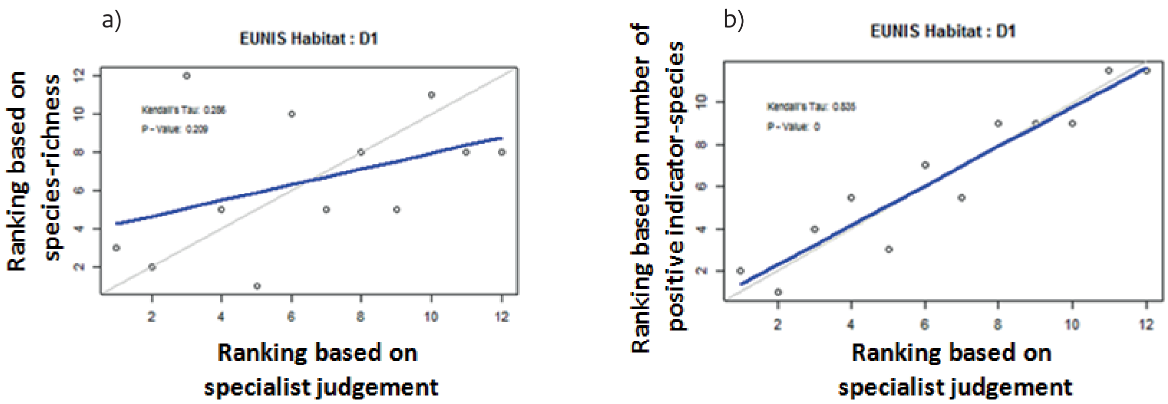
The UK study was restricted to widespread habitats known to be affected by N pollution and for which the available UK models work reasonably well – bogs, grasslands, and heathlands. In summer 2013, the specialists for these habitats at the UK Statutory Nature Conservation Bodies (SNCBs) were consulted using a combination of semi-structured interviews and quantitative ranking. The specialists were asked to discuss the reasoning behind their evaluation of sites as good, poor or degraded examples of the habitats, and to rank a set of examples of their habitat. The specialists discussed a variety of considerations when assessing sites and habitats, such as the need to monitor designated features, which often include scarce species, or the need to assess whether the integrity of a habitat is being maintained by functionally important species. However, the presence and abundance of positive indicator-species emerged as a key consideration. These are comparatively small sets of species that have been identified as indicating favourable condition for a habitat, and tend to be distinctive but not very scarce. The number of positive indicator-species within an example proved to be consistent indicator of the habitat quality of the example as assessed by specialists (e.g. Figure UK.1). The study was described in detail in Rowe et al. (2014a).

The consultation helped considerably with determining an appropriate basis for a biodiversity metric for use in this context. However, to meet the Call for Data additional steps were required:

- Select example sites, preferably Natura 2000 sites, for which at least floristic data and location are available.
- Derive mean values from floristic data for plant traits: Ellenberg N, Ellenberg R, Ellenberg W and Grime Height.
- Using transfer functions between trait-means and environmental variables (soil moisture content, soil pH, soil available-N content, soil total C/N ratio and standing biomass) and climate data for the site location, calibrate the MADOC biogeochemical model to these trait-means.
- Run the MADOC model forward to 2100 under different deposition scenarios provided by the CCE, to calculate the likely future environmental conditions.
- Derive a local list of positive indicator-species, based on the species identified in Common Standards Monitoring guidance, but filtered to include only those that occur in the local 10 x 10 km square.
- Calculate the habitat-suitability for each of these species under the future conditions, using MultiMOVE.
- Calculate the value for the biodiversity metric, as the mean habitat suitability for locally-occurring positive indicator-species.

These steps are outlined in more detail in the following section.

Figure UK.1 Correlations of habitat specialists' rank scores for a set of 12 examples of raised or blanket bog with rank scores based on: a) species richness; and b) number of positive indicator-species.



2. Methods

2.1 Selecting sites

The focus of the study was on 'Mire, bog and fen habitats' (EUNIS class D), 'Grassland and tall forb habitats' (E) and 'Heathland, scrub and tundra habitats' (F). Eighteen sites were chosen (Figure UK.2). These are mainly Natura 2000 sites of international importance for nature conservation, i.e. Special Areas of Conservation (SACs) or Special Protection Area (SPAs), or nationally important sites (SSSIs). Some additional sites were included on the basis that they are part of integrated long-term monitoring. The sites all have data on floristic composition, i.e. species lists with cover estimates for each species. Some of the sites also have measurements of soil pH, soil carbon content, and other biophysical measurements. These biophysical measurements are useful for model checking, but are not essential since the method applied used floristic data to establish many of the environmental characteristics of the site.

Figure UK.2 Locations of example sites.

2.2 From floristic data to environmental conditions

Species lists were obtained for each site and mean trait scores were calculated from the species composition. Environmental conditions were inferred for each site using mean trait values for the species present, which can provide a quick and robust means of assessing local conditions (Diekmann 2003). Mean values for floristic traits (Table UK.1) were calculated using indicator-scores (Ellenberg et al. 1991; Grime et al. 1988). These are scores on ordinal scales, usually with nine points, that reflect abiotic gradients; species have been assigned values which reflect best their position along each gradient. For this study, 'Ellenberg' indicator-scores as adapted for UK vascular plants (Hill et al. 2004) and bryophytes (Hill et al. 2007) were used to represent gradients in water availability (E_W), alkalinity (E_R) and nutrient availability (E_N).

The gradient in ground-level light availability was represented using the typical maximum heights of the vascular plant species present, obtained from PlantAtt (Hill et al. 2004). These were converted to the Grime height scale (Grime et al. 1988), and a mean value G_H calculated, weighted as follows. When calculating mean values for the E_W, E_R and E_N traits, no cover-weighting was applied, since all the species present are valid indicators of the soil conditions that govern these aspects of the environment. However, the species that are present may themselves influence light availability, so the calculation of mean G_H was weighted by relative cover. Visual or pinpoint estimates of cover were used for most sites. For long-term monitoring network sites (Moor House, Porton Down, Sourhope, Snowdon and Glensaugh) species lists were produced from the most recent Fine Grain vegetation survey for each site, and the proportional frequency of each species within 180-440 small (40×40 cm^2) cells was used as a proxy for cover.

To translate between floristic trait-means and the biophysical variables used in the MADOC model, transfer functions that have been established using large datasets were applied (Table UK.2). These equations were used to calculate values for biophysical conditions that are used either to set up (soil water content) or to calibrate (soil pH, soil available N, soil total C/N, canopy height) MADOC. The equations were inverted to calculate trait-mean values based on the biophysical conditions predicted by MADOC for the different scenarios, for subsequent MultiMOVE modelling.

Table UK.1 Sites representing different habitats, with conservation designation (Des.: N2K = Natura 2000 site i.e. SAC or SPA; UK = UK designation i.e. SSSI), location (E = UK easting, 100m; N = UK northing, 100m; Alt = altitude, m), environmental conditions as indicated by floristic trait-means (E_R = Ellenberg R, an indicator of alkalinity; E_N = Ellenberg N, an indicator of productivity; E_W = Ellenberg W or F, an indicator of site moisture; G_H = Grime height score), and long-term climatic means (July maximum temperature, °C; January minimum temperature, °C; annual precipitation, mm; all UKCIP 1961-90). Derived values for biophysical conditions are also shown: MC = soil moisture content, g 100 g^{-1} dry soil; pH = soil pH in water; Ht = vegetation canopy height, cm.

