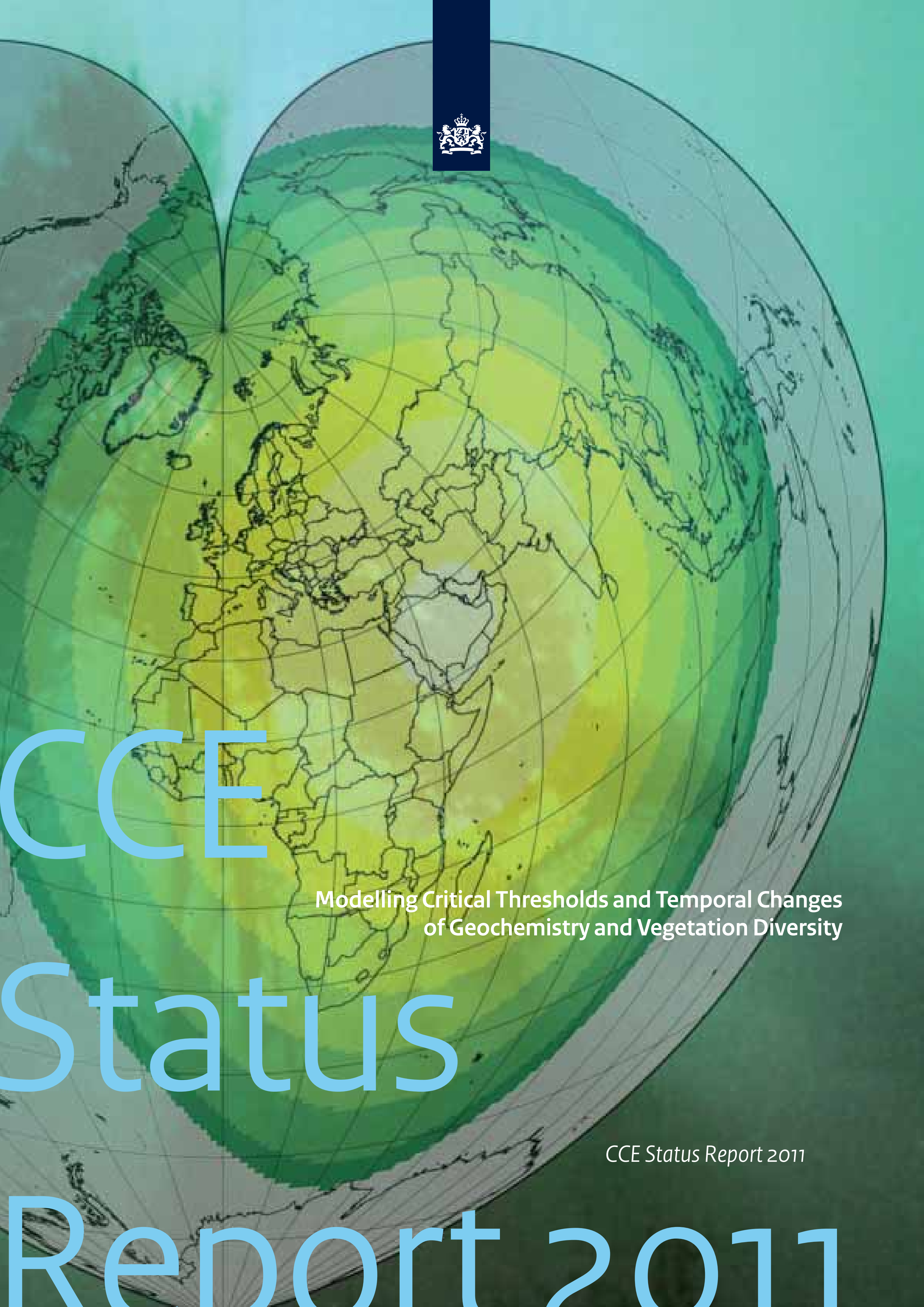

CCE Status Report 2011

Modelling Critical Thresholds and Temporal Changes of Geochemistry and Vegetation Diversity

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Modelling Critical Thresholds and Temporal Changes of Geochemistry and Vegetation Diversity

CCE Status Report 2011

M. Posch, J. Slootweg, J.-P. Hettelingh (eds)

This report contains an erratum and an addendum, starting at page 187

Cover: Global distribution of photosynthetically active radiation (PAR), a crucial input to vegetation models, on 21 June at 09:00 GMT, mapped in the Stabius-Werner projection (see Appendix C).

The work reported here has been performed by order and for the account of the Directorate for Climate and Air Quality of the Dutch Ministry of Infrastructure and the Environment, for the account of the European Commission LIFE III Programme within the framework 'European Consortium for Modelling Air Pollution and Climate Strategies (EC4MACS)' 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.

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Summary

This report describes the status of the impact assessment (formerly known as 'ex-post' assessment) of various sulphur and nitrogen deposition scenarios in Europe and the progress made regarding the relation between nitrogen deposition and changes in geochemistry and plant diversity.

Part 1 Progress CCE
Chapter 1 reports the impacts regarding exceedances of acidification and nitrogen critical loads, including results of the so-called 'ex-post analysis'. Conclusions include that 'environmental improvements' achieved under MFR in comparison to BL are considerable for all indicators. However, it should also be noted that MFR does not lead to non-exceedance of critical loads and requirements for sustainable soil chemistry (i.e. non-violation of the chemical criterion) for all ecosystem areas in Europe. Regarding uncertainties, emphasizing the persistent risk caused by reduced nitrogen, it is concluded that impacts have been shown to be fairly robust over the different versions of the scenarios developed under the Convention in the course of 2011.

Chapter 2 describes the data received from National Focal Centres (NFCs) of the ICP on Modelling and Mapping in response to the 2010/11 Call for Data, the aims of which were: (i) to increase the resolution of critical loads to the 5×5 km^2 EMEP grid; (ii) to apply to national nature (conservation) areas the revised empirical critical loads; (iii) to encourage NFCs to relate to national habitat experts, including national focal points in EU Member States responsible for reporting under Article 17 of the EU Habitats Directive; and (iv) to continue applying the VSD+Veg model (or suitable national models) at sites with sufficient data to explore the suitability of such models for the assessment of air pollution and climate change effects on changes in plant diversity. In total, 18 NFCs responded to (parts of) the call. Chapter 2 also summarises the changes to the European background data base, which is used to compute critical loads and to carry out dynamic modelling for countries that do not provide national contributions. Furthermore, recent developments, such as the potential release of nitrogen from rocks and the interaction between N deposition and fixation are discussed.

Part 2 Progress in Modelling
This part describes the progress in the development of linking soil chemistry and vegetation models. This is in line with the long-term strategy of the LRTAP Convention which encourages the assessment of the effects of air pollution on changes in geochemistry and, consequently, plant diversity. To this end the VSD+ model, designed for applications with limited data availability, has been further developed, taking into account suggestions by NFCs (chapter 3). The VSD+ model has been linked to the dynamic vegetation model Veg, and in chapter 4 the recent changes to the Veg model are described which, inter alia, should simplify the acquisition of input data. See also Appendix B for guidelines on how to convert information on plants into parameters for the Veg model.

Part 3 NFC Reports
This part brings together the national reports provided by NFCs, describing their contributions to the 2010/11 Call for Data, including their experiences with the application of dynamic soil-vegetation models.

Rapport in het kort

Modellering van kritische waarden voor de verandering van bodemprocessen en de verscheidenheid aan plantensoorten

CCE Status Report 2011

Hoge stikstofdeposities op de bodem als gevolg van luchtverontreiniging blijven een risico vormen voor de natuur in Europa. Dat is zelfs het geval als alle beschikbare technische maatregelen worden ingevoerd. Dit blijkt uit het CCE-statusrapport 2011 van het RIVM. Hierin zijn enkele scenario's ontwikkeld die de impact op de natuur weergeven van bestaand beleid en ingrijpendere maatregelen om de uitstoot van stikstofoxiden en ammoniak te verminderen. Door een hoge stikstofconcentratie groeit op korte termijn onder andere het houtvolume in bossen sneller, waardoor het broeikaseffect kan worden uitgesteld. Op de lange termijn daarentegen verstoort een hoge stikstofconcentratie de chemische samenstelling van de bodem, waardoor de variatie in plantensoorten afneemt.

Scenario's ondersteunen onderhandelingen Europees luchtbeleid
De scenario's laten ook zien dat verzuring door zwavel de afgelopen decennia sterk is afgenomen, maar nog niet volledig is verdwenen. De scenario's ondersteunen de onderhandelingen die in 2011 gaande zijn over de herziening van het Europese luchtbeleid binnen de VN-Conventie voor Grootschalige Grensoverschrijdende Luchtverontreiniging.

Effecten van emissiereducties
De effecten in de scenario's worden berekend met een zogenoemd geïntegreerd model (GAINS), waar de kennis over emissies, maatregelen en kosten, verspreiding, blootstelling en effecten van verschillende stoffen op Europese schaalniveaus samengebracht. Voorbeelden van geanalyseerde maatregelen zijn mest in de bodem te injecteren in plaats van over het land te versproeien (onderwerken), en schonere stookinstallaties en auto's. Het Coordination Centre for Effects (CCE) van het RIVM ontwikkelt dat deel van dit model (GAINS) waarmee effecten op de natuur worden berekend.

Verband bodemchemie en plantengroei duidelijker
De modellering die het verband tussen veranderingen in de bodemchemie en de plantengroei inzichtelijker maakt, is in 2011 verbeterd. Zo kan met de modellen beter worden aangegeven welk evenwicht tussen de stoffen in de bodem nodig is om de biodiversiteit in de toekomst te behouden. Ten slotte staan in het rapport de gegevens over de effecten van luchtverontreiniging van Europese zusterinstellingen van het RIVM-CCE die binnen de VN-Conventie en de Europese Commissie samenwerken.

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Part 1
Progress CCE

1 Revision of the Gothenburg Protocol: Environmental Effects of GAINS Scenarios Developed during Summer 2011

Jean-Paul Hettelingh, Maximilian Posch, Jaap Slootweg, Anne-Christine Le Gall [1]

1.1 Introduction

During 2011 the scientific support of the revision of the Gothenburg Protocol has resulted in the creation and analysis by the Centre for Integrated Assessment Modelling (CIAM) of two sets of emission reduction scenarios that were reviewed by the Task Force on Integrated Assessment Modelling. The performance of each scenario is addressed in terms of national potentials for emission reductions and related costs, trade-off opportunities with greenhouse gasses, dispersion of pollutants over countries, exposure of population and nature in Europe and finally its computed effects to public health and the environment. Results have been described in Amann et al. (2011a) and Amann et al. (2011b) and were presented to the Working Group on Strategies and Review (WGSR) at their 48th (WGSR48 2011) in spring, and the 49th (WGSR49 2011) session at the end of the summer, respectively. This chapter focuses on emission reduction scenarios developed for the latter.

The CIAM reports (Amann et al. 2011a, b) include the nation-specific quantification in the GAINS integrated assessment model of areas at risk of critical load exceedance and of their magnitude, using methods and the European critical loads database developed and collated by the Coordination Centre for Effects (CCE). It is important to remember that the database currently used by CIAM dates from 2008 (Hettelingh et al. 2008). While the data at the CCE have regularly been updated since then, the Working Group on Effects (WGE) recommended to use the data of 2008 for the current work under the Convention (WGE 2008). Thus the critical load database has been stable over the past three years, which is important for target setting in (current revisions of) European air pollution abatement policies including the revision of the Gothenburg Protocol.

While the GAINS (earlier: RAINS) model includes CCE-indicators of critical loads and their exceedances, other effect related computations are done by the CCE outside of the GAINS *model*, as part of the GAINS *system* for the overall integrated assessment. This outside analysis was earlier known as the 'ex-post' analysis, in which International Cooperative Programmes (ICPs) of the WGE reported on various effects (WGE 2011).

This chapter provides a complete description of the analysis using the scenarios for WGSR49 of the risk of effects as computed by the CCE in collaboration with National Focal Centres of the ICP on Modelling and Mapping. The focus is

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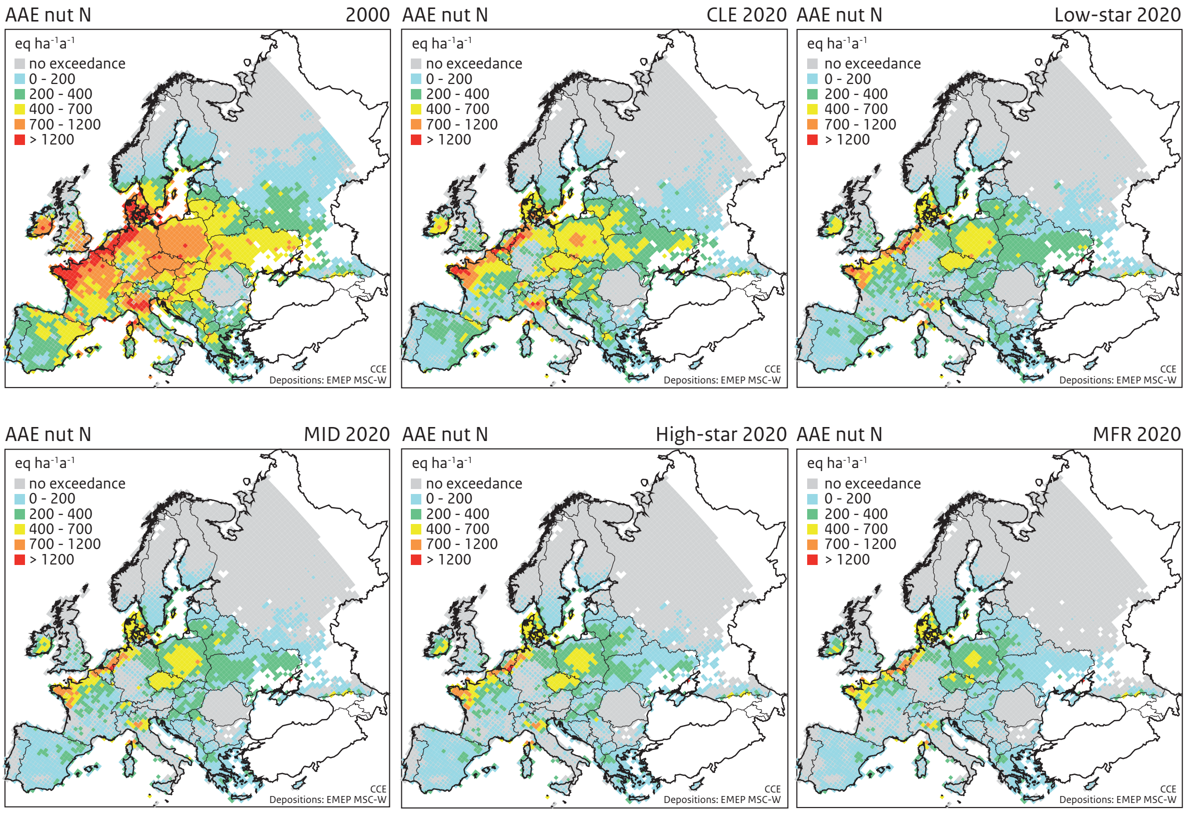
Table 1.1 Summary, for each scenario, of the environmental targets that are set as percentage closure of the gap between the effects of CLE (0% gap closure) and the effects of MFR (100% gap closure) for four effects (see Amann et al. 2011a, b).

Scenario[a]	Health PM	Acidification	Eutrophication	Ozone
Low*	25	25	50	25
MID	50	50	60	40
High*	75	75	75	50

[a] Scenario names are purely technical and do not imply any value judgement

Figure 1.1 Average Accumulated Exceedance (AAE) of critical loads for *eutrophication* in 2000 (top-left), and in 2020 under the CLE (top-centre), Low* (top-right), MID (bottom-left), High* (bottom-centre) and MFR (bottom-right) scenarios. The areas with peaks of exceedances in 2000 (red shading) are markedly decreased in 2020. However, areas at risk of nutrient nitrogen (size of shades indicates area coverage) remain widely distributed over Europe in 2020, even under MFR.

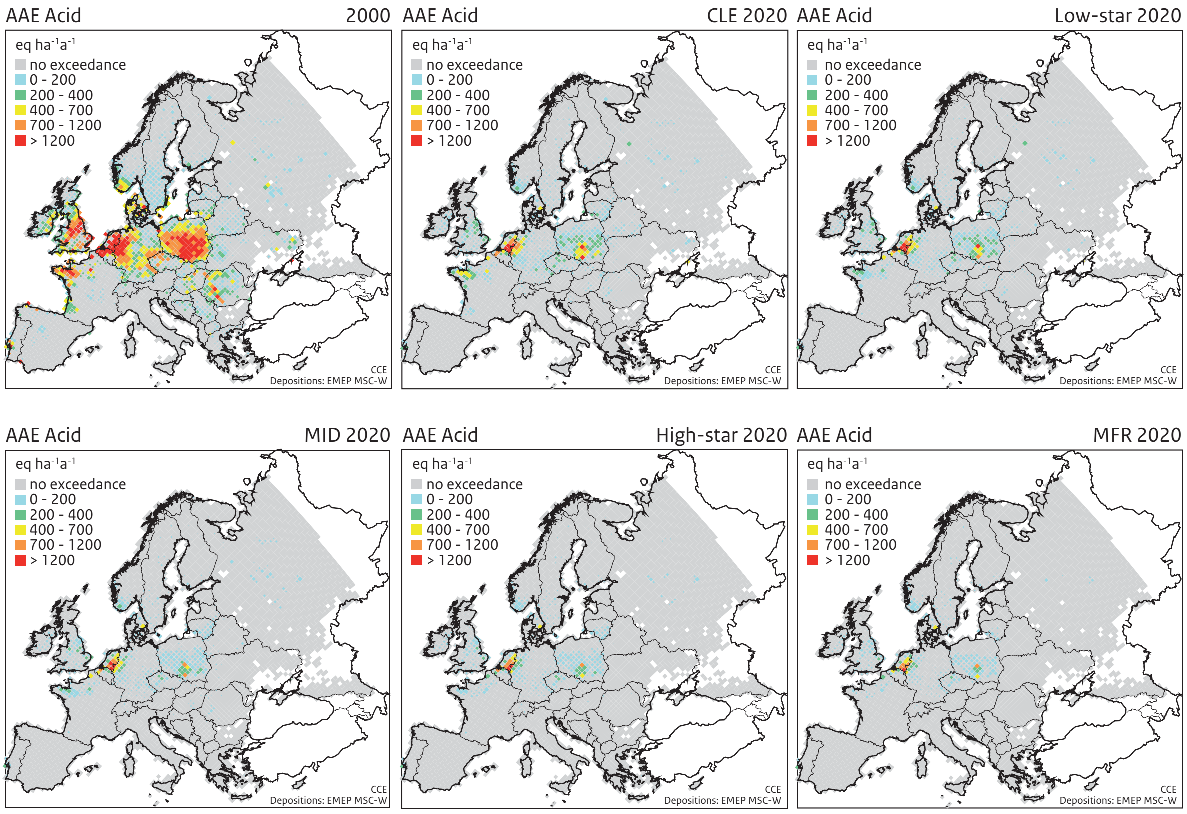


on critical load exceedance and on resulting effects to soil chemistry and biology as reported to the WGSR49, to the 30th session of the WGE and, prior to these, as presented by CIAM and the CCE to the 2011 meetings of the Task Force on Integrated Assessment Modelling (TFIAM) and WGSR48.