EUNIS	Site	Des.	E	N	Alt	E_R	E_N	E_W	G_H	July Max	Jan Min	Prec mm	MC	pH	Ht
D1.1 raised bogs	a) Whim Moss	UK	3204	6532	288	2.11	1.58	6.84	3.81	19.9	-4.6	889	0.62	3.78	74
	b) Thorne Moor	N2K	4738	4161	2	2.67	2.10	6.50	3.79	24.0	-3.8	583	0.58	4.13	72
D1.2 blanket bogs	a) Moor House	N2K	3755	5335	554	3.57	2.55	6.97	3.47	19.0	-6.1	1677	0.64	4.68	56
	b) Mynydd Llangatwyg	N2K	3188	2131	412	2.32	1.80	6.92	3.74	23.1	-6.3	1414	0.63	3.92	69
D2.2 poor fens and soft-water spring mires	a) Esgyrn Bottom	N2K	1976	2347	80	2.58	2.13	6.92	4.04	22.4	-3.9	1330	0.63	4.08	90
	b) Cors Llyn Farch a Llyn Fanod	UK	2594	2635	308	3.31	2.38	7.75	4.15	22.0	-5.0	1223	0.73	4.52	99
E1.2 perennial calcareous grassland and basic steppes	a) Porton Down	N2K	4255	1365	133	6.43	4.21	4.82	3.31	26.3	-6.2	768	0.35	6.44	45
	b) Newborough	N2K	2428	3644	11	5.45	3.42	4.33	3.17	22.7	-2.3	896	0.29	5.82	43
E1.7 closed dry acid and neutral grassland	a) Snowdon	N2K	2635	3545	440	3.98	3.06	5.79	3.32	20.1	-5.2	3666	0.49	4.87	49
	b) Friddoedd Garndolbenmaen	UK	2505	3445	214	4.88	3.48	5.40	3.43	22.6	-3.5	1557	0.43	5.44	53
E2.2 Low and medium altitude hay meadows	a) Eades Meadow	UK	3981	2647	83	6.04	4.48	5.23	3.74	26.2	-5.8	642	0.40	6.18	69
	b) Piper's Hole	N2K	3737	5033	268	5.88	4.72	5.24	3.58	21.0	-4.7	1700	0.39	6.10	61
E3.5 moist or wet oligotrophic grassland	a) Sourhope	-	3865	6215	390	4.65	3.61	5.69	3.69	18.5	-4.7	944	0.48	5.24	67
	b) Whitehill Down	UK	2290	2135	16	4.79	2.86	6.19	3.69	23.9	-4.3	1229	0.54	5.40	70
F4.1 wet heath	a) Glensaugh	-	3665	7795	259	3.15	2.54	6.39	3.57	19.2	-3.8	897	0.56	4.44	62
	b) Cannock Chase	N2K	3997	3142	216	3.74	3.47	5.63	3.60	24.4	-6.2	679	0.45	4.70	61
F4.2 dry heath	a) Skipwith Common	N2K	4660	4385	9	2.65	1.95	6.81	4.26	23.7	-3.8	595	0.63	4.20	108
	b) Eryri	N2K	2660	3617	825	2.41	2.06	5.35	3.62	17.5	-6.0	3153	0.42	3.97	63

Table UK.2 Conversion equations used to estimate biophysical properties of the site from floristic trait-means. E_W = mean Ellenberg 'moisture' score for species present; E_R = mean Ellenberg 'alkalinity' score for present species; E_N = mean Ellenberg 'fertility' score for present species; G_H = mean Grime 'height' score for present species; CN = CN ratio, g C g^{-1} N; H = canopy height, cm. Mean G_H was weighted by observed cover or occurrence frequency; other means were not weighted.

Value to be estimated	Equation	Source
Soil water content (g g^{-1} fresh soil)	$\exp(0.55E_W-3.27)/(1 + \exp(0.55E_W)-3.27))$	Smart et al. (2010)
Soil pH	$0.61E_R + 2.5$	Smart et al. (2004)
Soil available N (g m^{-2} year)	$10\hat{}((E_N - 1.689 - 28.4/CN)/0.318)$	Rowe et al. (2011)
Canopy height (cm)	$\exp((G_H + 1.22)/1.17)$	Rowe et al. (2011)
Above-ground biomass (g C m^{-2})	$\exp((\ln(100H) + 7.8319)/1.1625)$	derived from Parton (1978) and Yu et al. (2010)

2.3 Biogeochemical modelling

Deposition sequences

The CCE requested that the Call for Data response be calculated on the basis of deposition sequences as estimated using the EMEP model. The MADOC model requires total inputs of S, N and other elements, which were calculated on the following basis. The EMEP values for deposition of non-marine S and N were used, and scaled through time using the EMEP temporal sequence for the site. Marine S inputs were obtained from the UK Concentration Based Estimated Deposition (CBED; RoTAP 2012) estimates for the site, and marine inputs of Ca, Mg, K, Na and Cl were calculated using sea-salt ratios to S. Non-marine Ca inputs were also obtained from CBED data, and were temporally scaled using the same sequence of ratios as for S. Non-marine inputs were assumed to be zero until 1850 and then to scale up to the EMEP estimates for 1880.

Calibrating MADOC

The MADOC model (Rowe et al. 2014c) was set up for each of the sites using the deposition sequences described above, and climatic inputs, i.e. annual mean temperature and annual precipitation, obtained from UKCIP (1961-90 means). Values for soil drainage (runoff) were those used by the UK NFC for the 1×1 km^2 square containing the site. The model was calibrated to current environmental conditions by adjusting free (unknown) parameters to minimize the sum of absolute differences between observed and predicted values for the floristic trait-means. The mean E_N value was obtained by adjusting the proportion of mineral N than can be immobilised into soil organic matter, and the pre-industrial N-fixation rate. The mean E_R value was obtained by adjusting the calcium weathering rate and the density of exchangeable protons on dissolved organic carbon. The mean G_H value was obtained by adjusting the proportion of total plant C which is present as standing biomass. It proved impossible to simulate E_N scores below 2, presumably since few such low values were present in the training dataset used to develop the transfer function, but otherwise this calibration resulted in model outputs that matched observed values (Figure UK.3).

2.4 Selecting local indicator-species

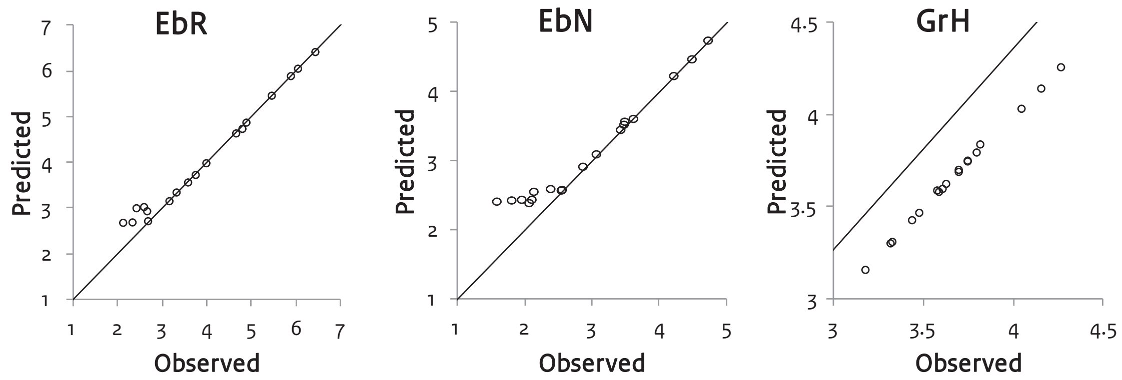
A current JNCC project aims to identify suitable indicator-species for UK habitats as defined using EUNIS (Chris Cheffings, *pers com.*), but results were not available in time to use in the study. The primary source of information on suitable positive indicator-species was therefore the Common Standards Monitoring (CSM) guidance (e.g. JNCC 2006), which lists indicator-species for several habitats. However, some consideration was needed before these lists could be applied to the current task. The habitats described in CSM guidance do not correspond to EUNIS classes and judgements have had to be made as to the corresponding habitat. Some species appear as both positive and negative indicators for different sub-types of the habitat in question. Groups of species are sometimes used, such as sedges or forbs, and it is necessary to decide which of these species should be included. The judgements made, and full lists of species included as positive indicators for the habitats included in the study, were presented in Rowe et al. (2014a), with the exception of 'Poor fens and soft-water spring mires' (D2.2). Positive indicator-species were derived for this EUNIS class from the 'desirable species' listed for NVC M4 and M5 communities in the Lowland Wetlands CSM guidance, and are listed in Rowe et al. (2014b).