The analysis described in this chapter focuses on five scenarios, i.e. Current Legislation (CLE), Low*, MID, High* and Maximum Technically Feasible Reduction (MFR). The CLE scenario is based on national emission reporting. The application of maximum technically feasible reductions is reflected in the MFR scenario, the details of which can be found in Amann et al. (2011a, b). The environmental targets for the reduction of the risk of effects, that characterise the remaining scenarios, are summarized in Table 1.1. These targets cover a range from 25% to 75% of the feasible improvements – of the Average Accumulated Exceedance (AAE, see Posch et al. (2001) for definitions) in each country – to close the gap between CLE and MFR for each effect (Amann et al. 2011a, b). Considering the current policy ambitions perspiring from recent sessions of the WGSR, emphasis in this chapter is put on the CLE and MID scenario.

The scenarios of Table 1.1 are used in this chapter to describe results of a country-specific analysis of the environmental effects with respect to eutrophication and acidification. For each country the AAE forms the basis for defining environmental targets. These targets are then used in GAINS' cost optimization analysis. The results for each scenario are exceedances in 2020 of acidification and

Figure 1.2 Average Accumulated Exceedance (AAE) of critical loads for *acidification* in 2000 (top-left), and in 2020 under the CLE (top-centre), Low* (top-right), MID (bottom-left), High* (bottom-centre) and MFR (bottom-right) scenarios. Peaks of exceedances in 2000 on the Dutch-German border and in Poland (red shading) are reduced in 2020, as is the area at risk in general (size of coloured area within grid cells). This is especially the case under the MFR scenario.



eutrophication that will close the gap (in terms of exceedances) between MFR and CLE in each country with (at least) the percentages given in Table 1.1.

Section 1.2 reports results based on the indicators that are also embedded in the GAINS model for computing both magnitudes of exceedances (AAE) of critical loads of acidification and eutrophication, and the geographical location of these exceedances. In section 1.3 results are described of effects of which the modelled indicators (e.g. time delay of effects) are part of the GAINS system (i.e. not embedded in the GAINS model). Finally, in section 1.4 the robustness of the impact analysis is reviewed using three different ways to look at the results, i.e. by 'ensemble' assessment, by the variability between spring and autumn scenario versions and by looking at the occurrence of overlap between the areas at risk of excessive ammonia deposition and of excessive ambient concentration.

Maps are provided to illustrate the location and magnitude of ecosystem areas at risk in each 50×50 km² EMEP grid cell. Tentative results are also reported of areas where the 'change of biodiversity' caused by excessive N deposition is significant, i.e. exceeds 5%. Finally, the status of recovery before and after 2050 with respect to the CLE scenario in comparison to the MFR scenario is described.

1.2 The computed risk of eutrophication and acidification in 2000 and 2020, using critical loads also embedded in the GAINS model

Figure 1.1 shows the change of the exceedances of the critical load of nutrient nitrogen between 2000 (top left) and 2020 according to the 5 scenarios summarized in Table 1.1. Highest exceedances (> 1200 eq $ha^{-1}a^{-1}$, shaded in red) occur in many areas in Central Western Europe in 2000. Low exceedances (< 200 eq $ha^{-1}a^{-1}$, shaded in green) dominate Europe in 2020 under the MFR scenario. Expressed in percentages (Table 1.2), the area at risk in Europe including all EUNIS classes is 54% in 2000. For the EU27 the percentage of all ecosystems and of Natura 2000 areas is 75% and 72% respectively. The CLE scenario results in areas at risk of eutrophication of 37%, 59% and 58% in Europe, the EU27 and Natura 2000 areas, respectively.

Table 1.2 Percentages of area at risk of *eutrophication* in 2000 and in 2020 under the CLE, Low*, MID, High* and MFR scenarios. The locations and magnitudes of the exceedances are illustrated in Figure 1.1.

Area at risk of eutrophication	2000	CLE_2020	Low*_2020	MID_2020	High*_2020	MFR_2020
Albania	100	98	94	92	88	80
Austria	100	73	45	38	23	12
Belarus	100	97	87	85	82	77
Belgium	100	85	75	69	61	50
Bosnia-Herzegovina	89	72	61	58	50	45
Bulgaria	94	59	37	33	26	17
Croatia	100	99	98	97	96	91
Cyprus	66	66	59	58	57	56
Czech Republic	100	100	100	100	100	99
Denmark	100	100	100	100	100	100
Estonia	75	31	19	18	14	10
Finland	50	26	19	18	14	10
France	98	87	73	68	61	50
Germany	86	62	50	47	43	36
Greece	100	98	94	92	90	85
Hungary	100	99	84	82	70	61
Ireland	91	79	75	75	73	70
Italy	71	50	37	34	31	26
Latvia	100	92	82	79	73	61
Lithuania	100	100	99	98	97	95
Luxembourg	100	99	99	99	99	99
Macedonia	100	100	93	86	81	72
Moldova	96	92	83	65	60	55
Netherlands	95	86	83	83	83	81
Norway	24	9	6	5	4	3
Poland	100	98	94	93	91	88
Portugal	97	66	42	37	30	14
Romania	23	2	0	0	0	0
Russia	31	11	7	5	4	2
Serbia and Montenegro	97	78	56	50	43	38
Slovak Republic	100	100	98	97	97	96
Slovenia	99	63	30	19	6	2
Spain	95	89	82	80	74	62
Sweden	59	36	31	30	28	26
Switzerland	99	96	85	84	77	70
Ukraine	100	100	100	100	99	90
United Kingdom	28	17	14	13	12	10
EU27[1]	75	59	50	48	44	38
Natura 2000[1]	72	58	50	48	44	38
All[1]	54	37	31	29	26	22

[1] The ecosystem area represented by data for *computed nutrient N critical loads* both from the CCE background database and, in case of NFC submissions, national data covers about 3.9, 1.6 and 0.63 million km^2 in Europe, the EU27 and Natura2000, respectively.

The results for acidification are shown in Figure 1.2, while percentages for the area at risk are given in Table 1.3. In 2000 the areas at risk are computed to cover 12% of the ecosystems in Europe, 20% in the EU27 and 23% of the EU-Natura 2000 areas. Peaks of exceedances (> 1200 eq ha^{-1} a^{-1}) in 2000 mostly occur in France, Germany, Poland, the Netherlands and the United Kingdom. Current Legislation policies reduce the occurrence of these peaks in 2020 to areas in Germany, Poland and the Netherlands, while the European area at risk of acidification is seen to persist in Central Western Europe, the southern part of Scandinavian countries and scattered areas further north and in Russia. Expressed in percentages the area at risk in Europe, the EU27 and Natura 2000 turns out to be 4%, 6% and 7%, respectively (Table 1.3).

Table 1.3 Percentages of area at risk of *acidification* in 2000 and in 2020 under the CLE, Low*, MID, High* and MTFR scenarios. The locations and magnitudes of the exceedances are illustrated in Figure 1.2.

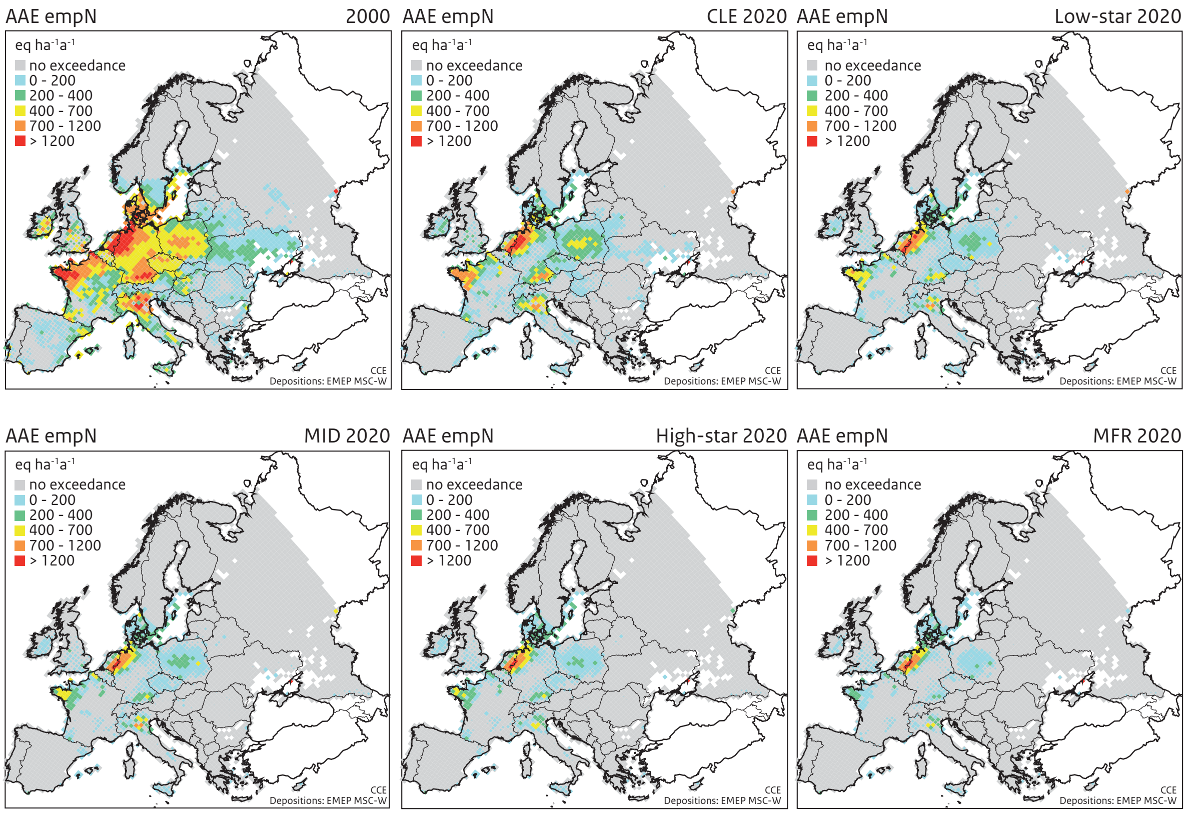
Area at risk of acidification	2000	CLE_2020	Low*_2020	MID_2020	High*_2020	MFR_2020
Albania	0	0	0	0	0	0
Austria	2	0	0	0	0	0
Belarus	19	7	3	1	0	0
Belgium	32	15	14	12	11	8
Bosnia-Herzegovina	13	0	0	0	0	0
Bulgaria	0	0	0	0	0	0
Croatia	4	2	0	0	0	0
Cyprus	0	0	0	0	0	0
Czech Republic	32	18	16	14	13	11
Denmark	52	7	6	6	4	3
Estonia	0	0	0	0	0	0
Finland	3	1	1	1	1	0
France	13	3	2	2	1	1
Germany	61	19	13	11	9	6
Greece	4	0	0	0	0	0
Hungary	32	4	2	2	0	0
Ireland	26	6	5	4	3	3
Italy	0	0	0	0	0	0
Latvia	20	3	3	2	0	0
Lithuania	34	30	28	26	20	9
Luxembourg	15	12	12	12	12	0
Macedonia	13	0	0	0	0	0
Moldova	1	0	0	0	0	0
Netherlands	84	75	73	73	71	70
Norway	17	7	6	6	5	5
Poland	82	37	31	27	23	18
Portugal	11	3	2	2	0	0
Romania	55	4	3	2	0	0
Russia	1	1	1	1	0	0
Serbia and Montenegro	19	0	0	0	0	0
Slovak Republic	25	7	5	2	0	0
Slovenia	8	0	0	0	0	0
Spain	4	0	0	0	0	0
Sweden	17	4	3	3	2	2
Switzerland	10	4	3	3	2	2
Ukraine	9	1	1	0	0	0
United Kingdom	44	14	13	12	10	8
EU27[1]	20	6	5	4	3	3
Natura 2000[1]	*23*	*7*	*6*	*5*	*4*	*3*
All[1]	12	4	3	2	2	1

[1] The ecosystem area represented by data for *acidity critical loads* both from the CCE background database and, in case of NFC submissions, national data covers about 4, 1.9 and 0.663 million km² in Europe, the EU27 and Natura2000, respectively.

1.3 Impacts using CCE indicators *not* embedded in the GAINS model

In this chapter impact indicators are described which are not included in the GAINS model. Emphasis is put on nitrogen (N) related indicators as reactive N is, next to climate change, the most prominent environmental issue at this juncture. These indicators are currently used in support of the revision of the Gothenburg Protocol and have been presented at the meetings of the TFIAM prior to WGSR49 (2011) in what has been termed 'ex-post' assessment (i.e. *after or in addition to* the GAINS model assessments of impacts). Results of the latest (September 2011) assessments in support of the revision of the Gothenburg Protocol are described in the remainder of this chapter, i.e. the application of (1) empirical critical

Figure 1.3 Average Accumulated Exceedance (AAE) of *empirical critical loads* of nutrient N in 2000 (top-left), in 2020 under the CLE (top-centre), Low* (top-right), MID (bottom-left), High* (bottom-centre) and MFR (bottom-right) scenarios. The areas where exceedances occur in 2000 (colour shading) are markedly decreased in 2020.



loads of N, (2) nitrogen dose response relationships, (3) dynamic modelling of temporal developments of soil chemistry in response to acidification and eutrophication, and of (4) robustness analysis of the results of the impacts of the different scenarios.

Exceedances of empirical critical loads of nitrogen

Empirical critical loads of N for European nature, classified according to EUNIS, have been recently updated (Bobbing and Hettelingh 2011) and applied in this analysis. Different from computed critical loads of N, which are based on models that simulate soil chemistry, empirical critical loads have been established from field experiments in which N is added in varying paces and quantities to establish ranges between a low and high exposure-threshold between which vegetation changes occur. The fact that empirical critical loads are established as ranges rather than a single value – as with computed critical loads[2] – results in a leeway for risk assessments. The exceedances and areas at risk described below are based on using the lowest empirical N critical load in the range established for each EUNIS category, in-line with the scientific consensus at the workshop, which is the basis of Bobbink and Hettelingh (2011). Overall, these minima turn out to be higher than the computed critical loads of N described in the previous section (compare Figure 1.1 and Figure 1.3).

Figure 1.3 shows the AAE of empirical critical loads of N in 2000 and in 2020 according to the five scenarios CLE, Low*, MID, High* and MFR. Percentages of the area at risk are shown in Table 1.4. Areas with moderate and high exceedances (> 400 eq $ha^{-1} a^{-1}$) occur in Central and Western Europe (Figure 1.3), but the coverage is less widespread than that resulting from computed N critical loads (Figure 1.1). In 2020, according to CLE, 11%, 21% and 28% of European, EU27 and Natura 2000 ecosystem areas are at risk of excessive N deposition when using empirical critical loads. Implementing emission reductions assumed under the MID scenario, it is seen that the areas at risk in 2020 become smaller than under CLE covering 6%, 12% and 15% in Europe, the EU27 and Natura 2000 ecosystem area, respectively.

[2] Provided a single critical limit value is used in the steady state model application.

Table 1.4 Percentages area at risk of *nutrient N* in 2000 and in 2020 using *empirical critical loads* to compute exceedances under the CLE, Low*, MID, High* and MFR scenarios. The locations and magnitudes of the exceedances in the areas at risk can be seen in Figure 1.2.

Area at risk of nutrient N	2000	CLE_2020	Low*_2020	MID_2020	High*_2020	MFR_2020
Albania	1	1	0	0	0	0
Austria	69	12	3	3	1	1
Belarus	56	23	2	1	0	0
Belgium	65	31	21	19	13	11
Bosnia-Herzegovina	7	0	0	0	0	0
Bulgaria	28	5	3	3	3	0
Croatia	33	5	0	0	0	0
Cyprus	12	8	4	4	4	3
Czech Republic	81	72	62	57	41	17
Denmark	85	74	70	69	68	63
Estonia	1	0	0	0	0	0
Finland	2	0	0	0	0	0
France	80	41	22	18	15	9
Germany	99	75	51	44	37	26
Greece	17	2	1	0	0	0
Hungary	69	48	9	3	1	0
Ireland	40	29	25	24	20	13
Italy	73	42	25	22	16	10
Latvia	5	0	0	0	0	0
Lithuania	57	15	5	2	0	0
Luxembourg	67	60	17	17	15	2
Macedonia	15	4	0	0	0	0
Moldova	47	0	0	0	0	0
Netherlands	96	86	85	81	81	79
Norway	10	1	1	0	0	0
Poland	93	81	68	63	55	33
Portugal	14	3	1	1	0	0
Romania	42	3	1	0	0	0
Russia	1	0	0	0	0	0
Serbia and Montenegro	11	1	0	0	0	0
Slovak Republic	75	14	3	1	1	0
Slovenia	76	8	3	0	0	0
Spain	32	8	3	3	2	0
Sweden	23	8	5	4	4	3
Switzerland	75	48	28	23	11	7
Ukraine	70	11	0	0	0	0
United Kingdom	15	7	6	5	5	4
EU27[1]	42	21	14	12	10	6
Natura 2000[1]	50	28	18	15	13	8
All[1]	25	11	7	6	5	3

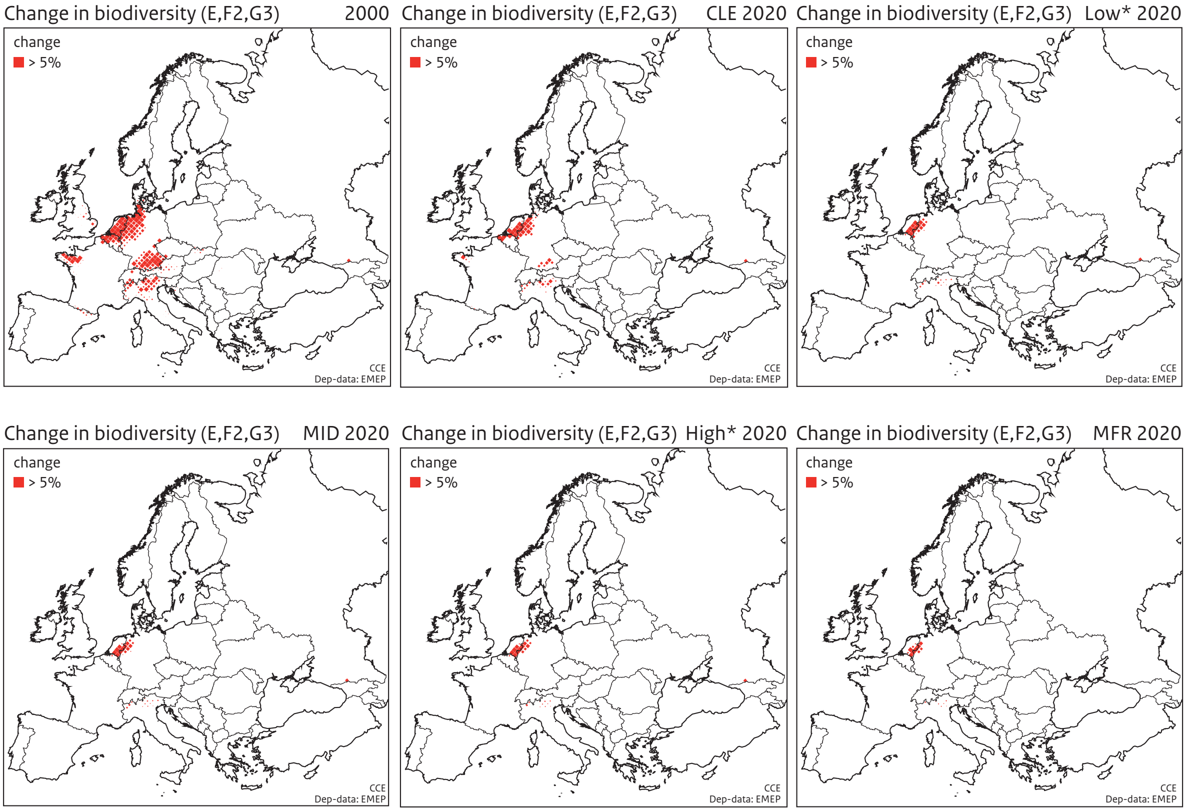
[1] The ecosystem area represented by data for *empirical nutrient N-critical loads* both from the CCE background database and, in case of NFC submissions, national data covers about 3.5, 1.7 and 0.564 million km^2 in Europe, the EU27 and Natura2000, respectively.