A site might be unsuitable for a particular species due to an unsuitable climate rather than because of effects of N pollution. For this reason, those positive indicator-species that do not occur in the local area were excluded from the list for a particular site. The local area was defined as the 10×10 km^2 square containing the site. Species lists for each surrounding 10km area were obtained from databases of vascular plant, bryophyte and lichen occurrences courtesy of the Botanical Society of the British Isles, British Bryological Society and British Lichen Society, and accessed through the National Biodiversity Network Gateway.

2.5 Habitat suitability for plant and lichen species

Values for biophysical conditions predicted by MADOC were used to estimate likely values for floristic trait-means, using transfer functions (Table UK.2). These trait-means, together with climate data for the sites, were used to determine the suitability of the site under the predicted conditions for a set of plant and lichen species, using the Generalised Additive Model method as developed for MultiMOVE v1.0.1 (Butler 2010). This predicts habitat suitability for each of 1200 UK plant species, on the basis of seven input variables: mean plant-trait scores for wetness (E_W), alkalinity (E_R) and fertility (E_N); cover-weighted mean plant-trait score for canopy height (G_H); and three climate variables (maximum July temperature, minimum January temperature and

Figure UK.3 Observed values for floristic trait-means: E_N = mean Ellenberg 'fertility' score for present species, E_R = mean Ellenberg 'alkalinity' score for present species, and G_H = mean Grime 'height' score for present species; plotted against predicted values as obtained by calibrating the MADOC model.



total annual precipitation). Climate data were provided by the UK Met Office (available at www.metoffice.gov.uk) for the period 1961-90.
Habitat suitability at each site under each scenario was estimated for all species that were: a) positive indicator-species for the habitat (see Section 2.4); and b) present in the surrounding 10×10 km² square. Because the probability of occurrence reflects how often the species occurs within the training dataset as well as the environmental suitability of the site, it is necessary to rescale this value to enable comparisons among species. The probabilities calculated using MultiMOVE were therefore rescaled using the method developed by Albert and Thuiller (2008):

$$\text{(1)} \quad HSR = \frac{P/(1-P)}{n_1/n_0 + P/(1-P)}$$

where *HSR* is rescaled habitat-suitability; *P* is raw probability as fitted by MultiMOVE; and n_1 and n_0 are the respective numbers of presences and absences in the training dataset.

2.6 Calculating values for a biodiversity metric

As noted in Section 1, the number of positive indicator-species present in an example of a habitat was a good indicator of the value assigned to the example by habitat specialists. This metric cannot be directly calculated from MultiMOVE outputs, since it is not currently possible to translate these into an artificial assemblage. The outputs represent habitat suitability, whereas actual occurrence depends also on dispersal and extinction rates. The species-richness at the site (the number of species within a defined area such as 2×2 m²) is also uncertain. However, the mean habitat suitability for positive indicator-species gives a good indication of the overall suitability of the site for these species. We therefore calculated a habitat quality metric (*HQ*) as:

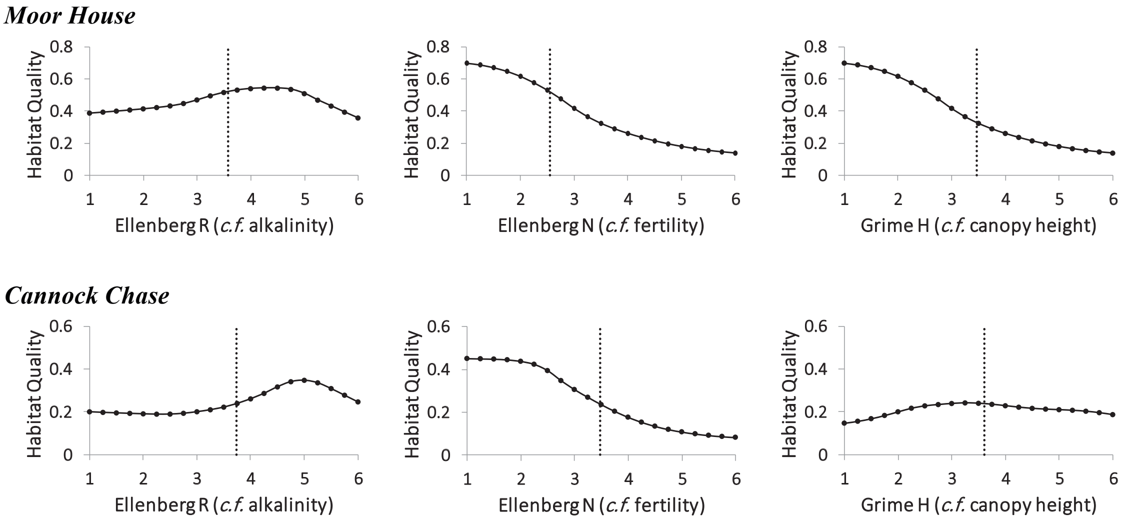
***HQ* = mean prevalence-corrected habitat suitability for locally-present positive indicator-species**

2.7 Scenarios

The models were set up to assess changes in *HQ* on example sites under the scenarios provided by the CCE. Models were set up to match current conditions, and run forward under two scenarios: 'Gothenburg', with the N and S emissions reductions expected under the Gothenburg Protocol held constant after 2020; and 'Background', in which N and S inputs were scaled down from Gothenburg Protocol levels in 2020 to natural background levels by 2030, and then run forward at natural background levels. Since the slow and passive organic matter pools in the MADOC model take a long time to stabilise, and would not have done so by 2100 which was the date suggested in the Call for Data, the model was instead run forward under each scenario to 2500 to provide an indication of equilibrium conditions.

The environmental conditions that are affected by N deposition are mainly fertility and alkalinity, which are expressed in MultiMOVE in terms of the E_N and E_R traits. Canopy height may also be affected if N increases vegetation productivity, although this depends on whether management intensity increases to compensate for the extra herbage production. Responses of canopy height to the interacting effects of N fertilisation and management are uncertain. The assumption was

Figure UK.4 Responses of habitat quality to variation around observed environmental conditions, for blanket bog at Moor House (top row of plots) and wet heath at Cannock Chase (bottom row of plots). Observed values are shown as vertical dashed lines: Moor House E_R = 3.6, E_N = 2.6, G_H = 3.5; Cannock Chase E_R = 3.7, E_N = 3.5, G_H = 3.6.



therefore made that management would be adjusted to maintain canopy height, and G_H, at the present-day value for the site. Moisture availability, expressed as E_W, was also assumed not to change. The MultiMOVE model was therefore solved using projected values for E_N and E_R and present-day values for E_W, G_H and climatic variables, to determine the habitat suitability for locally-occurring indicator species in 2500 as described in the previous sections.

3. Results

3.1 Sensitivity of metric values

To assess how responsive the *HQ* metric is, it is useful to explore how its value changes as site conditions change. The environmental conditions that are affected by N deposition are mainly fertility and alkalinity, although canopy height may also be affected if N increases vegetation productivity and management intensity does not increase (see Section 2.7). These axes are defined respectively by the E_N, E_R and G_H trait-means. Responses of the *HQ* metric to variation in these conditions are illustrated in Figure UK.4. At both of the sites shown, greater values for the *HQ* metric were seen under different conditions to those currently observed at the site. In both cases, lower values for the E_N fertility indicator would increase *HQ*, implying that reductions in N deposition would improve habitat quality. However, both sites appeared to have alkalinity (E_R) scores that were above optimal, implying that more acidic conditions would favour the positive indicator-species for these habitats. Canopy height was clearly super-optimal at the wet heath site, whereas at the blanket bog site a slight increase in canopy height would favour the positive indicator-species, on average. It should be noted that although this analysis suggests that conditions on these sites could be improved in some respects, they would in most cases still be assessed as being in good or 'favourable' condition.

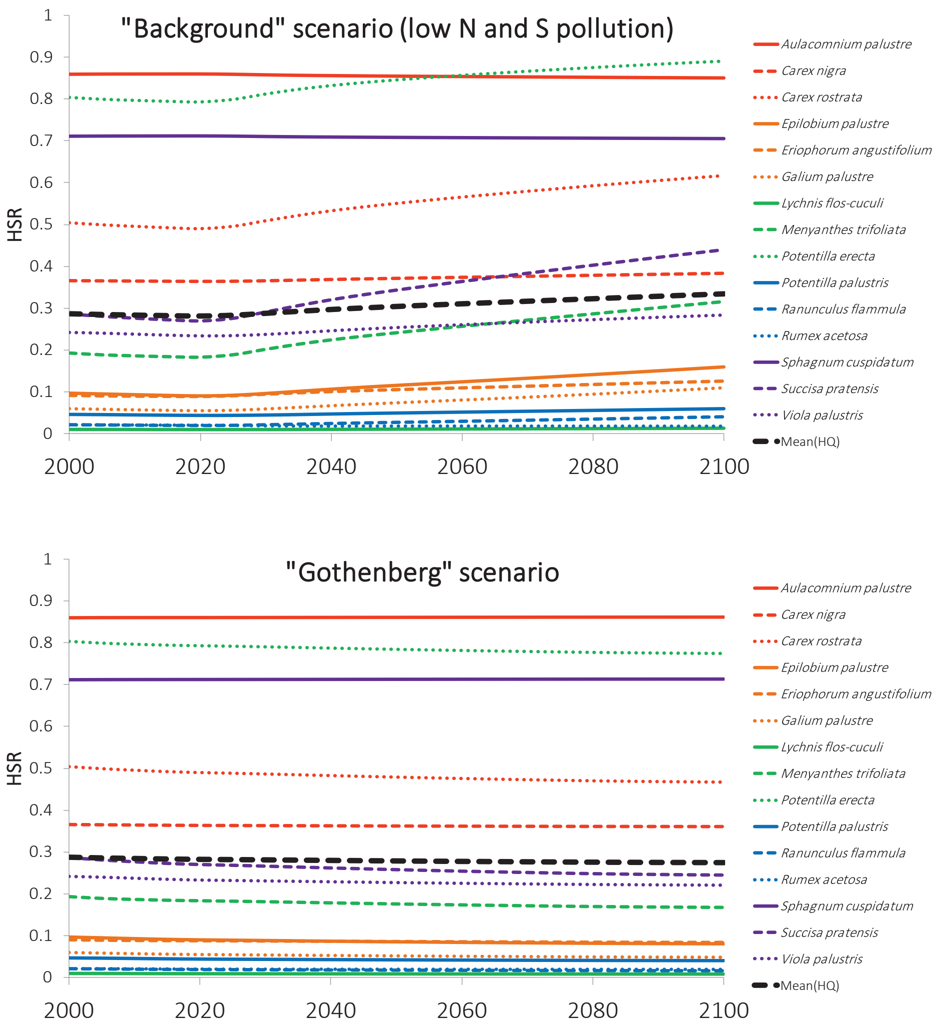
3.2 Responses of indicator-species

The outputs of the MADOC-MultiMOVE model chain represent the suitability of the habitat for individual species under a set of environmental conditions, e.g. in a particular year under a certain scenario. Results are illustrated for one of the study sites, soft-water mire at Esgyrn Bottom, in Figure UK.5. Predicted responses varied among the set of positive indicator-species. During the 2000-2100 period the mean habitat suitability for these species, *HQ*, which is presumed to indicate overall habitat quality, increased by 16% under the Background scenario and decreased by 5% under the Gothenburg scenario.

Figure UK.5 Changes in habitat suitability (HSR) for individual locally-occurring positive indicator-species, and in the mean suitability for these species (HQ), in a soft-water mire, Esgyrn Bottom. Changes were predicted using the MADOC-MultiMOVE model chain under (a) "Background" and (b) "Gothenburg" deposition scenarios.

a)

b)



3.3 Response to Call for Data

An initial response was made on 3rd March 2014, and an update was submitted to the CCE on 11th June, representing the UK response to the Call for Data 2013-14. The data submitted on 11th June are described below. The format for responding to the Call for Data is prescribed. National Focal Centres are asked to provide a response within three tables. Two of these tables, however, are only necessary for countries intending to use the VSD+ model (the '*Ecords*' table provides inputs suitable for VSD+), and/or to calculate biodiversity metric values as the "Czekanowski distance" from a reference assemblage of species (the '*Composition*' table provides species lists for the reference and predicted assemblages). These tables are not relevant to the UK response. The third table, '*DRpoint*', will be used for developing dose-response relationships and has been populated in the current project. The most important element in this table is the values that have been calculated for the biodiversity metric under the two scenarios, which are shown in Table UK.3.

Table UK.3 Values for a biodiversity metric (mean rescaled habitat suitability for locally-occurring positive indicator-species) calculated for 2500 for example sites under the Gothenburg emissions scenario (GOT2500), and a scenario in which N and S deposition decline to background rates (BKN2500). The percentage increase when changing from the Gothenburg to Background scenarios is shown.