Tentatively using N dose-response relationships: the risk of change of biodiversity

As described in Hettelingh et al. (2010), the analysis of the 'change of biodiversity' consists of a numerical estimation of the effect of scenario-specific N deposition in 2000 and 2020 on the species richness of (semi-)natural grasslands (EUNIS class E) and arctic and (sub-)alpine scrub habitats (EUNIS class F2) as well as the similarity of the understory vegetation of coniferous boreal woodlands (EUNIS class G3 A-C). 'Change of biodiversity' is used as a common name for any of these indicators.

In this analysis, dose-response curves (Bobbink 2008, Bobbink and Hettelingh 2011) are used that have been applied to these three EUNIS classes in Europe (Hettelingh et al. 2008), using the European harmonized land cover map (Slootweg et al. 2009). The uncertainties of this analysis are rather important (see Hettelingh et al. 2010).

Figure 1.4 The location of natural areas (covering about half, i.e. about 2 million km2, of the European natural area characterised by the EUNIS classification) where the computed change of biodiversity is higher than 5% (red shading) in 2000 (top-left) and in 2020 under the CLE (top-centre), Low* (top-right), MID (bottom-left), High* (bottom-centre) and MFR (bottom-right) scenarios.



The causes of uncertainties include that the available dose-response relationships are applied to about half (53%) of the European natural area, which covers 4.7 million km2, distributed over EUNIS classes E, F2 and G3 as 26%, 1% and 25%, respectively. This share of the European natural area is denominated the 'modelled natural area'. However, whether the 'modelled natural area' is sufficiently representative of the European natural area cannot be established with the currently available data.

To account for some of the uncertainties, the computed change of biodiversity was only accounted for if the calculation result was 'significant', i.e. when the indicator changed by more than 5% relative to anthropogenic no-effect deposition. Background nitrogen deposition is assumed to be predominant in such areas. The choice of 5% as a threshold-percentage for identifying a so-called 'significant' change of biodiversity is arbitrary. It follows widely applied statistical conventions regarding the analysis and representation of phenomena for which confidence levels need to be established.

Results are presented in Figure 1.4 and Table 1.5 where natural areas for each country are quantified for which a change of biodiversity of more than 5% occurs in 2000 and in 2020 under the 5 scenarios. Figure 1.4 illustrates these areas in 2000 (top left map) to be included in most of the Netherlands and Belgium, the north-western and southern part of Germany, in the north of Italy and Spain, and in a few EMEP grid cells in central Austria, the north-west of France and the south-east of the UK. In 2020 these areas become less scattered under CLE (top centre map), remaining visible under the MID scenario in the border area of Germany and the Netherlands and in the northern part of Italy.

Looking at Table 1.5, numbers can be associated with the red locations in Figure 1.4. Thus, in 2000 about 16% of the modelled natural area in the EU27 is at risk of significant change of biodiversity. This area is reduced to approximately 5% and 2% in 2020 under the CLE and MID scenarios. In Europe (i.e. the EMEP domain) the modelled natural area at risk of a significant change of biodiversity in 2000 and under CLE and MID in 2020 is about 10%, 3% and 1%, respectively (Table 1.5, last row).

Finally note that the application of dose-response relationships to other EUNIS classes in Europe is not possible with current scientific knowledge. The interpretation in this chapter of the areas at risk of a

Table 1.5 The percentages of area at risk in 2000, and in 2020 under the five scenarios, of a change by more than 5% of biodiversity, i.e. of the species richness of (semi-) natural grasslands (EUNIS class E) and arctic and (sub-)alpine scrub habitats (EUNIS class F2) and of the Sorensen similarity index of the understorey vegetation of coniferous boreal woodlands (EUNIS class G3 A-C).

Countries in which a change of biodiversity is assessed[1]	2000	CLE_2020	Low*_2020	MID_2020	High*_2020	MFR_2020
Albania	0	0	0	0	0	0
Austria	33	3	1	1	0	0
Belarus	0	0	0	0	0	0
Belgium	62	39	13	10	7	5
Bosnia-Herzegovina	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0
Croatia	5	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Czech Republic	72	12	0	0	0	0
Denmark	62	44	25	7	4	1
Estonia	0	0	0	0	0	0
Finland	0	0	0	0	0	0
France	10	1	0	0	0	0
Germany	72	38	18	13	11	6
Greece	0	0	0	0	0	0
Hungary	4	0	0	0	0	0
Ireland	3	0	0	0	0	0
Italy	38	20	12	12	9	2
Latvia	0	0	0	0	0	0
Lithuania	1	0	0	0	0	0
Luxembourg	18	15	12	0	0	0
Macedonia	0	0	0	0	0	0
Moldova	0	0	0	0	0	0
Netherlands	87	56	50	42	42	30
Norway	1	0	0	0	0	0
Poland	59	4	1	1	0	0
Portugal	0	0	0	0	0	0
Romania	0	0	0	0	0	0
Russia	0	0	0	0	0	0
Serbia and Montenegro	0	0	0	0	0	0
Slovak Republic	48	0	0	0	0	0
Slovenia	43	0	0	0	0	0
Spain	6	0	0	0	0	0
Sweden	1	0	0	0	0	0
Switzerland	48	19	12	12	6	2
Ukraine	0	0	0	0	0	0
United Kingdom	6	1	0	0	0	0
EU27[2]	16	5	2	2	2	1
All[2]	10	3	2	1	1	1

[1] The area may be 0 because EUNIS classes E, F2 and G3 may not be in the CCE database for the country in question, or – more likely – the computed change of biodiversity for any of these EUNIS classes is not equal to or higher than 5%

[2] The ecosystem area to which dose response curves from Bobbink and Hettelingh (2011) were extrapolated covers about 2 million km^2 in Europe and about 1.2 million km^2 in the EU27, i.e. half of the natural area covered by the CCE European database of nutrient N critical loads.

change of biodiversity are likely to be an underestimation, considering 1) the fact that we limit our analysis to vegetation only, just covering about half of the natural area, and 2) that around one in four species in the EU is currently threatened with extinction.[3]

[3] http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm.

Table 1.6 The percentages of ecosystem area for which target loads are exceeded – required for achieving recovery from acidification and eutrophication in 2050 – according to the CLE and MID scenarios.

Country	acidification		eutrophication	
	CLE	MID	CLE	MID
Albania	0	0	73	38
Austria	15	12	85	69
Belarus	1	1	26	18
Belgium	4	3	96	85
Bosnia-Herzegovina	0	0	59	33
Bulgaria	28	20	62	47
Croatia	0	0	98	92
Cyprus	29	28	17	13
Czech Republic	6	4	79	75
Denmark	75	73	99	98
Estonia	12	11	9	5
Finland	4	2	2	0
France	1	1	11	5
Germany	0	0	50	34
Greece	0	0	63	19
Hungary	0	0	72	58
Ireland	7	1	97	85
Italy	0	0	66	63
Latvia	0	0	89	81
Lithuania	23	10	100	100
Luxembourg	0	0	31	18
Macedonia	2	0	99	97
Moldova	0	0	98	92
Netherlands	4	2	99	85
Norway	20	0	100	100
Poland	30	26	100	98
Portugal	13	12	99	99
Romania	3	2	92	79
Russia	0	0	94	84
Serbia and Montenegro	0	0	78	53
Slovak Republic	7	4	100	97
Slovenia	3	2	66	37
Spain	62	58	98	93
Sweden	0	0	100	90
Switzerland	5	4	90	78
Ukraine	1	0	100	100
United Kingdom	7	5	52	43
EU27	9	8	61	50
All	5	4	38	30

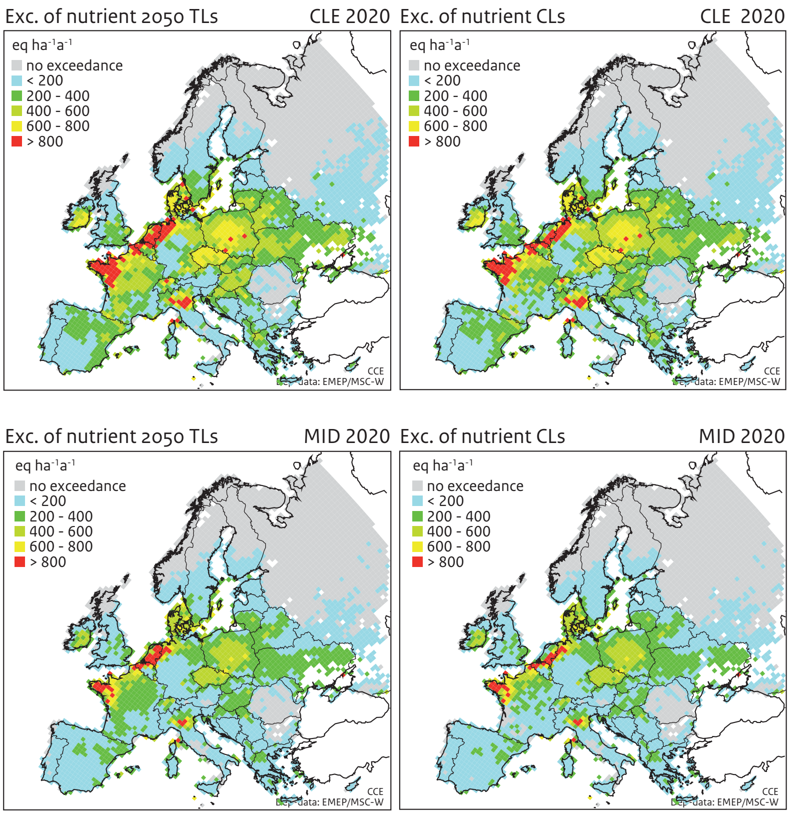
Exceedances of target loads for achieving recovery in 2050

Dynamic modelling was applied to analyze the delayed response of soil chemistry to the change of N deposition, in particular under the CLE and MID scenario. An overview of the development of dynamic modelling and its use in the analysis of effects on soil and water chemistry of air pollution in Europe can be found in Posch et al. (2003, 2005), Slootweg et al. (2007) and reports of other ICPs of the LRTAP Convention[4]. New developments – not reported in this chapter and also including the relationship to the dynamics of plant species diversity – can be found in Hettelingh et al. (2008, 2009) and in chapter 2 of this report.

The focus in this section is on the exceedance of target loads that would be required to obtain recovery from acidification and eutrophication in 2050 under the CLE and

[4] See e.g. http://www.unece.org/env/lrtap/WorkingGroups/wge/29meeting_Rev.htm

Figure 1.5 Exceedances in 2020 of target loads needed for recovery from eutrophication in 2050 under CLE (top left) and MID (bottom left) compared to the exceedance of critical loads under CLE (top right) and MID (bottom right).



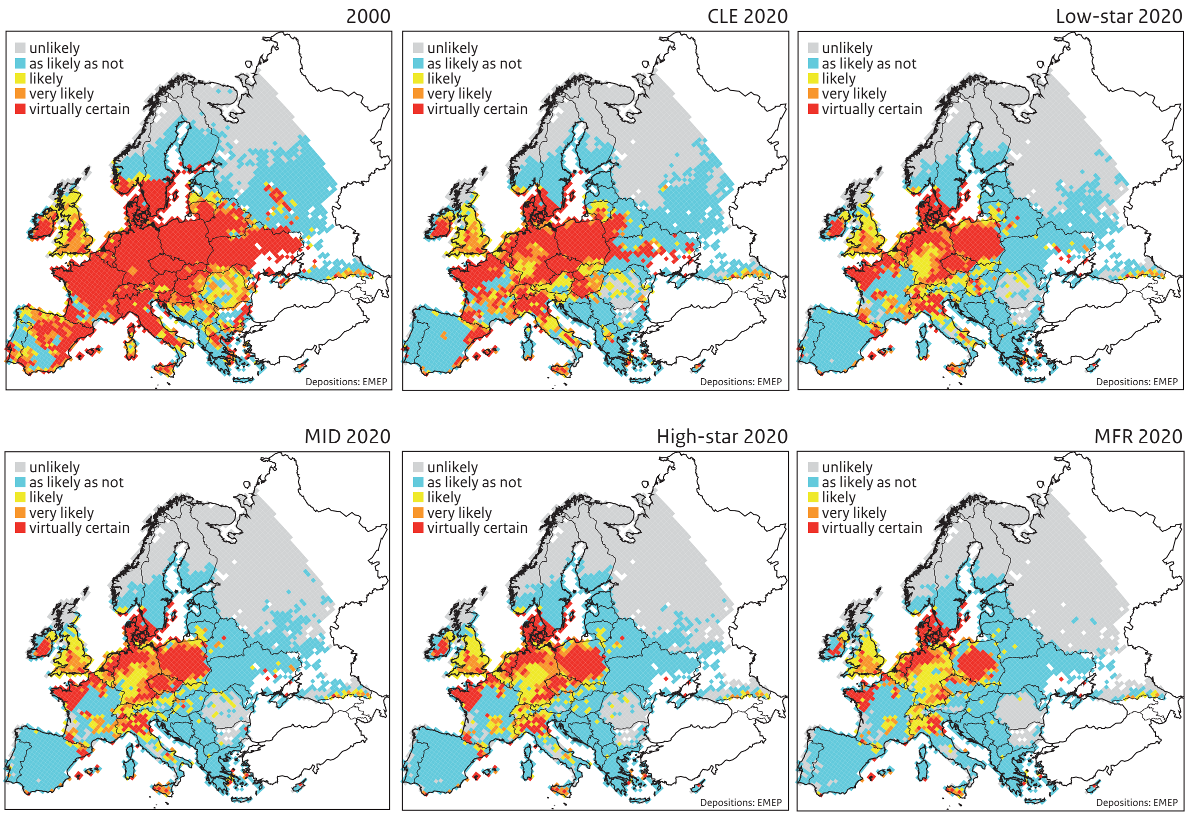
MID scenarios. Target loads are generally lower than critical loads. The reason is that a deposition that equals critical loads will lead to recovery, i.e. reaching the critical chemical limit, but maybe only in centuries from now. Shortening this time needed for recovery means lowering future deposition values below critical loads. Therefore, if recovery is targeted to occur in 2050, it is necessary that the critical load is not exceeded and that the chemical criterion is not – or no longer – violated in 2050 *at the latest*. Soil-chemical processes (buffers) imply a time delay between non-exceedance of the critical load and non-violation of the chemical criterion. This delay is termed Recovery Delay Time (RDT).

Table 1.6 shows the percentage of ecosystems in each country for which target loads are exceeded, for which the RDT under the CLE and MID scenarios is a maximum of 30 years (after 2020). These target loads are computed with dynamic models assuming these are implemented in 2020 and obtain recovery in 2050. Target loads for acidification are calculated (Table 1.5) to be exceeded under CLE in 5% of the EMEP domain and in 9% of EU27. Under the MID scenario these percentages are reduced to 4% and 8%, respectively. Requiring recovery from eutrophication before or in 2050 results in target loads that are exceeded under CLE in 38% of the EMEP domain, and in 61% of the EU27 region. Under MID these percentages are 30% and 50%, respectively. This is slightly than the exceedance of critical loads (Table 1-2), which are computed to occur in 29% of the EMEP domain and 48% of the EU27.

The location of the exceedances of target loads is shown in Figure 1.5, for CLE (top left) and MID (bottom left). Comparison of the location and magnitude of the target load exceedances with critical load exceedances (right pane) show areas where target load exceedance overlap areas with critical load exceedance. However, a clear difference between exceedances of target and critical loads can be seen in the southern part of France, especially under the MID scenario (bottom pair of maps).

[4] See e.g. http://www.unece.org/env/lrtap/WorkingGroups/wge/29meeting_Rev.htm

Figure 1.6 The likelihood that exceedance (computed as AAE) is 'virtually certain' (red shading), i.e. that a grid cell contains at least one ecosystem of which the critical load of nutrient N is exceeded in 2000 (top left), CLE (top centre), Low* (top right), MID (bottom left), High* (bottom centre) and MFR.



1.4 Robustness analysis of the estimated risk of effects in support of the revision of the Gothenburg Protocol

The robustness of the computed risk of impacts is analysed in three ways. Firstly the CCE Ensemble Assessment of Impacts is applied to areas at risk of exceedances of both computed and empirical nitrogen critical loads. Secondly a comparison is made between the impacts computed for the scenarios presented to WGSR48 with those for the WGSR49 in the spring and autumn of 2011 respectively. Finally a comparison is made between areas at risk of the exceedance of the critical level for ambient concentrations for ammonia and areas where ammonium depositions exceed critical loads.

Ensemble Assessment of Impacts (EAI)

The CCE developed the so-called Ensemble Assessment of Impacts (EAI) methodology for the assessment of uncertainties, based on IPCC (2005) as described in Hettelingh et al. (2007). Following this method, the likelihood of areas at risk is derived from whether either, or both, empirical and computed critical N loads are exceeded.

Applying this method to exceedances in 2000 and for 2020 following the five scenarios yields an overview (Figure 1.6) of the likelihood of exceedances. Figure 1.6 shows that exceedances, that are 'virtually certain' (red shading) in a large area in Europe in 2000, are reduced under the MID scenario to Central-Western Europe.

Robustness of impacts for policy support in the spring and autumn of 2011

The difference between the results regarding areas at risk in support of the revision of the Gothenburg Protocol in the spring (WGSR48) and autumn (WGSR49) of 2011 are presented in Table 1.7. The areas at risk of acidification in Europe differ by about 0% (MID) and 1 % under CLE. These percentages are 0% in the EU27 (the risk for N2k areas was not computed for WGSR48). The difference between the 2 assessments for eutrophication in Europe ranges between 0 (CLE) and 1% (MID). For the EU27 these percentages are 1% (CLE) and 2% (MID).