EUNIS	Site	GOT2500	BKG2500	% change
D1.1 raised bogs	a) Whim Moss	0.439	0.534	21
	b) Thorne Moor	0.400	0.463	16
D1.2 blanket bogs	a) Moor House	0.497	0.543	9
	b) Mynydd Llangatwyg	0.385	0.467	21
D2.2 poor fens and soft-water spring mires	a) Esgyrn Bottom	0.270	0.425	57
	b) Cors Llyn Farch a Llyn Fanod	0.525	0.645	23
E1.2 perennial calcareous grassland and basic steppes	a) Porton Down	0.376	0.430	15
	b) Newborough	0.385	0.474	23
E1.7 closed dry acid and neutral grassland	a) Snowdon	0.489	0.493	1
	b) Friddoedd Garndolbenmaen	0.345	0.454	31
E2.2 Low and medium altitude hay meadows	a) Eades Meadow	0.118	0.318	170
	b) Piper's Hole	0.114	0.247	117
E3.5 moist or wet oligotrophic grassland	a) Sourhope	0.288	0.293	2
	b) Whitehill Down	0.542	0.701	29
F4.1 wet heath	a) Glensaugh	0.468	0.539	15
	b) Cannock Chase	0.186	0.245	31
F4.2 dry heath	a) Skipwith Common	0.242	0.311	29
	b) Eryri	0.328	0.417	27

4. Discussion

The response to the CCE Call for Data 2012-14 as described in this report must be seen as preliminary, since the methods being applied are still under development. Uncertainties at each stage of the calculation are discussed in detail in Rowe et al. (2014b). In particular, the values given for the biodiversity metric *HQ* will be of limited use until they are placed in the context of typical values for the habitat. However, the study has shown the practicability of the method, even for sites where only floristic and climatic records exist. This represents a major step forward from models that require many biogeochemical measurements, since these measurements are often not available for a given site and the use of default values introduces uncertainty.

The values calculated for the metric under the different scenarios represent a summary of the changes in habitat suitability for positive indicator-species due to variation in N and S deposition. These changes are driven by the effects of fertility and alkalinity on individual species. The effects of changes in canopy height, soil moisture and climatic conditions have not been incorporated in the current study, mainly for clarity, but if changes in these aspects of the environment can be predicted then their effects on species could also be taken into account. Using this mechanistic approach allows many different responses to be incorporated. However, this approach also means that a negative response of the biodiversity metric to increased N and S deposition is not a foregone conclusion. Responses at a particular site will depend on current conditions, and for example if canopy height is currently sub-optimal, N deposition could result in an increase in habitat suitability. It is therefore encouraging to note that for all the example sites included in the study, a decrease in N and S deposition (from the Gothenburg to the Background scenario) resulted in an increase in the biodiversity metric.

Applying the method to further example sites would likely increase confidence in the applicability of the MADOC-MultiMOVE model chain and in the biodiversity metric derived from its outputs. Further work will be required to determine typical values for the biodiversity metric in different habitats, and to establish threshold values below which the habitat should be considered damaged. Typical values for the metric are likely to vary geographically, because of the effects of climate on habitat suitability for positive indicator-species, and because different species will be included after geographic filtering. Nevertheless, the UK response to the Call for Data 2012-14 shows that it is possible to achieve consensus on methods for evaluating model outputs in terms of biodiversity, and to apply these methods to real sites without extensive input data.

Acknowledgements

Funding for the study was provided by Defra under projects AQ0832, "A metric for assessing changes in biodiversity for the UK's response to a data request under the Convention on Long-range Transboundary Air Pollution", and AQ0826: "Modelling and mapping of exceedance of critical loads and critical levels for acidification and eutrophication in the UK 2012-2015". We are grateful to the other participants in the AQ0832 project (Susan Jarvis, Don Monteith, Peter Henrys and Simon Smart) and to Laurence Jones, Jan Sherry, Peter Jones and Stuart Smith for providing floristic data for example sites. We would also like to thank the Botanical Society of the British Isles, the British Bryological Society and the British Lichen Society for allowing the use of distribution data.

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United States of America

The United States is pursuing several different lines of research related to the 2012-14 CCE Call for Data on 'no net loss of biodiversity'. This includes dynamic modelling using ForSAFE-Veg, static modelling using the SMB approach (Simple Mass Balance), and empirical critical loads across a range of terrestrial and aquatic systems nationwide. These are not yet integrated into a holistic national assessment, but that is the direction the U.S. is headed and plan to contribute to the CCE at a later date. The national policy that is driving much of this renewed effort is the 2013-2018 review of the secondary standards that protect ecosystems under the National Ambient Air Quality Standards (NAAQS), which is a central component of the Clean Air Act (CAA).

Many of these research efforts are coordinated under the Critical Loads of Acid Deposition (CLAD) Science Committee working group under the National Atmospheric Deposition Program (NADP), and are spearheaded by researchers and programs in the Environmental Protection Agency (EPA), the US Forest Service (USFS), the National Parks Service (NPS), the US Geological Survey, as well as several key private and academic research institutions. Some of these key projects are described below in brief, but do not constitute a comprehensive list of activities:

- Dynamic modeling for impacts to terrestrial biodiversity using ForSAFE-VEG in two areas, the subalpine meadows of the Rocky Mountains (McDonnell et al. 2014, Sverdrup et al. 2012), and the sugar-maple deciduous forests of the northeast (in progress).
- Development of empirical critical loads for various taxa (e.g. lichen, herbs, trees) nationally for Level 1 Ecoregions (Pardo et al. 2011).
- National assessment of impacts on terrestrial herb species across N deposition gradients using data from 24,000 plots and 5,700 species nationwide (Simkin et al. in prep).
- National assessment of impacts on US lichen species across N deposition gradients from 8,000 forested plots covering 450 species (Geiser et al. in review).
- Modeling impacts on terrestrial biodiversity in 3-5 case studies across the U.S. using VSD+PROPS (in progress).
- Large scale assessment of aquatic and terrestrial load exceedances including vegetation the Appalachian National Scenic Trail (in progress).
- Four studies by the National Park Service on impacts from N deposition on various systems and regions, including coastal sage scrub communities of California (Allen et al. in prep), the Craters of the Moon National Monument in Idaho (Bell et al. in prep), alpine communities in the North Cascades

of California (Rochefort et al. in prep), and on the Four Corners Region of Colorado and Utah (Reed et al. in prep).

- Compilation of U.S. critical loads into a central online database (http://nadp.sws.uiuc.edu/committees/clad/db/), including terrestrial acidification, terrestrial eutrophication, aquatic eutrophication, and empirical critical loads for various taxa and systems (Blett et al. 2014, Lynch et al. 2013).
- SMB modeling for aquatic acidification for lakes and streams (described in Lynch et al. 2013), and for terrestrial acidification nationally (McNulty et al. 2007). Researchers are investigating the potential for linking these critical load exceedances to biodiversity indices.

There is an additional body of work related to impacts on aquatic biodiversity, but given the focus of this Call for Data we highlighted the activities focused on terrestrial biodiversity above. It would probably be advantageous in future efforts to synthesize research across systems and taxa to get a more comprehensive understanding on the impacts from this global stressor on biodiversity.

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Appendix A

Modelling and Mapping regional "no net loss of biodiversity"

CCE Call for Data 2012-2014

This appendix is a reprint of the instructions for the 2012-2014 Call for Data.

Summary

At the last CCE workshop (Warsaw, 16-19 April 2012) a new way forward was proposed to enable the (trans-boundary) comparison of effect indicator-values in a harmonized way. The aim is to assess to which extent "no net loss of biodiversity" is achieved using suitable biodiversity endpoints (e.g. protection of rare species, provisioning, regulating or cultural services) of interest on a regional scale.
This Call for Data – adopted by the Working Group on Effects at its 31st session (Geneva, 20-21 Sep 2012) – aims to respond to the Convention Long-term Strategy and to extend capabilities of NFCs and the CCE to support European environmental policies with information on adverse effects to biodiversity caused by air pollution, including interactions with climate change.

After recapitulating the background for this Call for Data, its objectives are formulated. This is followed by a description of the technical requirements for submitting the requested data to the CCE.

1. Background

At its 25th session in 2007 the Executive Body agreed to encourage the Working Group on Effects " … to increase its work on quantifying effects indicators, in particular for biodiversity. These should also be linked to the integrated assessment modelling activities" (ECE/EB.AIR/91, para. 31). This has been confirmed in the Long-term Strategy of the Convention till 2020 which "set a vision for the next 10 years and beyond to address the remaining issues from existing activities and to meet emerging challenges with the aim of delivering a sustainable optimal long-term balance between the effects of air pollution, climate change and biodiversity" (ECE/EB. AIR/2010/4, para 6a).

In this context it is worth noting that this Call also adresses indicators of the Convention on Biological Diversity (CBD) and the pan-European initiative, launched in January 2005 to develop appropriate indicators to assess achievement of the 2010 biodiversity target at European level - Streamlining

European 2010 Biodiversity Indicators – (SEBI 2010). For example, at its 10th COP meeting (Nagoya, 29 October 2010) the CBD strategic plan for biodiversity 2011–2020, which is the basis for the EU biodiversity strategy to 2020, identified 5 strategic goals for biodiversity (including the so-called "AICHI targets" [3]). For Europe, the EU specified six 2020-biodiversity targets[4]. For more detailed background information, NFCs may wish to consult the documents listed in the CCE Call for Contributions of 2011-2012.

In particular for EU Member States, results of this work could contribute and support the EU 2020 headline target "halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2010, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss". This objective has been abbreviated in the EU to "no net loss of biodiversity and ecosystem services" (EU, 2011, p.12, Target 2, Action 7) which we simplified to "no net loss of biodiversity" for the purpose of this Call.

Since 2007, the ICP Modelling and Mapping followed up on the request by the Executive Body by addressing biodiversity in its work programme. The work materialized, *inter alia*, in Task Force Meetings, CCE workshops, CCE Status reports (Hettelingh et al. 2008, 2009), a workshop on the "Review and revision of empirical critical loads and dose response relationships" (Bobbink and Hettelingh 2011) and by means of well-defined calls for data (Slootweg et al. 2011, Posch et al. 2011, 2012) among the ICP M&M network of National Focal Centres (NFCs). The focus of those calls was on familiarizing NFCs with new modelling approaches that address interactions between dynamics of soil chemistry and vegetation at test sites in their countries.

This Call takes this work forward by exploring ways to lay the ground for formulating nitrogen dose-response relationships on a regional (EUNIS) scale, upscaling from individual sites.

A method to explore this was presented and accepted at the 22nd CCE workshop and 28th Task Force M&M Meeting (Warsaw, 16-19 March 2012). A proposal for the Call was then adopted at the 31st session of the Working Group on Effects (Geneva, 20-21 September 2012).

To give NFCs more time to deal with this rather complex task, it was agreed to set the deadline for spring 2014. This will allow an interim review and discussions at the 23rd CCE workshop and 29th Task Force M&M meetings (Copenhagen, 8-11 April 2013).

2. Objectives

The objective of this Call for Data is to compile output variables of soil-vegetation models for every EUNIS class (level 3) within the country (preferably in Natura2000 or other protected areas). This should enable the calculation of (country-specific) biodiversity indicators for (scenario) assessment of changes in biodiversity on a regional scale.

Output variables will depend on the model chosen by the NFC (e.g. species composition, strength, abundance). Countries are encouraged to compute from the model output their selected biodiversity indicator. An overview, written by various authors and ICP M&M participants, of biodiversity indicator concepts and examples can be found in CCE Status reports (Hettelingh et al. 2009 and Slootweg et al. 2011, part 2 & Annex 4A).

The final goal is to derive a harmonized metric from these submitted variables and indicators with the objective to quantify "no net loss of biodiversity" on a regional scale. This harmonized metric allows comparisons of the state of biodiversity between regions and countries. Finally, the indicator should be easily applicable for European policy support in the context of Integrated Assessment Modelling and the GAINS system[5].

[3] http://www.cbd.int/sp/targets/

[4] COM(2011) 244 final: http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7[1].pdf also see http://biodiversity.europa.eu/bise/policy/eu-biodiversity-strategy

[5] The GAINS-system consists of a combination of both hard linked (embedded in the GAINS computer code) and soft-linked assessment options. The latter is also known as "ex-post"-assessment under the LRTAP Convention. A component of the FP7 ECLAIRE project is also contributing to this task.

3. A possible step-by-step procedure for deriving a biodiversity metric

This section provides a description of the steps to derive simple EUNIS-specific relationships between N deposition and a biodiversity indicator. That is then normalized by the CCE to express "no net loss of biodiversity" (NNLB) for each EUNIS class in a country.

In the following stepwise approach the NFC:
(1) … selects (at least) two sites within every (level-3) EUNIS class present in the country (preferably in a Natura 2000 area), for which the chosen soil-vegetation model ('the model') can (or has been) calibrated (with historic depositions);
(2) … selects the endpoint pertinent to the site and a corresponding biodiversity indicator;
(3) …runs the model (e.g. VSD+Veg) (a) with (at least) the background and the GP positions to 2100 (provided by the CCE);
(4) …reports the indicator values and other variables computed for 2100 to the CCE (see technical description below).

This submitted data will be used by the CCE to derive the no-net-loss-index for each run by appropriately scaling the results and possibly derive dose-response functions per EUNIS class in each country. The resulting database is aimed assessment of adverse effects to biodiversity for any emission scenario.

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4. Technical requirements

The dataset to be submitted consists of four tables with information on the sites and on each model run. With this call, an Access database is attached including the format of these tables. You are strongly urged to follow exactly this structure and preferably use the provided Access-file. Also accepted as submission are Excel-files or comma-delimited (.csv) files, which have the same structure as the Access database described below.
Every submission should be accompanied with a description of how the data has been derived, preferably in a Word-document. This documentation will be included in the 2014 CCE Status Report as National Report.

In earlier calls that included dynamic modelling the CCE provided the NFCs with depositions of nitrogen and sulphur, historic, from 1880 up to 2010 as well as the 'background' deposition (BKG) - the low scenario for this call. This deposition dataset is now extended with the deposition of the revised Gothenburg Protocol (GP). A dataset will be made available for every country separately.

The **deadline** for the submission is **3 March 2014**. During the 2013 CCE workshop (8-11 April in Copenhagen) issues relating to this call will be on the agenda. It might be useful to make test runs for a few sites before the workshop, in order to flag potential problems.

Please email your **submission** to jaap.slootweg@rivm.nl. Please delete the deposition tables from the database and 'compact and repair' it before submitting. You will find this procedure in the access-help files. You may compress the file, but if you do, please use the plain 'Legacy compression' algorithm from WinZip.

It is important to use 'null' (i.e. "nothing") to indicate **missing or no value**, and ***not*** (e.g.) '1' or '999' or '0'. The **software** provided by the CCE (the template Access database) has possibilities for performing consistency checks on your database. You are kindly urged to apply them. Open the form 'tests' and press the button "Run All Tests". Some of the checks verify the values to be in a meaningful range for the variable. It can be that some of the 'ecords' in your country have exceptional values. In those cases you can regard the messages as mere warnings.

Data structure

A submission consists of four tables. "*Ecords*" is the usual table for the site information. Every row in the "*DRpoint*" is a point for the potential dose-response relationship with a species composition in the "*Composition*" table. The table "*RefComposition*" holds the reference composition needed for calculating beta-indices, such as similarity. The four tables are related according Figure 1.

Descriptions of the four tables are given below.

Figure 1. Basic data structure for a single site the Call for Data.