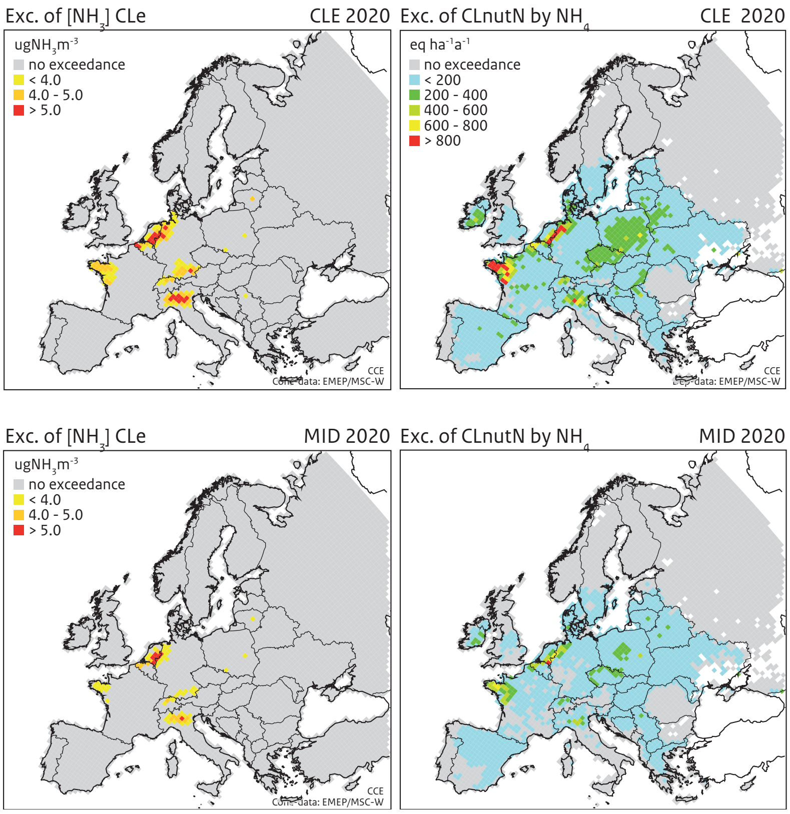
What is worse: the risk of NH_3 critical level or load exceedances?

Cape et al. (2009) established critical levels for the ambient concentration of ammonia that then led to the adoption, under the LRTAP Convention, of a revision of critical levels

Table 1.7 Percentages of the area at risk of acidification and eutrophication as computed in support of policy processes in the 48th session of the Working Group on Strategies and Review (WGSR48) in the spring of 2011, in comparison to those submitted to the WGSR49.

% Area at Risk												
	Acidification						Eutrophication					
	48th WGSR			49th WGSR			48th WGSR			49th WGSR		
Scenario	Europe	EU27	N2k	Europe	EU27	N2k	Europe	EU27	N2k	Europe	EU27	N2k
2000	-	-	-	12	20	23	-	-	-	54	75	72
CLE	3	6	-	4	6	7	37	58	-	37	59	58
Low*	3	5	-	3	5	6	30	48	-	31	50	50
MID	2	4	-	2	4	5	28	46	-	29	48	48
High*	2	3	-	2	3	4	25	42	-	26	38	38
MTFR	1	3	-	1	3	3	21	36	-	22	38	38

Figure 1.7 Areas at risk of exceedance of the critical level for ammonia in 2020 under CLE (top left) and MID (bottom left) in comparison to the areas at risk of the exceedance by the deposition of ammonium of the critical load of nutrient N under the CLE (top right) and MID scenarios.



for ammonia. For European areas where both the critical level is exceeded by ammonia concentrations and critical loads for nutrient nitrogen are exceeded by ammonia depositions, it is interesting to explore which of the two thresholds is more critical. This question was also raised in the context of the support of the revision of the Gothenburg Protocol, and therefore deserves attention in this section as in Figure 1.7. It shows areas where critical levels are exceeded by CLE-ammonia concentrations (left) and those where critical loads are exceeded by ammonium deposition (right) under the CLE (top) and MID (bottom) scenarios. The first conclusion to be drawn from Figure 1.7 is that ammonium deposition under both the CLE and MID scenario in 2020 exceed N critical loads in large parts of Europe. Peaks (red shading: higher than 800 eq $ha^{-1} a^{-1}$) are located on the border area between the Netherlands and Germany, western France en northern Italy. The left maps in Figure 1.7 show that these areas turn out also to be at risk of excessive ambient ammonia concentrations; excessive in the sense that critical levels of ammonia are exceeded. Other areas in Europe are computed to be 'protected' from the exceedance of critical levels of ammonia both under CLE and MID.

1.5 Conclusions and recommendations

In this chapter the computed environmental effects are shown of projections of emissions of acidifying and eutrophying pollutants, in scientific support of policy considerations in 2011 as part of the revision of the Gothenburg Protocol under the Convention on Long-range Transboundary Air Pollution.

The analysis starts with the assessment of effects of emissions in the base year 2000, compared to effects in 2020 following five scenarios that cover a range of emission reductions that vary between a baseline i.e. the Current Legislation (CLE) scenario and Maximum technically Feasible Reductions (MFR). Between those, three additional emission reduction scenarios are considered: Low*, MID and High* in order of increasing emission reduction objectives.

It is shown that the percentages of ecosystem areas in Europe at risk of acidification are 4% (CLE) and 2% (MID), whereas in the EU27 they are 7% and 5%, respectively. Areas at risk of eutrophication cover much broader areas in Europe under CLE and MID: 37% (59% in the EU27) and 29% (48% in EU27), respectively. Note that the percentages of area at risk in Natura 2000 areas are slightly higher than the coverage within the EU27. Using dynamic modelling to assess time delays that could be involved for recovery, it is noted that most of the areas could recover by 2050 from the risk of eutrophication. The pre-requisite for this is that depositions in 2020 do not exceed critical loads.

Finally, a dose-response analysis has been attempted to assess biological effects of the subset of plant species diversity (currently covering 53% of the natural area), for which the CCE holds dose-response relationships. They confirm conclusions that the CLE and MID scenarios continue to imply risk to biodiversity.

Regarding uncertainties, emphasizing the persistent risk caused by reduced nitrogen, it is concluded that the assessments of scenario impacts are fairly robust. This holds for the following reasons: (i) areas at risk of both computed and empirical critical loads tend to overlap, (ii) impacts of different versions (spring and autumn of 2011) of the scenarios do not reveal significant differences, and (iii) it is shown that areas at risk of ammonium deposition effects overlap with those of ammonia concentration effects. These three different angles at viewing the risk of nitrogen all point in the same direction: nitrogen continues to pose a threat to the environment.

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2
Summary of National Data

Jaap Slootweg, Maximilian Posch, Jean-Paul Hettelingh

2.1 Introduction

The Working Group on Effects (WGE), at its 29th session held 22-24 September 2010 in Geneva, 'endorsed the proposal made at the 26th meeting of the Task Force of ICP Modelling and Mapping (Paris, 22-23 April 2010) to issue a call for data to National Focal Centres (NFCs) in autumn 2010 (deadline, spring 2011).' The aims of this call were:

i to increase the resolution of critical loads to allow an adequate assessment of exceedances in view of the new resolution of EMEP dispersion modelling;

ii to invite NFCs to apply to national nature areas a revised table of empirical critical loads which was expected to be obtained as a result of a United Nations Economic Commission for Europe (UNECE) workshop that had been held in Noordwijkerhout (the Netherlands), 23-25 June 2010;

iii to encourage NFCs to relate to national habitat experts in Parties to the Convention, including national focal points in EU member States which were responsible for reporting requirements under Article 17 of the EU Habitats Directive; and to

iv to continue work on an extended very simple dynamic model (VSD+) and vegetation modelling, including the assessment of interactions between effects of air pollution and climate change.

Early November 2010 the CCE issued the call, the details of which are described in the *Instructions for submitting Critical Loads of N and S and site-specific soil-vegetation model runs* (see Appendix A). Also made available to NFCs were the Guidance for the Article 17 reporting, including habitat contacts, draft versions of the background document on the revision of empirical critical loads, the latest versions of VSD+Veg Studio and MetHyd software with instruction videos on their use, and a vegetation parameter list for the Veg model. In addition, downloads in support of the Call for Data included a template database (mdb) file, a GIS file with the new EMEP grid and its description, and a correspondence table between EUNIS classes and EU Habitats according to Annex I of the EU Habitats Directive were also made available. In the months following the Call updates of information and software were distributed by the CCE.
Initial results of the Call have been presented at the CCE workshop, held 18-19 April 2011 in Bilthoven, the Netherlands. Updates by NFCs were accepted until 16 May 2011.

This chapter provides a compilation of all responses to the call for data, resulting maps and graphs concerning the updated critical loads as well as cross-country comparisons. The descriptions of the national responses can be found in part three of this report.

Table 2.1 Responses of countries to the Call for Data.

		Modelled Nutrient N	Acid	Empirical	Soil/Veg modelling
AT	Austria	X	X	X	X
BE	Belgium*	X	X	X	
BG	Bulgaria	X	X	X	X
CA	Canada		X	X	
CH	Switzerland	X	X	X	X
CZ	Czech Republic	X	X	X	
DE	Germany	X	X	X	X
FI	Finland			X	
FR	France	X	X	X	X
GB	United Kingdom	X	X	X	
IE	Ireland	X	X	X	
IT	Italy	X	X		
NL	Netherlands	X	X	X	X
NO	Norway		X	X	
PL	Poland	X	X	X	X
SE	Sweden	X	X	X	X
SI	Slovenia	X	X	X	X
US	USA	X	X	X	
Total 18		**15**	**17**	**17**	**9**

* Wallonia only

At the end of the chapter recent issues relating to modelling nitrogen in the environment are summarised with the purpose to stimulate discussions in the modelling community.

2.2 National responses to the Call for Data

The aims to i) increase the resolution and ii) apply the revised table of empirical critical loads have been achieved by requesting updated critical loads (both modelled and empirical). Nine NFCs submitted complete sets of input files to the soil-vegetation model runs in support of the continuation of the work on an extended very simple dynamic model (VSD+) and vegetation modelling (aim iv in the list). In total 18 countries responded to the Call for Data. The USA submitted data for testing purposes only. These data are not shown and discussed in this report, but the national report can be found in part three. Also in the NFC reports of Austria, Finland, Norway, Poland, Sweden, Slovenia and Switzerland are responses on the query for Art.17 reporting contacts (aim iii) or reporting of other contacts with habitat experts.

To complete the European critical load database for use in integrated assessment the CCE applies the 'background database' (2008 CCE Status Report; see also below) for countries that did not submit critical loads. Also critical loads submitted in the past cannot be used in new assessments because they are no longer geographically compatible. Therefore critical loads for, e.g., Romania and Russia, which have national data in the 2008 database, are now taken from the background database. Still, a map of critical loads of nutrient N would be blank for Norway and Finland, given the fact that they delivered critical loads, but not for CLnutN. Thus, in Table 2.2 and the exceedance maps in this chapter, all missing countries for each critical load separately (empirical, modelled nutrient and acidification) are filled in by the background database. This needs further discussion, e.g., at the next Task Force meeting.

2.3 Coverage of critical load submissions

Countries that submitted critical loads did so for different receptors and in datasets of different sizes. Table 2.2 shows the number of ecosystems and their area, for which critical loads for modelled nutrient nitrogen, empirical nitrogen and acidification have been submitted, summarised at EUNIS-class level 1. Countries and numbers in bold show the national submissions, the others are the countries for which data from the European background database are used. Although Finland, Italy and Norway submitted data, they did not do so for each critical load category (empirical, modelled nutrient and acidification). Thus for exceedance maps in this chapter, the background database is used whenever a CL category is missing from the submission; and the number of ecosystems and their

Table 2.2 Number of ecosystems and their area for which critical loads have been submitted (bold) or are taken from the European background data base.

Country Code	EUNIS Class	Modelled Nutrient N		Empirical N		Acidification	
		# records	Area (km²)	# records	Area (km²)	# records	Area (km²)
AL	C			67	126		
	D	9	9			9	9
	E	3,213	6,183	2,137	4,410	3,213	6,183
	F	1,921	4,022	478	930	1,921	4,022
	G	2,571	6,347	2,571	6,347	2,571	6,347
AM	E	2,203	6,935	2,203	6,935	2,203	6,935
	F	454	1,628	454	1,628	454	1,628
	G	924	1,993	924	1,993	924	1,993
AT	**D**			**2,486**	**272**		
	E			**21,824**	**18,954**		
	G	**36,130**	**37,125**	**28,031**	**39,789**	**496**	**6,336**
AZ	E	8,429	29,806	8,429	29,806	8,429	29,806
	F	842	2,373	842	2,373	842	2,373
	G	2,446	7,123	2,446	7,123	2,446	7,123
BA	C			74	129		
	D	24	38			24	38
	E	5,452	8,850	4,364	6,863	5,452	8,850
	F	1,701	2,527	1,069	1,426	1,701	2,527
	G	9,350	19,344	9,350	19,344	9,350	19,344
BE	**D**			**65**	**58**		
	E			**9**	**6**		
	F			**422**	**180**		
	G	**28,530**	**5,541**			**26,206**	**5,458**
BG	**A**			**481**	**170**		
	B			**482**	**136**		
	C			**3,640**	**1,280**		
	D			**1,690**	**162**		
	E			**3,106**	**233**		
	F			**1,333**	**48**		
	G	**6,481**	**42,660**	**6,480**	**42,646**	**6,481**	**42,660**
BY	D	808	2,718			808	2,718
	E	1,680	3,442	1,680	3,442	1,680	3,442
	F	70	104	70	104	70	104
	G	16,683	57,360	16,683	57,360	16,683	57,360
CA	**C**					**2,952**	**207,961**
	G			**138,415**	**1,648,716**	**138,415**	**1,648,716**
CH	**C**			**49**	**42**	**100**	**86**
	D			**2,099**	**1,546**		
	E			**13,158**	**10,432**		
	F			**1,734**	**1,584**		
	G	**10,608**	**9,625**	**1,429**	**891**	**10,608**	**9,625**

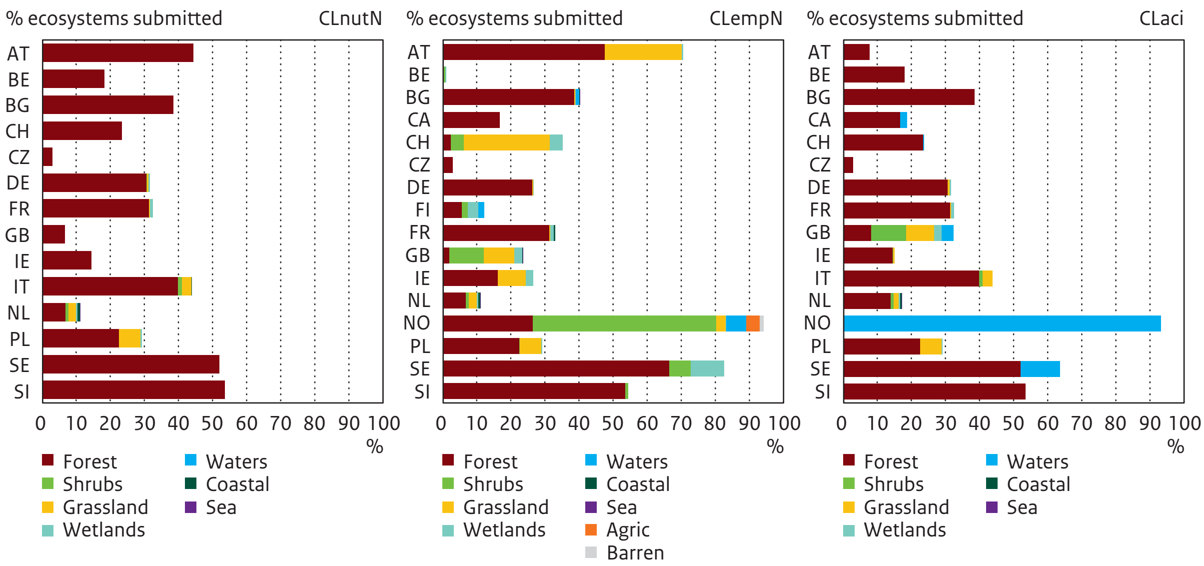
total area are in italics in Table 2.2. In the country submissions there are significantly less ecosystem types (EUNIS classes) for which critical loads for nutrient N have been modelled, compared to empirical or acidification critical loads (see figure 2.1).