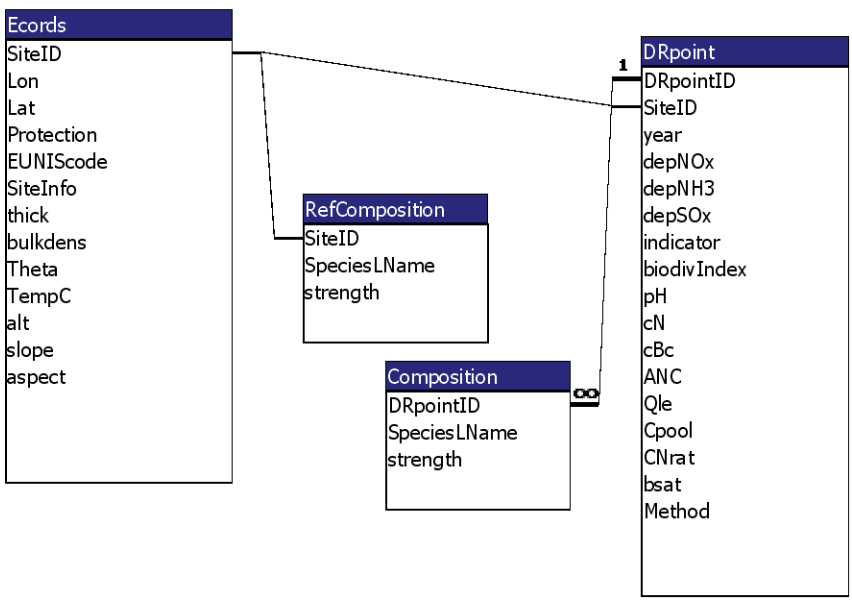


Table 1. Fields of the *Ecords* table.

SiteID	Unique number identifying the site
Lon	Longitude (decimal degrees)
Lat	Latitude (decimal degrees)
Protection	0: No specific nature protection applies 1: Special Protection Area (SPA), Birds Directive applies 2: Special Area of Conservation (SAC), Habitats Directive applies 3: SPA *and* SAC (1 *and* 2) 4: SPA *or* SAC (1 *or* 2) [don't know which one(s)] 9: a national nature protection program applies (but *not* 1 or 2!) -1: protection status unknown
EUNIScode	EUNIS code, max. 6 characters (including possible dot)
SiteInfo	Optional description/name of the site
Thick	Thickness of the root zone [m]
Bulkdens	Bulk density of the soil [g/cm^3]
Theta	Water/moisture content [m^3/m^3]
TempC	Temperature [°C]
Alt	Altitude above sea level [m]
Slope	Slope [degrees, <90]
Aspect	Angle, clockwise from North, to the projection of the normal vector of the slope onto a horizontal plane [degrees <360]

Table 2. Fields of the *DRpoint* table.

DRpointID	Unique number identifying the point
SiteID	Reference to *Ecords* table (see Table 1)
Year	Gregorian calendar (A.D.)
depNOx	Total deposition of NO_x
depNH3	Total deposition of NH_3
depSOx	Total deposition of SO_x
indicator	1: Shannon, 2: Simpson, 3: Similarity, 4: Kullback 8: number of species, 9: other [Nat.Report]
BiodivIndex	The actual value for the indicator above for this point
pH	in soil solution
cN	[N] in soil solution [meq/m^3]
cBc	[Ca+K+Mg] in soil solution [meq/m^3]
ANC	Acid Neutralizing Capacity [meq/m^3]
Qle	Perculating water [mm/a]
Cpool	Carbon pool [g/m^2]
CNrat	Carbon-Nitrogen ratio [g/g]
Bsat	Base saturation [-]
Method	1: Calibrated and GP, 2: Calibrated and BKG, 3: measured, 9: other

Table 3. Fields of the *Composition* table.

DRpointID	Reference to DRpoint (see Table 2)
SpeciesLName	Latin name of the (plant) species
strength	Species strength in relation to others or relative abundance

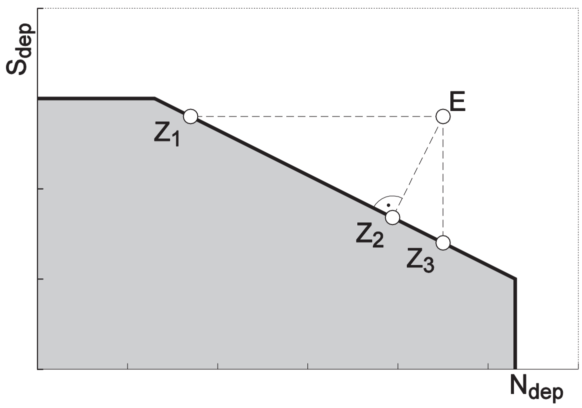
The structure of the table "*RefComposition*" is identical that of the table "*Composition*".

For questions or remarks, please contact us at jaap.slootweg@rivm.nl or max.posch@rivm.nl

Appendix B Calculating Exceedances for a N-S Critical Load Function

In the case of a critical load function (as defined in Chapter 3) there is no unique exceedance. This is illustrated in Figure B1: Let the point E denote the deposition of N and S. By reducing N_{dep} substantially, one reaches the point Z_1 and thus non-exceedance without reducing S_{dep}; on the other hand one can reach non-exceedance by only reducing S_{dep} until reaching Z_3; finally, with a reduction of both N_{dep} and S_{dep}, one can reach non-exceedance as well (e.g. point Z_2).

Figure B1. Critical load function (CLF) of N and S (thick line). The grey-shaded area below the critical load function defines deposition pairs (N_{dep},S_{dep}) for which there is non-exceedance. The points E and Z_1-Z_3 demonstrate that non-exceedance can be attained in different ways, i.e. there is no unique exceedance.



Intuitively, the reduction required in N and S deposition to reach point Z_2 (see Figure B1), i.e. the shortest distance to the critical load function, seems a good measure for exceedance. Thus we *define* the exceedance for a given pair of depositions (N_{dep},S_{dep}) as the sum of the N and S deposition reductions required to reach the critical load function by the 'shortest' path. Figure B2 depicts the cases that can arise: if the deposition falls ...