Country Code	EUNIS Class	Modelled Nutrient N		Empirical N		Acidification	
		# records	Area (km²)	# records	Area (km²)	# records	Area (km²)
CS	E	5,578	12,639	5,578	12,639	5,578	12,639
	F	733	1,463	619	1,299	733	1,463
	G	10,428	25,796	10,428	25,796	10,428	25,796
CY	C			15	5		
	E	611	495	186	143	611	495
	F	678	845			678	845
	G	642	1,189	642	1,189	642	1,189
CZ	**G**	**6,971**	**2,203**	**6,971**	**2,203**	**6,971**	**2,203**
DE	**A**	**42**	**38**	**19**	**17**	**42**	**38**
	B	**184**	**164**			**184**	**164**
	C	**100**	**90**			**100**	**90**
	D	**1,524**	**1,370**	**520**	**467**	**1,524**	**1,370**
	E	**2,000**	**1,811**	**1,180**	**1,072**	**2,000**	**1,811**
	F	**413**	**370**	**331**	**295**	**413**	**370**
	G	**120,606**	**108,689**	**103,330**	**93,102**	**120,606**	**108,689**
DK	C			899	303		
	D	1,476	331	601	172	1,476	331
	E	3,401	1,070	2,133	674	3,401	1,070
	F	696	368	696	368	696	368
	G	4,575	2,508	4,575	2,508	4,575	2,508
EE	C			680	180		
	D	2,385	1,131	1,027	738	2,385	1,131
	E	8,467	5,695	3,752	2,642	8,467	5,695
	F	351	81	351	81	351	81
	G	18,530	18,799	18,530	18,799	18,530	18,799
ES	C			5,084	1,227		
	D	594	505	44	6	594	505
	E	131,061	83,535	60,803	39,197	131,061	83,535
	F	68,463	50,479	9,492	7,399	68,463	50,479
	G	112,565	78,609	112,519	78,549	112,565	78,609
FI	**A**			**191**	**72**		
	B			**36**	**3**		
	C			**3,643**	**6,294**		
	D	*21,679*	*18,932*	**5,720**	**10,347**	*21,679*	*18,932*
	E	*35,346*	*37,772*	**84**	**101**	*35,346*	*37,772*
	F	*4,584*	*9,449*	**881**	**5,629**	*4,584*	*9,449*
	G	*110,907*	*176,945*	**14,238**	**18,367**	*110,907*	*176,945*
FR	**B**			**711**	**2,761**		
	D	**580**	**5,125**	**580**	**5,125**	**580**	**5,125**
	E	**350**	**1,550**	**350**	**1,550**	**350**	**1,550**
	G	**26,742**	**169,529**	**26,745**	**169,533**	**26,742**	**169,529**
GB	**A**			**3,867**	**422**		
	B			**2,974**	**321**		
	C					**3,627**	**8,689**
	D			**19,019**	**5,514**	**18,181**	**5,390**
	E			**119,020**	**21,890**	**99,409**	**20,002**
	F			**78,942**	**24,780**	**78,507**	**24,663**
	G	**113,155**	**15,790**	**43,711**	**4,092**	**154,421**	**19,700**

Country Code	EUNIS Class	Modelled Nutrient N		Empirical N		Acidification	
		# records	Area (km^2)	# records	Area (km^2)	# records	Area (km^2)
GE	E	5,987	16,167	5,987	16,167	5,987	16,167
	F	5,681	17,135	5,681	17,135	5,681	17,135
	G	4,084	9,126	4,084	9,126	4,084	9,126
GR	C			793	238		
	D	915	149			915	149
	E	42,333	22,701	15,418	8,218	42,333	22,701
	F	22,095	16,330	82	5	22,095	16,330
	G	28,509	19,154	28,509	19,154	28,509	19,154
HR	C			121	208		
	D	80	130			80	130
	E	7,245	11,520	4,618	7,925	7,245	11,520
	F	1,236	1,697	574	760	1,236	1,697
	G	8,043	17,380	8,043	17,380	8,043	17,380
HU	C			1,594	582		
	D	2,579	730	220	104	2,579	730
	E	20,137	8,515	14,595	7,305	20,137	8,515
	G	19,691	14,600	19,691	14,600	19,691	14,600
IE	**A**			**21**	**1**		
	D			**1,703**	**1,622**		
	E			**4,811**	**5,683**	**1,180**	**317**
	F			**417**	**75**	**406**	**74**
	G	**26,419**	**10,055**	**37,734**	**11,193**	**26,419**	**10,055**
IS	D	985	6,020	985	6,020	985	6,020
	E	50	66	50	66	50	66
	F	5,891	44,257	5,891	44,257	5,891	44,257
IT	**B**	**73**	**54**			**68**	**37**
	C			*354*	*1,869*		
	E	**18,617**	**8,832**	*17,490*	*33,895*	**18,585**	**8,826**
	F	**6,515**	**3,260**	*3,808*	*10,574*	**6,491**	**3,230**
	G	**83,712**	**119,727**	*67,408*	*79,795*	**83,616**	**119,499**
LT	C			1,407	711		
	D	1,290	408	716	317	1,290	408
	E	8,461	4,553	4,951	3,245	8,461	4,553
	F	88	28	88	28	88	28
	G	18,747	14,576	18,747	14,576	18,747	14,576
LU	C			29	6		
	E	679	372	594	357	679	372
	G	1,516	784	1,516	784	1,516	784
LV	C			1,210	442		
	D	1,696	1,189	1,229	1,091	1,696	1,189
	E	14,455	11,916	8,381	8,355	14,455	11,916
	G	24,935	21,973	24,935	21,973	24,935	21,973
MD	E	546	1,768	546	1,768	546	1,768
	F	334	73	334	73	334	73
	G	906	1,697	906	1,697	906	1,697
MK	C			51	71		
	D	2	2			2	2
	E	2,986	4,790	1,831	2,891	2,986	4,790
	F	1,011	1,708	914	1,534	1,011	1,708
	G	3,212	7,009	3,212	7,009	3,212	7,009

Country Code	EUNIS Class	Modelled Nutrient N		Empirical N		Acidification	
		# records	Area (km²)	# records	Area (km²)	# records	Area (km²)
NL	**A**	**1,096**	**69**	**456**	**29**	**976**	**61**
	B	**4,385**	**275**	**4,385**	**275**	**3,467**	**218**
	D	**3,182**	**199**	**3,182**	**199**	**2,908**	**182**
	E	**15,107**	**944**	**15,107**	**944**	**9,489**	**593**
	F	**5,788**	**362**	**5,788**	**362**	**5,551**	**347**
	G	**44,027**	**2,753**	**43,942**	**2,747**	**91,525**	**5,720**
NO	**C**			**5,228**	**19,001**	**13,598**	**301,873**
	D	*271*	*641*	**113**	**689**		
	E	*3,872*	*6,964*	**4,044**	**8,946**		
	F	*48,692*	*166,533*	**13,742**	**174,400**		
	G	*33,060*	*67,267*	**16,858**	**85,042**		
	H			**866**	**3,945**		
	I			**3,575**	**12,663**		
PL	**D**	**2,868**	**998**	**2,868**	**998**	**2,868**	**998**
	E	**53,241**	**20,067**	**53,241**	**20,067**	**53,241**	**20,067**
	F	**127**	**44**	**127**	**44**	**127**	**44**
	G	**125,173**	**69,869**	**125,173**	**69,869**	**125,173**	**69,869**
PT	C			663	100		
	D	69	7			69	7
	E	20,789	10,890	7,757	3,624	20,789	10,890
	F	7,990	3,709	4,460	2,112	7,990	3,709
	G	23,245	18,136	23,245	18,136	23,245	18,136
RO	C			1,360	911		
	D	15	9	15	9	15	9
	E	29,966	27,254	26,567	25,564	29,966	27,254
	F	4,899	2,732	4,899	2,732	4,899	2,732
	G	43,414	66,771	43,414	66,771	43,414	66,771
RU	E	67,631	334,153	67,631	334,153	67,631	334,153
	F	9,915	56,792	9,915	56,792	9,915	56,792
	G	224,416	1,139,212	224,416	1,139,212	224,416	1,139,212
SE	**C**					**17,249**	**52,549**
	D			**13,883**	**44,044**		
	F			**4,141**	**28,256**		
	G	**17,164**	**233,411**	**41,967**	**298,737**	**17,164**	**233,411**
SI	**F**			**325**	**164**		
	G	**17,364**	**10,826**	**17,364**	**10,826**	**17,364**	**10,826**
SK	C			408	113		
	D	289	31	12	1	289	31
	E	8,981	3,254	8,261	3,093	8,981	3,254
	F	4,663	1,069	4,663	1,069	4,663	1,069
	G	23,441	18,196	23,441	18,196	23,441	18,196
TR	C			2,313	4,926		
	E	160,341	542,763	127,327	451,885	160,341	542,763
	F	1,363	2,421	1,165	2,160	1,363	2,421
	G	31,176	49,964	31,176	49,964	31,176	49,964
UA	C			3	9		
	E	6,573	21,151	6,573	21,151	6,573	21,151
	F	531	1,096	531	1,096	531	1,096
	G	25,503	70,095	25,503	70,095	25,503	70,095
Totals		**779,274**	**883,425**	**1,081,057**	**2,941,923**	**1,196,380**	**3,129,021**

Figure 2.1 Distribution of ecosystem types of national submissions as percentage of the total country area.



2.4 Comparison with the 2008 database

Nutrient nitrogen

Figures 2.2 and 2.3 show how modelled critical loads of nutrient nitrogen (CLnutN) have changed between 2008 and 2011. The cumulative distribution functions (CDFs) in Figure 2.2 show no change for the majority of ecosystems submitted by the countries. Belgian forests are now considered much less sensitive, also compared to all other European forests. Differences are clearly visible, e.g., freshwater ecosystems are no longer considered in the Netherlands. The biggest difference in the 5th percentile maps in Figure 2.3 – in addition to the higher resolution – are found in those countries that have not submitted data in 2011, and therefore the background data base has been used.

Although there are no big changes regarding CLnutN, a comparison of the maps of the 5th percentiles for the 2008 and the 2011 data show some remarkable characteristics. First of all the resolution is much finer in the 2011 database (one of the reasons for the Call for Data). The European Monitoring and Evaluation Programme (EMEP) indicated to increase the resolution of their deposition calculations to 25×25 or even 10×10 km^2. Both can be accommodated by changing the EMEP grid index for the ecosystems to a resolution of 5 km. Note, however, that the maps shown are with a resolution of 10 km, since the higher resolution would not show in print.

A second fact that jumps to the eye is the much higher sensitivity of the ecosystems in the background database, compared to the countries that submitted national data (see also Table 2.1). Especially ecosystems in the south of Europe are very sensitive in the background database. Finally, some countries, that were blank earlier or did not re-submit data, are now filled in by the background database (Romania, Russia, Armenia, Azerbaijan, Georgia, Iceland, Turkey). The higher resolution also makes the absence of critical loads in the Flemish Region of Belgium more pronounced. Bulgaria re-submitted the same (number of) ecosystems as before, but simply split the ecosystem area from the 50 km grid cells over the corresponding 5 km grid cells.

The most important parameters for modelling the sinks of nitrogen, and therefore the critical load, are the acceptable N concentration in the leachate (cNacc), the net N uptake, the denitrification fraction (fde) and the N immobilisation. Figure 2.4 shows these four parameters for the nationally submitted values and the European background database. For all but fde there is a clear difference, values in the background database are significantly lower for most part of the distributions. This explains the large difference between national critical loads and the values in the background database.

Empirical critical loads of nitrogen

The review and revision of empirical critical loads of nitrogen (CLempN) led to changes in the upper and lower limit of the CLempN ranges for some EUNIS classes (Bobbink and Hettelingh 2011). Also the modifying factors and their use have changed. The CDFs in Figure 2.5 are drawn for a EUNIS class at the highest level. Compared to CLnutN by far the most of these CDFs show clear steps induced by different EUNIS subclasses. A complete list of values used for each identified EUNIS class is listed in

Figure 2.2 The CDFs of the modelled critical loads for nutrient N of countries that submitted in both 2008 (left) and 2011(right), split by EUNIS classes.

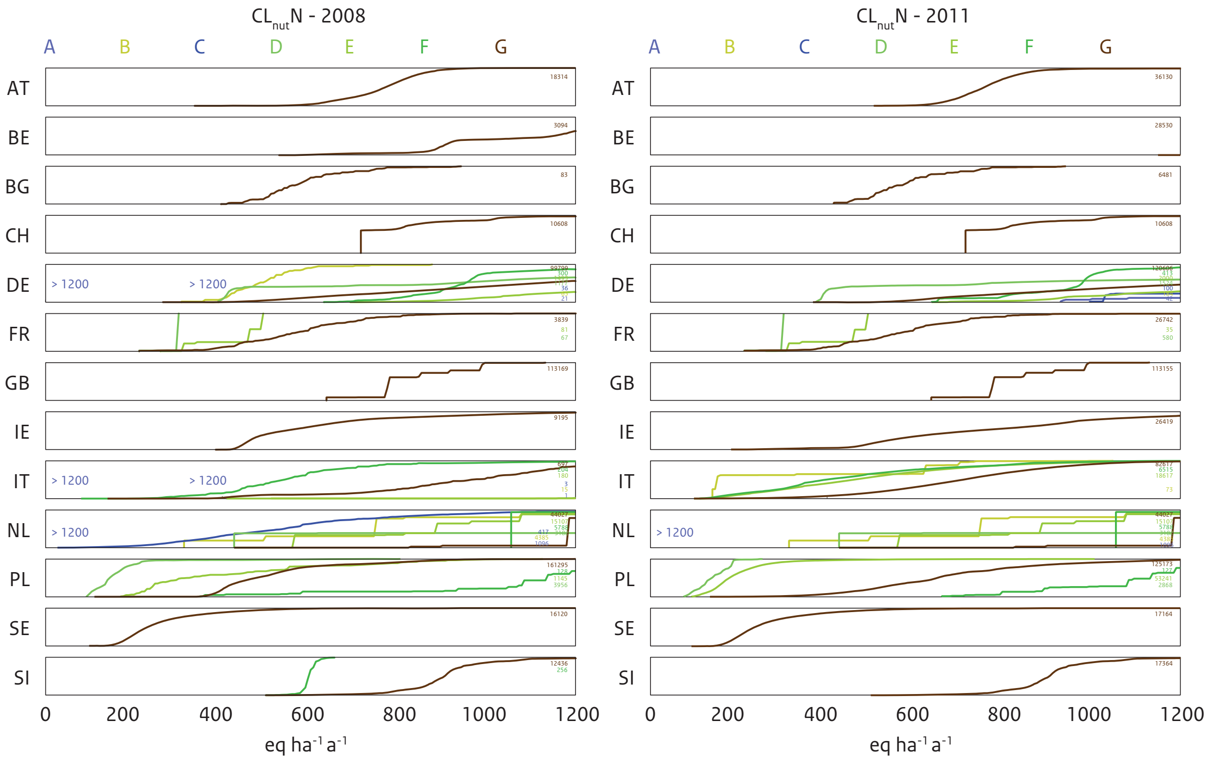


Figure 2.3 The 5[th] percentiles of the critical loads of modelled nutrient N for the 2008 dataset (left, 50×50 km² EMEP grid) and the 2011 dataset (right, 10×10 km² EMEP grid).

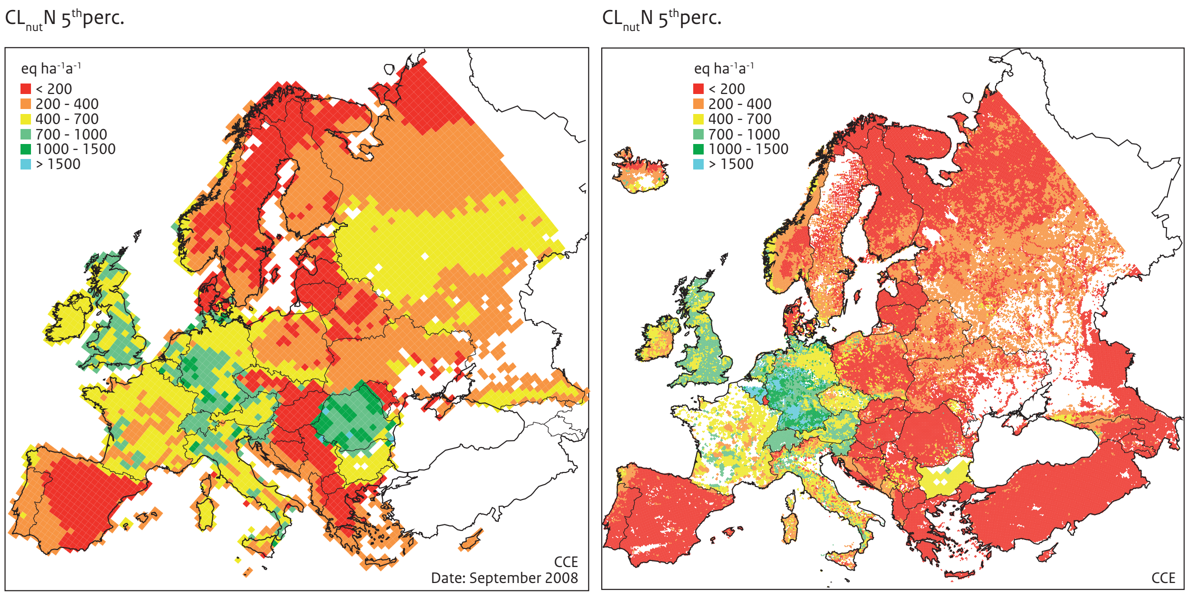


Figure 2.4 CDFs of important parameters for the CLnutN calculation: acceptable N concentration (cNacc), net N uptake (N uptake), denitrification fraction (fde) and N immobilisation of the country submissions (Nat) and of the data for countries in which the European background database is used (EU).

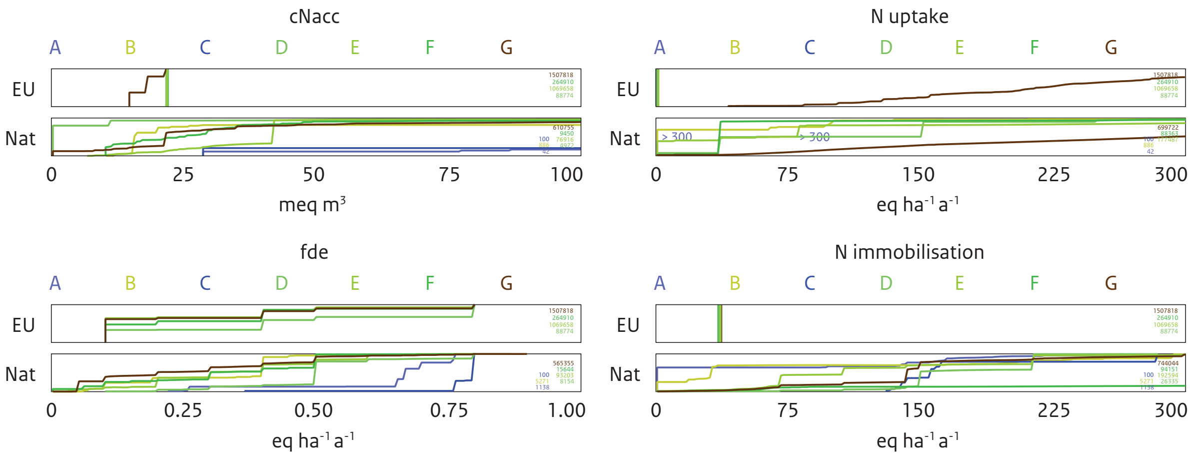
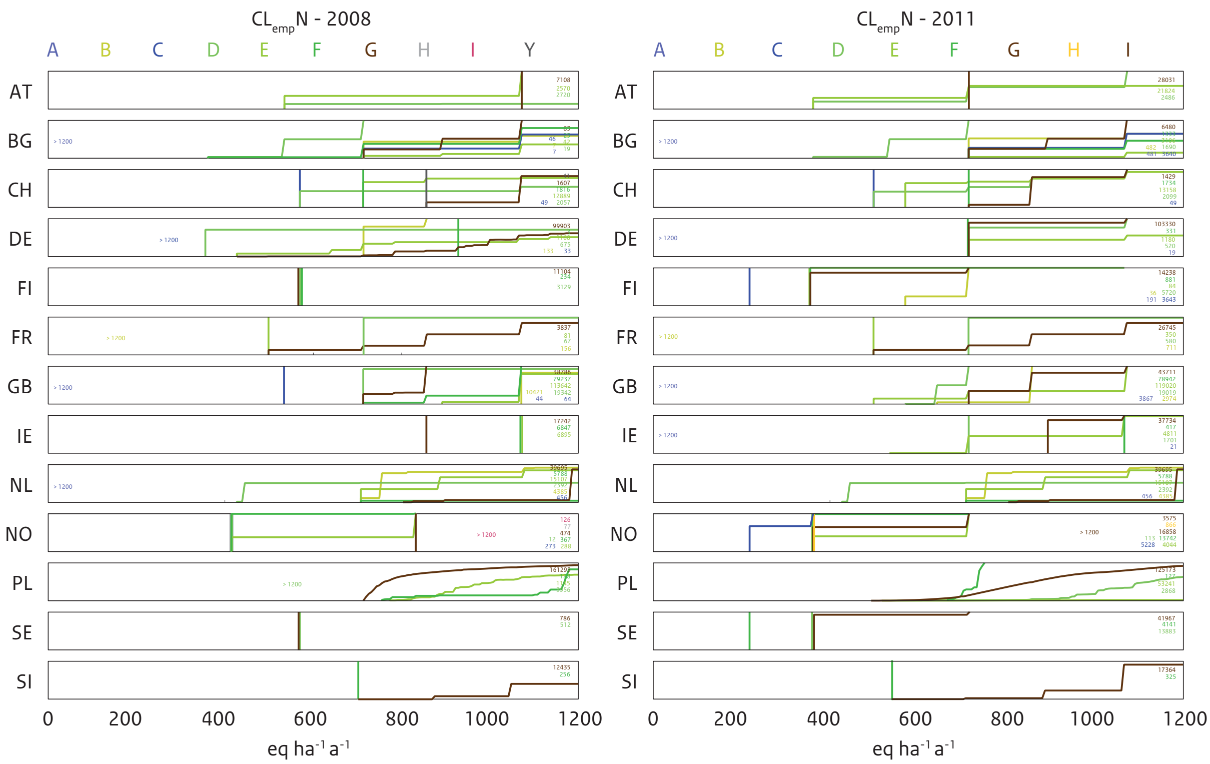


Figure 2.5 CDFs of empirical critical loads of N of countries that submitted both in 2008 (left) and in 2011(right), split by EUNIS classes.



Annex 2-A. Poland has applied continuous functions for the modifying factors, and is listed separately with the minimum and maximum values for each class.

There is a clear shift to lower values in empirical critical loads of N, with the exception of parts of northern Germany, eastern Ukraine, Spain, the United Kingdom and Italy with a shift from light green (700-1000 eq $ha^{-1} a^{-1}$) to dark green (1000–1500 eq $ha^{-1} a^{-1}$). One should, however, bear in mind that only the 5th percentile is shown, indicating only the sensitive portion of the distribution within each grid cell.

Critical loads of acidity

From Figure 2.7 one can see only marginal changes in the submitted critical loads for acidity. The changes in the European maps, shown in Figure 2.8, are due to the use of CLs from the background database for countries that did not (re-)submit national CLs, and the resolution influencing the visual impression only.

Figure 2.6 The 5th percentiles of the empirical critical loads of N for the 2008 dataset (left, 50×50 km² EMEP grid) and the 2011 dataset (right, 10×10 km² EMEP grid).

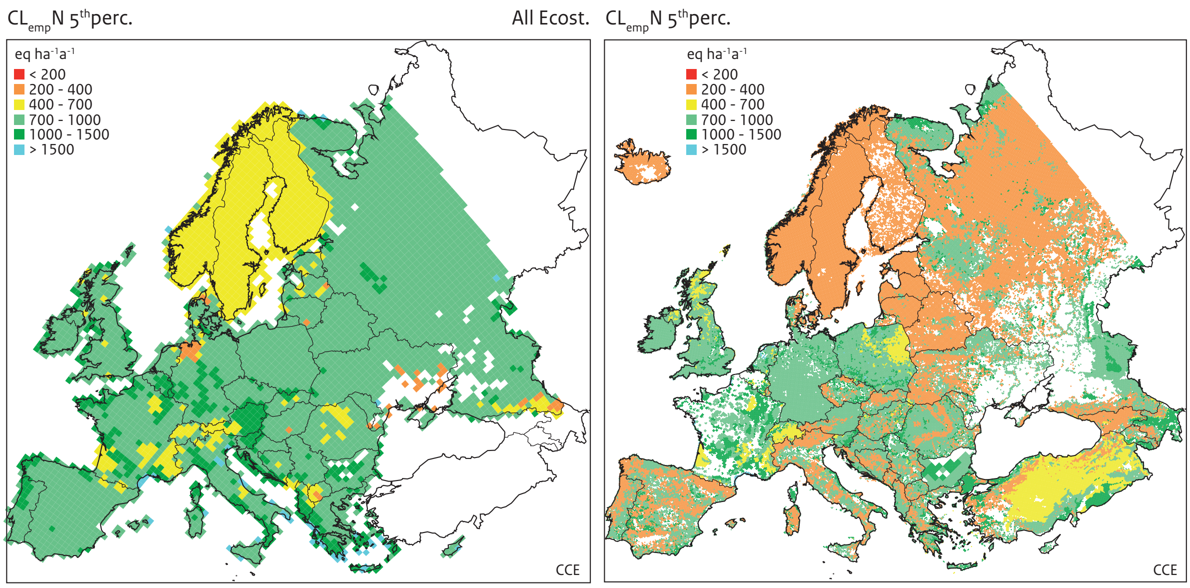


Figure 2.7 CDFs of the maximum critical load of acidity (CLmaxS) of countries that submitted in both 2008 (left) and 2011(right), split by EUNIS class.

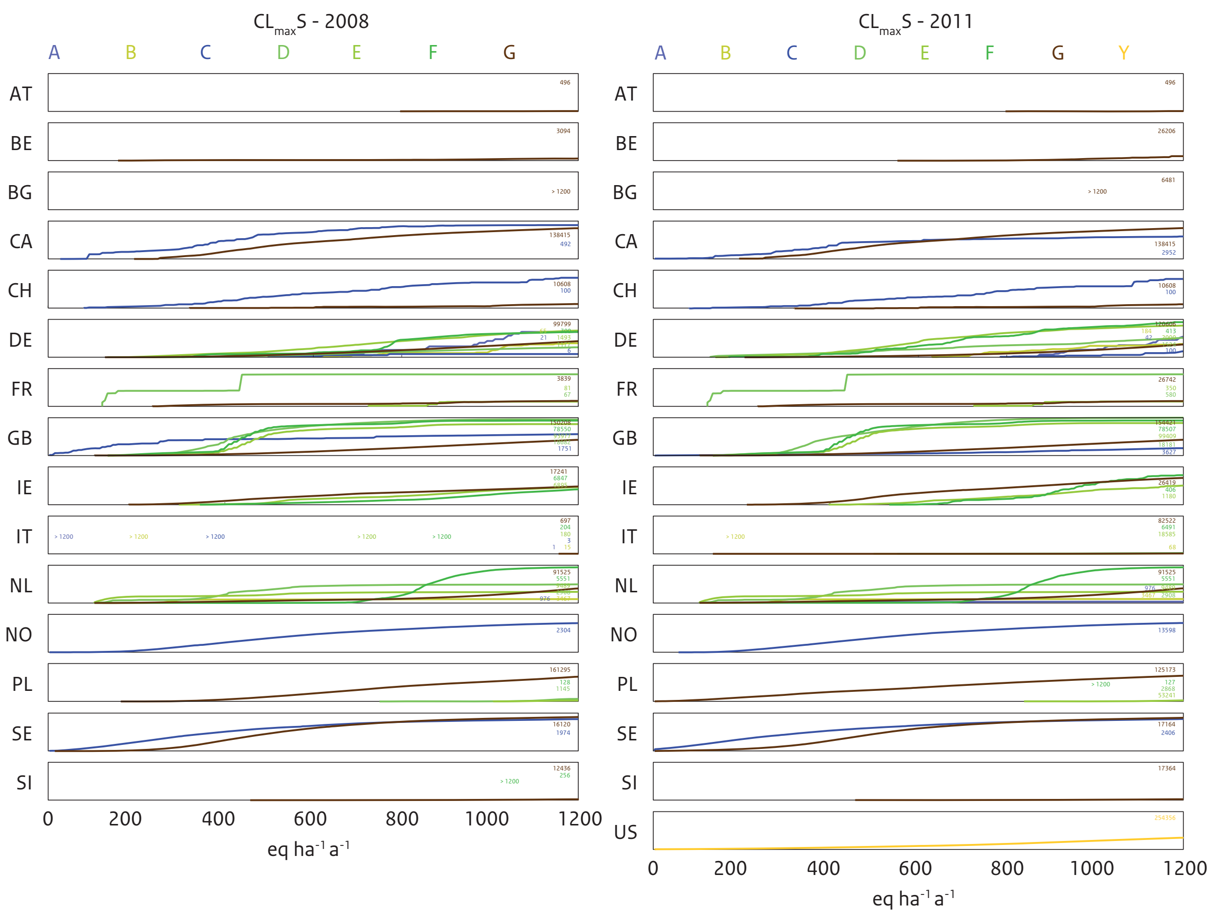


Figure 2.8 The 5th percentiles of the maximum critical loads of acidity (CLmaxS) for the 2008 dataset (left, 50×50 km² EMEP grid) and the 2011 dataset (right, 10×10 km² EMEP grid).

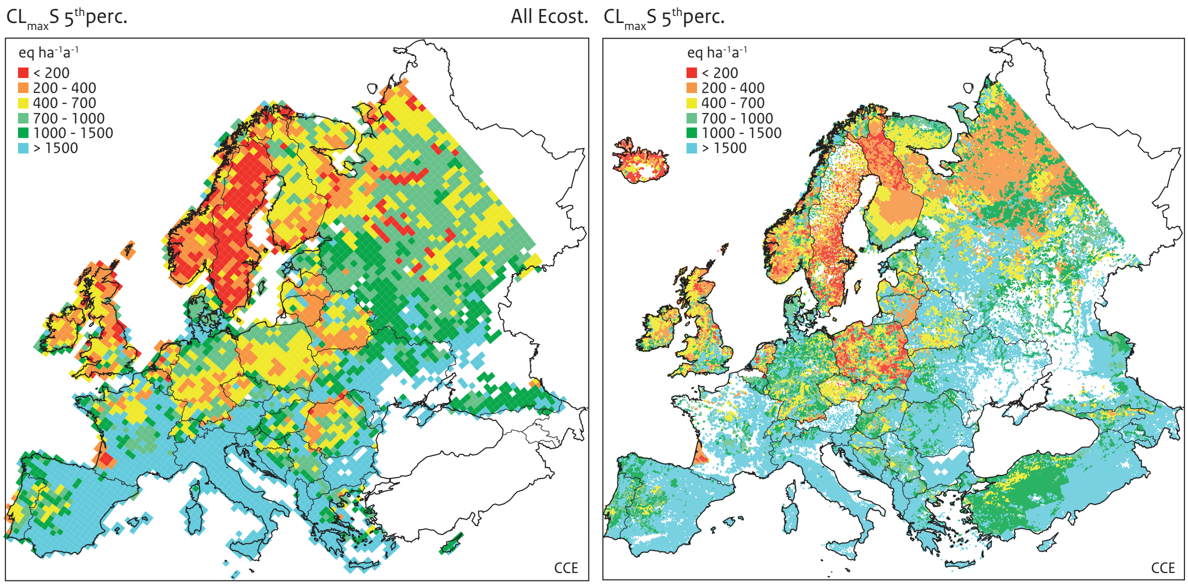


Table 2.3 Vegetation types and number of sites for which NFCs carried out dynamic modelling.

Vegetation type	AT	BG	CH	DE	FR	NL	PL	SE	SI
spruce	1	1	6	6	1			16	
pine				1	2		5		1
broadleaf hardwood	4	2	1	9	1	2			1
grassland						1			

2.5 VSD+vegetation modelling

In total 9 countries submitted VSD+ model runs, of which 6 have also carried out vegetation modelling: Austria, Germany, France, Poland, Sweden and Switzerland. They mostly used VSD+Veg, but also the 'ForSAFE' and the 'Bern' model have been tested, and the countries described their experiences and results in their national reports (see part three). This section gives a general overview of the sites and the parameters used.

Almost all dynamic modelling with soil-vegetation model couplings has been executed for forested areas. The parameter veg_*type*, indicating the dominant vegetation type and defining default values for five important N-related parameters, is not (yet) related to the EUNIS classification. Table 2.3 lists the number of sites for all indicated vegetation types by country. A total of 61 sites have been modelled, with a single non-forested site.

The Studio-version of VSD+ includes the feature of running Veg subsequently to running the model itself, with five additional parameters included in the input file to enable this feature. A description of these variables can be found in the 'Help' of VSD+Veg Studio (by clicking on the respective variable). PARtop, ThetaWP and ThetaSat can be obtained from the MetHyd model (see Appendix C in the 2010 CCE Status Report), the other two are vegetation-specific. The ranges of values used by countries are listed in Table 2.4.

Calibration is an integral part of running VSD+. In Table 2.5 the observed chemical properties of the sites that are used in the bayesian calibration are listed.

2.6 Modifications to the European background database (EU-DB)

In this section we shortly describe the changes made to the European background data base (EU-DB) which is used to compute critical loads on a European scale and use them for those countries that do not submit national data. Descriptions of the EU-DB can be found in earlier CCE status reports; since then three (major) changes have been made:

1. Obviously, to comply with the goals of the Call for Data, also the data in the EU-DB are now referenced with respect to the 5×5 km² EMEP grid.

Table 2.4 Ranges of additional parameters used and reported by the countries that applied Veg integrated in VSD+Studio.

Parameter	AT	BG	CH	FR	PL
PARtop	498–606	-	491–556	544	-
ThetaWP	0.3–0.4	-	0.046–0.302	0.235	-
ThetaSat	0.7–0.8	-	0.313–0.593	0.575	-
LeafToR	1	1	-	0.5	0.5
LeafSpM	0.061	0.061	-	0.5	3

Table 2.5 Number of times observed chemical properties are used in the bayesian calibration of the sites by the 9 countries.

Variable	AT	BG	CH	DE	FR	NL	PL	SE	SI
pH	5		7	15	4	3	5		
Npool			7		4				2
[SO_4]	5		7		2				
Cpool	5		7	5	4	3	5		2
CNrat	5		7	7	4	3	5		2
[NO_3]	5		7			3			
[NH_4]						3			
[Na]	5		7		3	3			
[H]			7						
[Cl]	5		7		3	3			
[Bc]	5		7		3	3			
[Al]	5		7		3	1			
Bsat	5		7	13	4	3	5	16	2
AlBc			8		3				

2. Information from a new database with forest occurrence and growth data has been incorporated into EU-DB (Nabuurs et al. 2000). The reference year of forest growth is now 2005, instead of 1980.
3. In the 2008 CCE Status Report we introduced a temperature-dependent formulation for the long-term net immobilisation of N (N_i). This formulation, however, could not be substantiated, and therefore it was abandoned and we reverted to a constant value of N_i = 0.5 kgN ha⁻¹ a⁻¹ for all of Europe. This value is in line with the recommendations in the Mapping Manual, and based on the scarce field evidence available.

2.7 Miscellanea

In this section we present issues – all related to nitrogen – which came up recently (again) and might/could/should/ will have an influence on the ecosystem modelling of N.

Nitrogen fixation

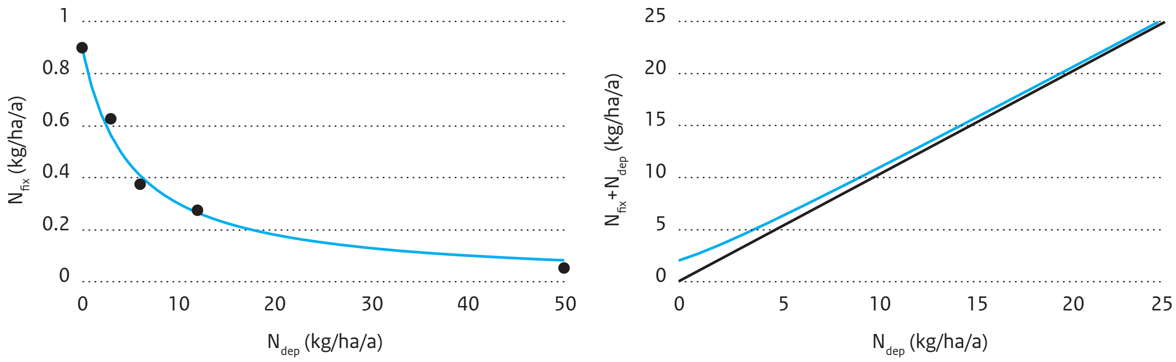
Little attention has been paid (so far) in the European modelling to the process of N fixation. However, it has to play a role – at least in areas with (very) low N deposition, otherwise the observed tree growth would hardly be explainable. In most cases it will (and can) not be the trees that fix N, but other organisms in the ecosystem, such as mosses and bryophytes (e.g., DeLuca et al. 2002), thus providing 'useable' N for tree growth. In a recent paper (Gundale et al. 2011; see also DeLuca et al. 2008) showed – via addition experiments – how N fixation in a boreal ecosystem is influenced by N deposition. One of their results (Table 1 in Gundale et al. 2011) is summarised in Figure 2.9, showing that N fixation is suppressed by N deposition. We use these data to derive the following interpolating function:

$$N_{fix} = N_{fix,o} \cdot \frac{1}{1 + a \cdot N_{dep}} \qquad (2.1)$$

where N_{dep} is the N deposition, $N_{fix,o}$ is the maximum fixation (if there is no N input), and the parameter a = 0.2 ha a kg⁻¹ is determined from the experimental data. A value of $N_{fix,o}$ = 2 kg N ha⁻¹ a⁻¹, based on DeLuca et al. (2002) – who found that the feather moss, *Pleurozium schreberi* alone fixes between 1.5 and 2.0 kg N ha⁻¹ a⁻¹ in boreal forests of northern Scandinavia and Finland – could be used. In Figure 2.9 the total N input (fixation + deposition) as a function of N deposition is shown for $N_{fix,o}$ = 2 kg N ha⁻¹ a⁻¹.

Furthermore, the temperature-dependence of N fixation could/should be considered, using the insights by Houlton et al. (2008).

Figure 2.9 Left: N fixation as a function of N deposition. Circles represent data from Gundale et al. (2011) and the blue line is the interpolating function (see eq.2.1; r=0.994). Right: N fixation + N deposition as function of N deposition, using $N_{fix,0}$ = 2 kg N ha^{-1} a^{-1}; for high N deposition this function can hardly be distinguished from the 1:1-line (black).



Nitrogen from rocks

In a recent paper, Morford et al. (2011) present evidence that forests (in the north-western US) utilize N contained in sedimentary rocks. In particular, they showed that forests growing on sedimentary rocks grow much better and have higher N contents in their compartments than comparable forests (in terms of species and deposition) that grow on igneous rocks (which contain no or very little N). That the N came from the underlying bedrock was determined by $\delta^{15}N$ isotope analyses.

This is not the first time that the influence of N from rocks on acidification, nitrogen saturation and stream water N has been reported (Dahlgren 1994, Holloway et al. 1998, Holloway and Dahlgren 2002), and so it seems time to have a look whether this needs to be considered in our modelling – keeping in mind that, globally, there are 10^{21} g of N fixed in sedimentary rocks, about a factor of 100 more than N fixed in the total biosphere.

Deposition of organic nitrogen

The abstract of a recent overview paper by Cornell (2011) reads:
"The organic component of atmospheric reactive nitrogen plays a role in biogeochemical cycles, climate and ecosystems. Although its deposition has long been known to be quantitatively significant, it is not routinely assessed in deposition studies and monitoring programmes. Excluding this fraction, typically 25-35%, introduces significant uncertainty in the determination of nitrogen deposition, with implications for the critical loads approach. The last decade of rainwater studies substantially expands the worldwide dataset, giving enough global coverage for specific hypotheses to be considered about the distribution, composition, sources and effects of organic-nitrogen deposition. …"

Thus, it seems worth-while that the issue of dissolved organic N (DON) in deposition be discussed and considered by the effects-community (see also, e.g., Neff et al. 2002).

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Annex 2.A Empirical critical loads of nitrogen (in kg ha^{-1} a^{-1}) for each EUNIS class and country (for Poland a range is given as modifying factors have been applied).