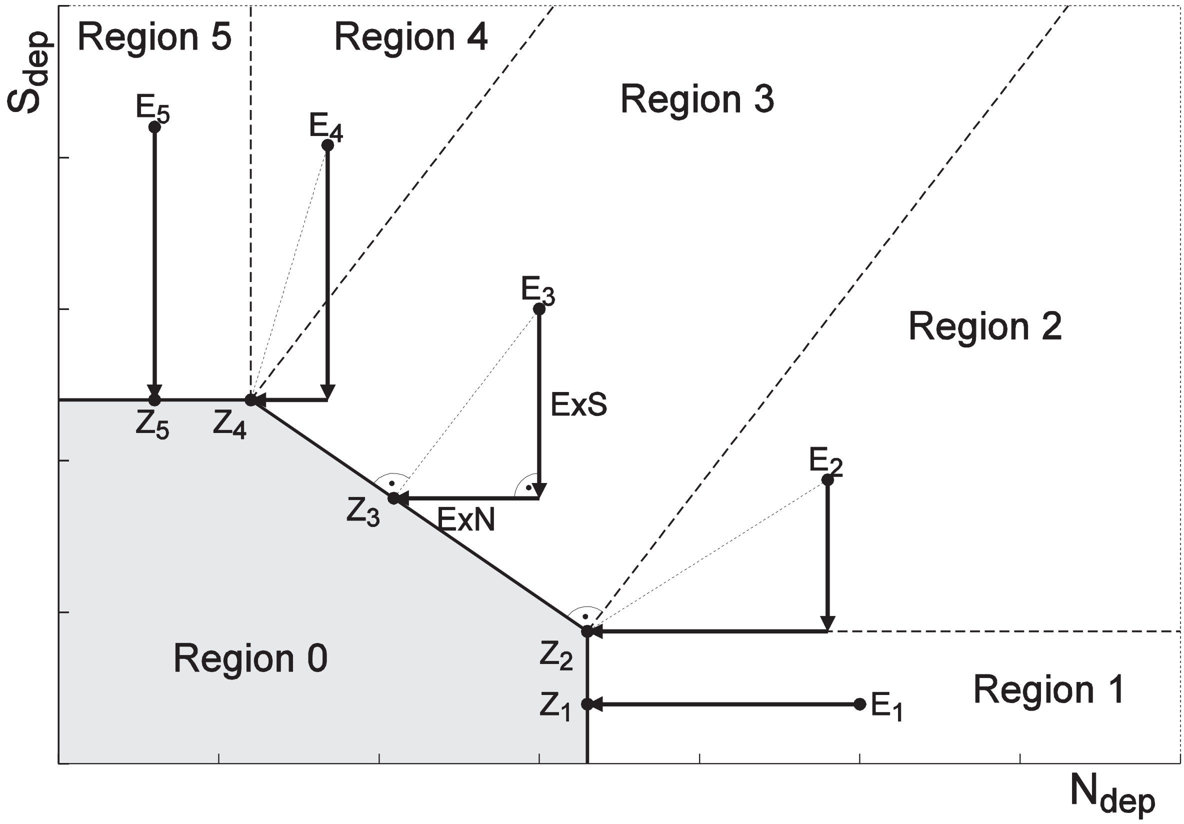
(a)... on or below the critical load function (Region 0). In this case the exceedance is defined as zero (non-exceedance);

(b)... into Region 1 (e.g. point E_1): An S deposition reduction does not help; an N deposition reduction is needed: the exceedance is defined as $N_{dep}-CLN_{max}$;

(c) ... into Region 2 (e.g. point E_2): the exceedance in this region is defined as the sum of N and S deposition reduction needed to reach the corner-point point Z_2;

(d)... into Region 3 (e.g. point E_3): the exceedance is given by the sum of N and S deposition reduction, *ExN+ExS*, required to reach the point Z_3, with the line E_3–Z_3 perpendicular to the CLF;

Figure B2. Illustration of the different cases for calculating the exceedance for a given critical load function.



(e) ... into Region 4 (e.g. point E_4): the exceedance is defined as the sum of N and S deposition reduction needed to reach the corner-point Z_4;

(f) ... into Region 5 (e.g. point E_5): an N deposition reduction does not help; an S deposition reduction is needed: the exceedance is defined as $S_{dep}-CLS_{max}$.

The exceedance function $Ex(N_{dep},S_{dep})$ can be described by the following equation (the coordinates of the point Z_3 are denoted by (N_o,S_o)):

(B-1) $$Ex(N_{dep},S_{dep}) = \begin{cases} 0 & \text{if } (N_{dep},S_{dep}) \in \text{Region 0} \\ N_{dep}-CLN_{max} & \text{if } (N_{dep},S_{dep}) \in \text{Region 1} \\ N_{dep}-CLN_{max}+S_{dep}-CLS_{min} & \text{if } (N_{dep},S_{dep}) \in \text{Region 2} \\ N_{dep}-N_0+S_{dep}-S_0 & \text{if } (N_{dep},S_{dep}) \in \text{Region 3} \\ N_{dep}-CLN_{min}+S_{dep}-CLS_{max} & \text{if } (N_{dep},S_{dep}) \in \text{Region 4} \\ S_{dep}-CLS_{max} & \text{if } (N_{dep},S_{dep}) \in \text{Region 5} \end{cases}$$

The computation of the exceedance function requires the coordinates of the point (N_o,S_o) on the critical load function. If (x_1,y_1) and (x_2,y_2) are two arbitrary points of a straight line g and (x_e,y_e) another point (not on that line), then the coordinates $(x_o,y_o) = (N_o,S_o)$ of the point obtained by intersecting the line passing through (x_e,y_e) and perpendicular to g are given by:

(B-2a) $$x_0 = (d_1 s + d_2 v)/d^2 \quad \text{and} \quad y_0 = (d_2 s - d_1 v)/d^2$$

with

(B-2b) $$d_1 = x_2 - x_1\,,\ \ d_2 = y_2 - y_1\,,\ \ d^2 = d_1^2 + d_2^2$$

and

(B-2c) $s = x_e d_1 + y_e d_2$, $v = x_1 d_2 - y_1 d_1 = x_1 y_2 - y_1 x_2$

The final difficulty in computing the $Ex(N_{dep},S_{dep})$ is to determine into which of the regions (Region 0 through Region 5 in Figure B2) a given pair of deposition (N_{dep},S_{dep}) falls. Without going into the details of the geometrical considerations, a FORTRAN subroutine is listed below, which returns the number of the region as well as *ExN* and *ExS*:

```
subroutine  exceedNS  (CLNmin,CLSmax,CLNmax,CLSmin,depN,depS,ExN,ExS,ireg)
!
! Returns - in double precision - the exceedances ExN and ExS (Ex=ExN+ExS)
! for double-precision N and S depositions depN and depS and the CLF
! defined by (CLNmin,CLSmax) and (CLNmax,CLSmin).
! The "region" in which (depN,depS) lies, is returned in ireg.
!
  implicit none
!
  real,    intent(in)  :: CLNmin, CLSmax, CLNmax, CLSmin
  real(8), intent(in)  :: depN, depS
  real(8), intent(out) :: ExN, ExS
  integer, intent(out) :: ireg
!
  real(8)              :: dN, dS, dd, s, v, xf, yf
!
  ExN = -1; ExS = -1; ireg = -1
  if (CLNmin < 0 .or. CLSmax < 0 .or. CLNmax < 0 .or. CLSmin < 0) return
  ExN = depN; ExS = depS; ireg = 9
!  CLN = CLNmax
  if (CLSmax == 0 .and. CLNmax == 0)    return
!  CLS = CLSmin
  dN = CLNmin-CLNmax
  dS = CLSmax-CLSmin
  if (depS <= CLSmax .and. depN <= CLNmax .and. &
&     (depN-CLNmax)*dS <= (depS-CLSmin)*dN) then ! non-exceedance:
    ireg = 0
    ExN = 0; ExS = 0
  else if (depS <= CLSmin) then
    ireg = 1
    ExN = depN-CLNmax; ExS = 0
  else if (depN <= CLNmin) then
    ireg = 5
    ExN = 0; ExS = depS-CLSmax
  else if (-(depN-CLNmax)*dN >=(depS-CLSmin)*dS) then
    ireg = 2
    ExN = depN-CLNmax; ExS = depS-CLSmin
  else if (-(depN-CLNmin)*dN <= (depS-CLSmax)*dS) then
    ireg = 4
    ExN = depN-CLNmin; ExS = depS-CLSmax
  else
    ireg = 3
    dd = dN*dN+dS*dS
    s = depN*dN+depS*dS
    v = CLNmax*dS-CLSmin*dN
    xf = (dN*s+dS*v)/dd
    yf = (dS*s-dN*v)/dd
    ExN = depN-xf; ExS = depS-yf
  end if
                                        return
end subroutine exceedNS
```