EUNIS code	AT	BE	BG	CA	CH	CZ	DE	FI	FR	GB	IE	NL	NO	PL	SE	SI
A			30													
A2								20								
A2.5										25	25					
A2.561							20									
A2.6												33.7				
B1			10					10								
B1.3								10								
B1.4								8	17	9		10.5				
B1.5								10				15.4				
B1.7								10								
B1.8								10				9.9				
C1			10					3					3			
C1.1					7			3								
C1.3								3								
C1.4								3								
C2			10										5			
D	5													7.7–26.5	5	
D1	5		5					5	10	8	10	6	5			
D1.1					7											
D2		11							10							
D2.1	10															
D2.2	10				12							9.9				
D2.21					10											
D2.22							10									
D2.31							10									
D2.32							10									
D2.3D							10									
D3.2								5								
D4									10							
D4.1	15				15			15				25.1				
D4.1G							15									
D4.1H							15									
D5		11														
E					8									7.2–29.6		
E1		18	10										10			
E1.2					12											
E1.23					15											
E1.24					10											
E1.26					15		15			15	20	15				
E1.27					12											
E1.7	10									10	10	9.9				
E1.71					12											
E1.72							10									
E1.94												15.1				
E1.95												12.4				
E2			20										10			
E2.2	20				20							9.9				

EUNIS code	AT	BE	BG	CA	CH	CZ	DE	FI	FR	GB	IE	NL	NO	PL	SE	SI
E2.22							20									
E2.23							20									
E2.25							20									
E2.3	10				15											
E3													10			
E3.5												9.9				
E3.51					15		15					12.4				
E3.52							10			15	15					
E4													5			
E4.2	5									7	7.5					
E4.3					8			5	7							
E4.4					8				7							
E4.41					8											
E4.42					8											
E4.43					8											
F														9.3–10.5	3	
F2								5					5			
F2.21					10											
F2.23					10											
F2.42																7.6
F2.47																7.6
F3.1C		16														
F4			10										10			
F4.1												9.9				
F4.11							10			10	15					
F4.2		9								10	15	19.7				
F4.21							10									
F4.22							10									
F4.262							10									
G1	10		10	15		10		10			15	11.2	10	6.9–28.5	10	
G1				15												
G1.1112																15
G1.1211																12.5
G1.2111																15
G1.4																
G1.6				15						15						
G1.61							10									
G1.63							10									
G1.6334																15
G1.6351																15
G1.65							10		7							
G1.66							10		15							
G1.676																15
G1.6C1																15
G1.6C2*																12.5
G1.6C21																15
G1.6C22																15
G1.6C31																15
G1.6C4																12.5
G1.7					15											
G1.71					15				15							

EUNIS code	AT	BE	BG	CA	CH	CZ	DE	FI	FR	GB	IE	NL	NO	PL	SE	SI
G1.73					15											
G1.7431																12.5
G1.7432																15
G1.7C14																12.5
G1.8									10	10	12.5					
G1.83									10							
G1.87							10									
G1.9								5								
G1.A				17.5												
G1.A1									7							
G1.A1A1																17.5
G1.A1A2																17.5
G1.A463																15
G1A.16							15									
G2.11									10							
G2.12									15							
G3	10		10	10		5		5			12.5	12.6	5	7.2–28.4	5	
G3.1				12.5					10							
G3.112*																12.5
G3.124																12.5
G3.1322																12.5
G3.135																12.5
G3.1B21																12.5
G3.1C							10									
G3.1C2																9.9
G3.1D							10									
G3.1F							10									
G3.1F3																12.5
G3.1F42																12.5
G3.1F51																12.5
G3.23									10							
G3.3					10											
G3.31									7							
G3.4					12					12						
G3.42							10									
G3.425																9.9
G3.43					12											
G3.44					12											
G3.441																9.9
G3.48									7							
G3.4C52																9.9
G3.5215																9.9
G3.72									7							
G3.743									15							
G3.A				7.5												
G3.A				7.5												
G3.B				7.5												
G3.E																7.6
G4	10		15			10				12			5	7.5–28.4		
G4.1							10									
G4.2				6.5				5								

EUNIS code	AT	BE	BG	CA	CH	CZ	DE	FI	FR	GB	IE	NL	NO	PL	SE	SI
G4.4							10									
G4.5							10									
G4.6				15			10		10							
G4.71							10									
G4.8							10									
H4													5			
H5													5			
I1													20			

Part II

Progress in Modelling

3 Validation of VSD+ and Critical Loads for Nutrient N

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3.1 Introduction

The soil chemistry model VSD+ (Bonten et al. 2009) has been developed from the soil acidification model VSD (Posch and Reinds 2009), to calculate effects of atmospheric deposition on i) nutrient enrichment of the soil and subsequent effects on the vegetation and ii) carbon sequestration in the soil. The reasons for this are the changing objectives regarding the effects of atmospheric deposition on nature areas. Initial objectives were the effects of deposition of sulphur and nitrogen (N) compounds on the acidification of the soil and the effects on forest health and surface water quality. As sulphur deposition has decreased dramatically in most areas in Europe during the last decades, the focus shifted more and more towards the effects of nitrogen deposition on biodiversity (e.g., Hettelingh et al. 2008, Millennium Ecosystem Assessment 2005, EEA 2007), more specifically plant biodiversity, as a higher N deposition generally leads to a lower plant species biodiversity. The increasing awareness of climate change due to greenhouse gas emissions has further lead to the demand to calculate carbon (C) sequestration potentials and the effects of atmospheric deposition on this. To be able to calculate the effects of N deposition on biodiversity and to include soil carbon sequestration we added an explicit model for organic carbon and nitrogen to the original VSD model, which then became VSD+. This C and N model and the coupling of VSD+ to plant species biodiversity models like Veg (see chapter 4) has been described previously (see Appendix B in Slootweg et al. 2010). In this text we show a first validation of VSD+ results regarding N enrichment in the soil and the potentials of VSD+ to calculate critical loads for nutrient N critical limits.

3.2 Validation

Figure 3.1 shows the N fluxes within a forest ecosystem. The largest fluxes are possibly the internal cycling of N in the soil, i.e. the turnover of soil organic matter and soil microbial biomass. The actual sizes of these fluxes are however hard to measure. Also relatively large is the cycling of N by the vegetation, i.e. litterfall and uptake by the vegetation. Both the N cycling by the vegetation and the soil internal N cycling determine the size of the organic N pool in the soil. A first validation is therefore on these N pools. A second validation is on the leaching of N from the soil. This N leaching is small compared to other N fluxes in the system and is actually the difference of two 'big' numbers: available N and N uptake.

Figure 3.1 Fluxes of N within a forest ecosystem.

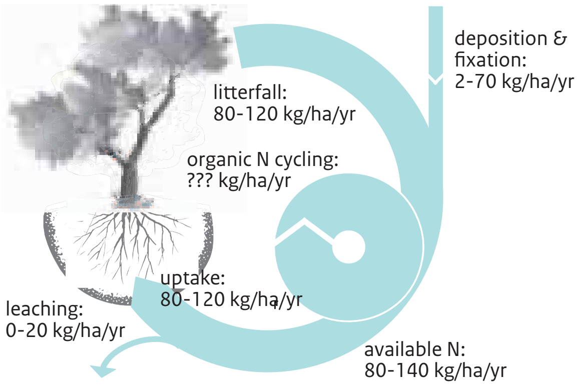
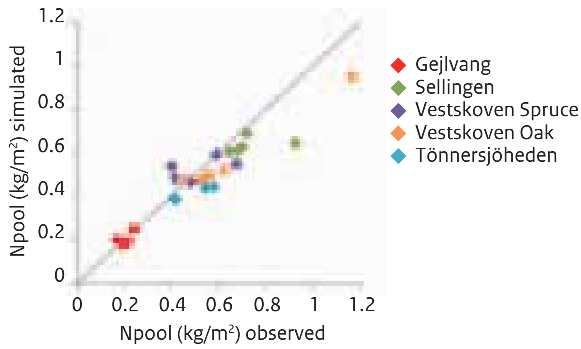


Figure 3.2 Simulated and observed N pools in the soil for five chrono-sequences.



Validation on N pools

Figure 3.2 shows the results on N pools in five chrono-sequences in the Netherlands and southern Scandinavia. Although this is not a true validation because these sites have been used previously in the calibration of VSD+, it is clear that VSD+ can describe changes in N pools with a single parameter set for organic C and N turnover. The figure further shows that changes in organic N pools are small for most sites and that a sound validation requires really long-term datasets.

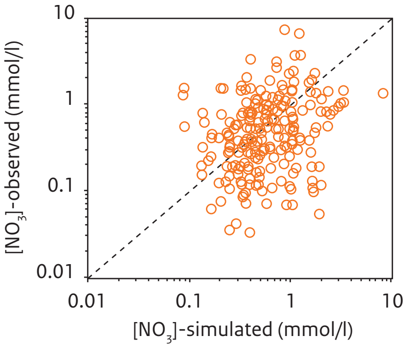
Validation on N leaching

The calculation of N leaching by VSD+ was tested for two different datasets. First, for a set of 137 Dutch forest sites, for which we used national scale model calculations for N deposition and estimates for vegetation growth and N contents of the vegetation. The second dataset contains two forest sites, one in Solling, Germany (Bonten et al. 2011) and one in the Hardenberg, the Netherlands, with more detailed information. Atmospheric deposition, forest growth and N contents were measured on-site. In both calculations we did not calibrate organic C and N turnover separately for each site, but we used a single parameter set for organic C and N turnover taken from the calibration on the five chrono-sequences (see above).

Figure 3.3a shows a comparison between observed and calculated N leaching concentrations for the 137 Dutch forest sites. This figures shows that there can be a large deviation between measurements and calculations, although average concentrations seem to correspond. Figure 3.3b shows the frequency distributions of the measured and calculated N concentrations, and these match perfectly. This demonstrates that site-specific N leaching can not be calculated using estimates for N deposition and/or N uptake. As mentioned previously, N leaching is the difference between N availability and N uptake and a small error in one of these can lead to large errors in N leaching. However, average regional scale N leaching can be properly assessed using VSD+.

Figure 3.4 shows the N leaching concentrations for the two forest sites for which more site-specific data are available. The two graphs show that a much better agreement

Figure 3.3 3.3a Simulated and observed N leaching concentrations at 137 Dutch forest sites (left); 3.3b Frequency distributions of observed and simulated N leaching concentrations at these sites (right).



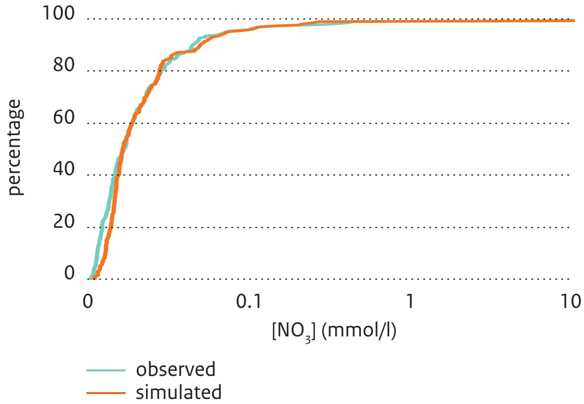
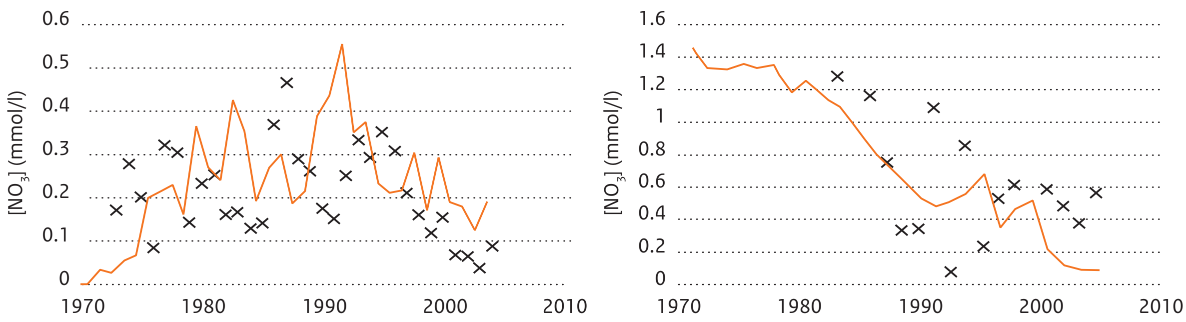


Figure 3.4 Average annual N leaching concentrations at forest in Solling, DE (left) and Hardenberg, NL (right).



between calculations and observations can be achieved using site-specific data on N deposition and N uptake.

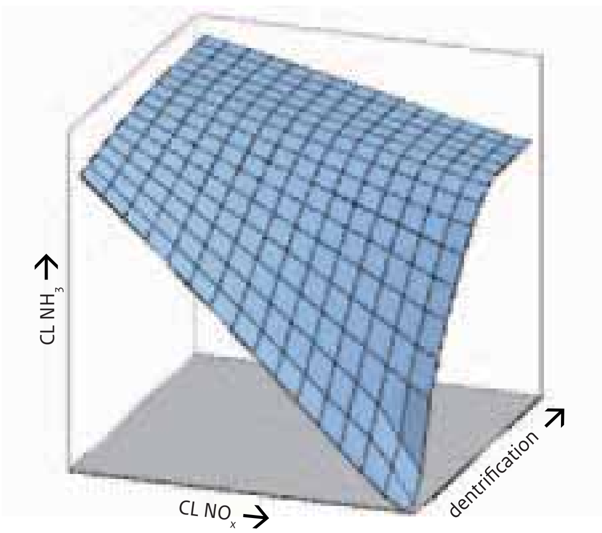
3.3 Critical loads for nutrient N

The VSD+ model includes the calculation of critical N deposition for criteria of N as a nutrient. Critical loads for N as acidifying compound were already included in VSD. In VSD+ critical loads can be calculated for two different critical limits: i) a maximum N leaching concentrations, and ii) a maximum N availability (defined as the sum of N deposition and N mineralization).

CL for critical N leaching

Figure 3.5 shows critical loads of NH3 and NOx deposition as a function of denitrification. Denitrification itself is influenced by a number of parameters like moisture, pH, temperature, availability of electron donor. When there is no denitrification all nitrogen deposition that is not taken up will leach. There is no distinction then between NH_3 and NO_x deposition. For high denitrification rates, the leaching

Figure 3.5 Critical loads of NO_x and NH_3 for critical N leaching as a function of denitrification.



is mainly dependent on the NH_3 deposition, because most NO_x will be lost to the atmosphere as N_2 after denitrification.

CL for critical N availability

Nitrogen availability has been defined as the sum of N mineralization, N deposition and N fixation. In steady state the N mineralization is equal to the organic N inputs to the soil, i.e. litterfall and fine root turnover. Because of this, critical loads for a critical N availability can be calculated simply as:

$$CL(N) = N_{available,crit} - N_{litterfall} - N_{root\ turnover} - N_{fixation}$$

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4

Progress in Vegetation and Soil Chemistry Modelling

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4.1 Introduction

In this chapter we describe the progress and changes made with respect to the VSD-Veg and VSD+Veg models. In addition we report on some testing carried out at Swiss sites.

4.2 Calculating PAR at ground level

In the VSD+Veg program, the photosynthetically active radiation (PAR, in µmol m⁻² s⁻¹) at the forest floor, PAR, is calculated as (see also Posch et al. 2010):

$$(4.1)\quad PAR = PAR_o \cdot exp(-k \cdot LAI)$$

where PAR_o is the PAR at the top of the canopy, *k* an attenuation coefficient and *LAI* the (one-sided!) leaf area index of the forest (tree). Aber and Federer (1992) use *k* = 0.4 for conifers and *k* = 0.5 for deciduous trees, and in VSD+ *k* = 0.45 is used, irrespective of tree species. For *LAI* = 2, 5 and 10 the ground-level PAR is 40%, 10% and 1% of PAR_o, resp. The LAI, if not measured or simulated, is computed from a tree's foliage mass per unit area, m_{fol} (in kg m^{-2}) and the leaf-specific mass, *LSM* (in kg m^{-2}), of the respective species. In case of a mixture of *n* tree species, the total LAI is the sum of the individual LAIs.

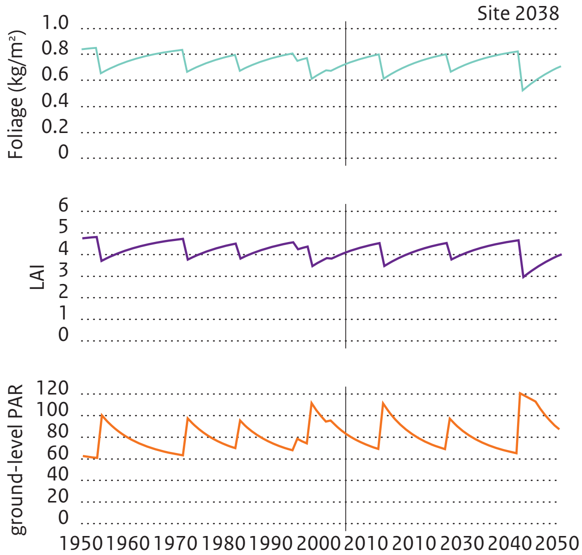
As an example we use data from the Swiss site 2038 (Frienisberg): For 2006 the data (from IAP) have m_{con} = 0.601 kg m^{-2} for conifers and m_{dec} = 0.134 kg m^{-2} for deciduous trees. The program MakeDep (Alveteg et al. 1998) produces the time series shown for 1950-2050 in Figure 4.1 (top), which fits the 2006 observation of $m_{con} + m_{dec}$ = 0.735 kg m^{-2}. Assuming LSM_{con} = 0.280 kg m^{-2} (from S. Braun, *pers. comm.*, and consistent with data from Warren et al. 2003) for conifers and LSM_{dec} = 0.066 kg m^{-2} for deciduous trees (derived from values in Niinemets and Kull (1994)) we get for the 2006 LAI:

$$(4.2)\quad LAI = LAI_{con} + LAI_{dec} = \frac{m_{con}}{LSM_{con}} + \frac{m_{dec}}{LSM_{dec}} = \frac{0.601}{0.280} + \frac{0.134}{0.066} = 4.177$$

For the period 1950-2050 the LAI for site 2038 is shown in Figure 4.1 (centre), assuming a time-independent foliage mass fraction of deciduous trees of 0.134/0.735 = 0.182.

From the LAI time series the ground-level PAR is computed with eq. 4.1, using a constant PAR_o of 526.9 µmol m^{-2} s^{-1} (which is computed from latitude and long-term average cloudiness, using the meteorological-hydrological pre-processor MetHyd; see Slootweg et al., 2010) (Figure 4.1 bottom).

Figure 4.1 Top: Foliage mass (in kg m^{-2}); Centre: LAI; and Bottom: ground-level PAR (in µmol m^{-2} s^{-1}) for the Swiss site 2038, computed with the above formulae (the thin vertical line marks the year 2006).



4.3 Updated parameterization of Veg

Following the CCE Call for Data 2010/11, a number of questions were raised on the consistency and accuracy of the vegetation parameterization, which forms the basis of the Veg model (Sverdrup et al. 2007). In response, we carried out a systematic revision of the European vegetation list and related parameters in the Veg-table and, as a consequence, the following modifications to the Veg-table were made:

1. The table now is internally consistent, though there still is a need to revise much of the parameters in light of recent field tests.
2. Parameters for N and pH responses were modified to reflect the drivers units.
3. N response parameters we simplified from five to three by:
   a. internally calculating the normalization factor and
   b. merging the promoting and retarding exponents into a single parameter.
4. We decided to continue ignoring the explicit Bc/Al response, as it is always complementary to the pH response, and thus to drop the respective parameter from the list. This conceptual modification in Veg, already made in the early phase of linking VSD and Veg, refers to the plant response to soil acidity.
5. To allow a consistent grouping when displaying vegetation communities, we added a column which classifies every plant into one of six plant types (Mosses and Lichen, Ferns, Grasses, Herbs, Shrubs, Trees).

The nitrogen response

The N response function was initially given as the product of a promoting function, a retarding function and a normalization factor (eq. 4.3). The promoting curve describes how increasing soil N concentrations stimulate the strength of the plants (first function in eq. 4.3). For some plants, as in the case of nitrogen fixers, N availability does not necessarily promote plant strength. Increasing N availability can, however, be harmful to certain plants. The negative response to excess N in these cases is represented by a retarding function (second function in eq. 4.3). Finally, a normalization factor, a_0, was used to normalize the product of the promoting and retarding functions to 1 at optimum N concentration for each plant:

$$(4.3)\quad f(N) = a_0 \cdot \frac{[N]^{w_+}}{k_+ + [N]^{w_+}} + \frac{k_-}{k_- + [N]^{w_-}}$$

Initially, four parameters were used to describe the promoting and retarding functions. The parameter k_+ indicated how early along the N axis the promotion effect occurs, while w_+ describes the speed at which the response occurs. A simple sensitivity investigation showed that while the promoting function depended closely on k_+, it was only marginally sensitive to w_+. On the other hand, the retardation function was distinctly sensitive to both k_- (which indicates how late on the [N] axis the retardation response starts) and w_- (which determines how fast the retardation proceeds).

The normalization factor a_0 was previously an input parameter, but is now internally computed; it equals $1/f([N]_{max})$, where $[N]_{max}$ is the soil nitrogen concentration yielding the maximum plant response $f(N)$ (without a_0). This maximum is obtained by differentiating eq. 4.3 with respect to [N] and setting the first derivative equal to zero. The equation obtained is:

$$(4.4)\quad [N]^{w_+ + w_-} - p \cdot [N]^{w_-} - q = 0$$

with

$$(4.5)\quad p = k_+ \cdot \left(\frac{w_+}{w_-} - 1 \right) \text{ and } q = k_+ \cdot k_- \cdot \left(\frac{w_+}{w_-} \right)$$

If we set $w_+ = w_- = w$, the location of the optimal response is obtained from eq. 4.4 as:

$$(4.6)\quad f(N) = a_0 \cdot \frac{[N]^{w_+}}{k_+ + [N]^{w_+}} + \frac{k_-}{k_- + [N]^{w_-}}$$

Replacing [N] by $[N]_{max}$ and setting $f(N) = 1$ in eq. 4.3 allows us to calculate a_0:

$$(4.7)\quad a_0 = \left(\sqrt{\frac{k_+}{k_-}} + 1 \right)^2$$

We tested reducing the factors further by setting w_+ equal to w_-. They could previously take the values 1 or 2 in the case of w_+ and 0, 1 or 3 for w_- (though not for N fixers, which always have a w_+ value of 0). Setting w_+ to 2 has a marginal effect on the response curves to N, while setting w_- to 2 insured a confined bell-shaped response curve for all plants that experience retardation at high N levels. Thus we simplified the N response parameterization from five to three parameters by internally calculating a0 and by equating w_+ and w_-. This implies that the response curves are consistently normalized to 1 at $[N]_{max}$ and that the boundaries and shape of the response curve can be defined by adjusting k_+, k_- and w. For plants with no N retardation, the value of w given in the input is only used to define the slope of the promoting fraction of the response curve.

The original values for k_+ and k_- have the counterintuitive units of $(\text{mg L}^{-1})^w$. We changed these variables to units of mg L^{-1}, by raising the original values to the power $1/w$. By doing this, we will from now on use k_+ and k_- to refer to the new parameters in units of mg L^{-1}, and eq. 4.3 becomes:

$$(4.8)\quad f(N) = a_0 \cdot \frac{\left(\frac{[N]}{k_+}\right)^w}{1+\left(\frac{[N]}{k_+}\right)^w} \cdot \frac{1}{1+\left(\frac{[N]}{k_-}\right)^w}$$

Accordingly, a_0 is now obtained as:

$$(4.9)\quad a_0 = \left(\left(\frac{k_+}{k_-}\right)^{w/2} + 1\right)^2$$

Figure 4.2 illustrates the effect of the three parameters describing the N response curves (eq. 4.8). Each pane shows 3 response curves for the exponent w = 1, 2, 3, resp.; and the 15 panes show the combinations of 3 values of k_+ (0.5, 3, 50) and 5 values of k_- (3, 10, 50, 100, 1000). The graphs show how higher values of k_+ imply a delayed positive response to N, meaning that nitrophobic plants should have low k_+ values, while nitrophilic plants should have higher k_+ values. Low values of k_- represent plants, which are readily retarded at low levels of N, in accordance with the positive response. Plants that are not negatively affected by high levels of N have the highest values of k_-. The exponent w describes how fast plants respond either negatively or positively to N. High values of w mean that the positive response is more skewed to the left (higher on the N axis), and that the declining slope of the negative response is steeper. Figure 4.3 shows the N response curves for the 372 species currently in the Veg-table.

The pH response

Originally, pH response in the Veg-model was formulated as:

$$(4.10)\quad f(pH) = \frac{1}{1 + k_{pH} \cdot [N^+]}$$

Replacing $[H^+]$ by 10^{-pH}, we can use pH-related parameters, avoiding the use of H+ concentrations. By doing this, the pH response becomes:

$$(4.11)\quad f(pH) = \frac{1}{1 + 10^{pH_{half} - pH}}$$

where pH_{half} is the pH-value at which plant strength in response to pH is 0.5. By adopting eq. 4.11 instead of eq. 4.10, the parameterization of the acidity response function becomes more intuitive to the users and experts contributing to the parameterization of the model.
We can compute pH_{half} values from the original k_{pH} values, according to:

$$(4.12)\quad pH_{half} = \log_{10}(k_{pH})$$

Figure 4.3 shows the pH response curves for the 372 species currently in the Veg-table.

The Bc/Al response

Initially, both the effects of pH and of Bc/Al on the plants were modelled. These responses were simplified to a single response represented by pH (see above). One of the reasons for this decision is that different geochemical model platforms, to which Veg can be attached, simulate aluminium differently and yield different Al species and concentrations. Another reason for simplifying the two responses to one is that they are complementary and always affect plants in a similar direction.

The calcifuge retardation

Bc is only used to limit some plants sensitive to calcifuge conditions as the latter could negatively affect plant nutrient uptake. The original calcifuge retardation function was given by:

$$(4.13)\quad f(Bc) = \frac{1}{1 + k_{Bc} \cdot [Ca^{2+}]}$$

In this equation the k_{Bc} factor has the unit of $(\text{eq L}^{-1})^{-2}$. We modified this equation by changing the k_{Bc} factor to a new factor k_{Ca}, specific to calcium and with unit mg L^{-1}, i.e.:

$$(4.14)\quad f(Bc) = \frac{1}{1+\left(\frac{[Ca^{2+}]}{k_{Ca}}\right)^2}$$

where $[Ca^{2+}]$ is the concentration of calcium ions in soil solution and has the unit of mg L^{-1}. The new plant-specific factor k_{Ca} can be computed from the original k_{Bc} according to:

$$(4.15)\quad k_{Ca} = k_{Bc}^{-0.5} \cdot \frac{1000}{2} \cdot 40.08$$

k_{Ca} represents the concentration of Ca^{2+} (in mg L^{-1}) at which plant strength is reduced by half due to the adverse calcifuge effect.

Figure 4.2 N response curves (eq. 4.8) for w = 1 (blue), w = 2 (green) and w = 3 (orange) for different k_+ and k– values.

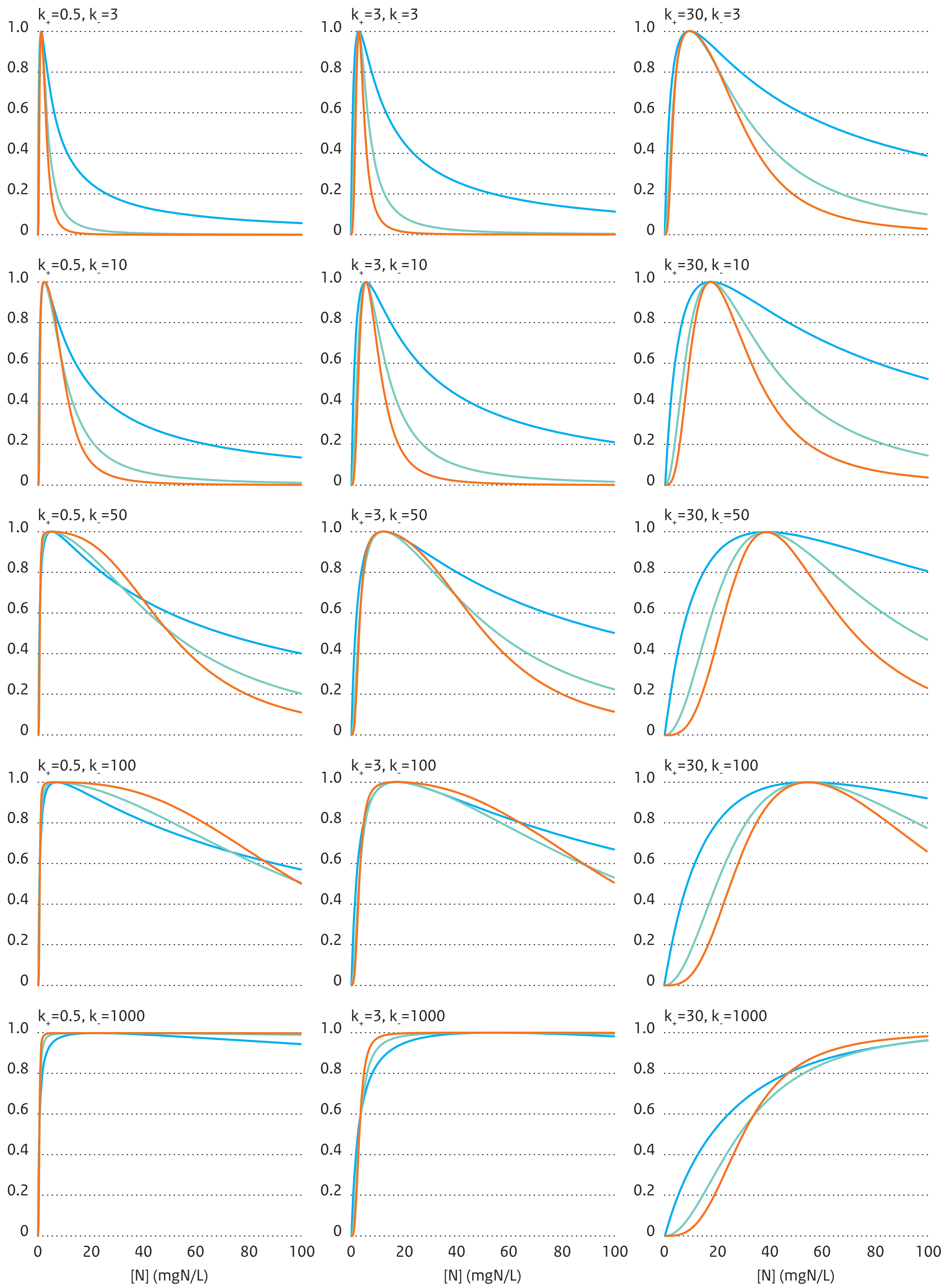


Figure 4.3 Response curves for the 372 species currently in the Veg-table for [N] (left; see eq. 4.8) and for pH (right; see eq. 4.10).

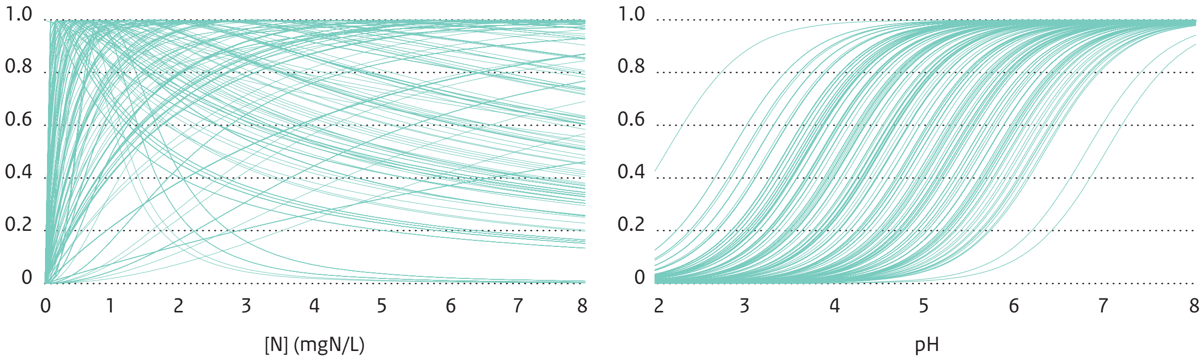
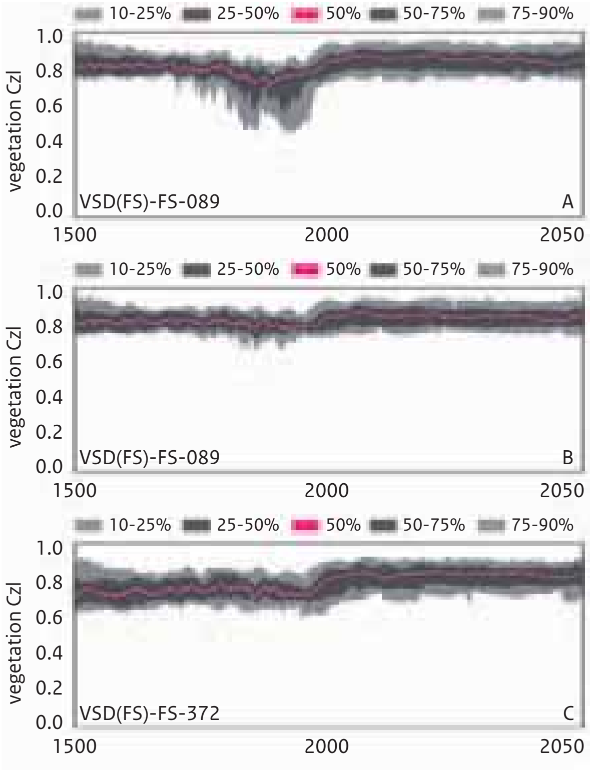


Figure 4.4 Time series of the distribution of the Czekanowski similarity indices (CzI) of the 32 Swiss sites' ground vegetation composition, simulated with the original (A) and the revised version of Veg (B with 89 and C with 372 species). VSD(FS) refers to VSD using input extracted from ForSAFE runs.



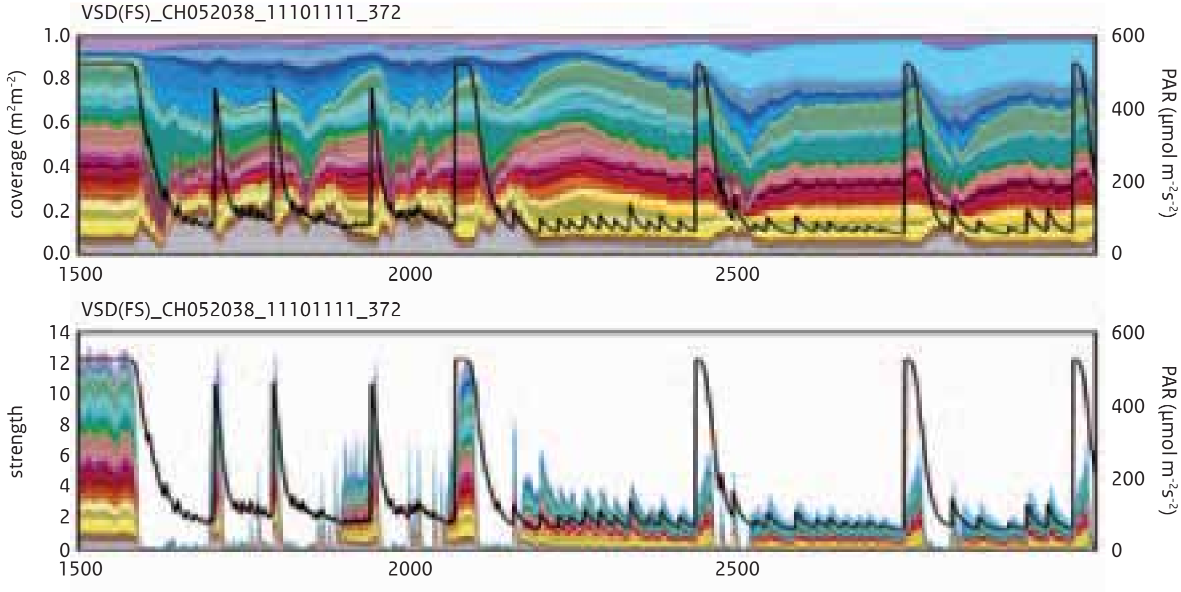
4.4 Model testing

To test the implementation of the revised Veg model, ForSAFE-Veg (FS) and VSD-Veg using inputs from ForSAFE (VSD(FS)) were used to simulate the ground vegetation composition at the previously used 32 Swiss forest monitoring sites. Regarding soil inputs, the model chains were run with multi-layer input and the recalculation of the parameters for one layer (the rooting zone) was done within VSD. Two vegetation parameter tables differing in the number of species considered were used as input for Veg. The earlier used 'Swiss' table (089) contains 89 and the generic European vegetation list (372) covers 372 species. Veg was operated with all drivers on except browsing, which is not being considered due to missing input data. As measure for the similarity/dissimilarity of the ground vegetation composition modelled by the paired model chains we used the Czekanowski (similarity) index (see Slootweg et al. 2010, pp.53-54).

Figure 4.4B compares the ground vegetation composition results of VSD(FS)-Veg and ForSAFE-Veg runs considering 89 species, which is the set-up used to produce the earlier Figure 4.4A. The similarity index for 90% of the sites now generally ranges from 0.72 to 0.95 during most of the simulation phase, and only moderately falls to 0.66-0.91 in the early 1900s. The median is mostly above 0.80 with the exception of the period 1830-1960, when it may fall to 0.76. Although there is still a slight deterioration of the CzI, the revised Veg version produces less deviating ground vegetation compositions for this period, for which we originally observed a substantial dissimilarity (Figure 4.4A). In the previous study, the analysis of the impact of single drivers of Veg on the comparability of the ground vegetation composition returned by the 2 models revealed the $[NO_3^-]$ driver as major reason for the increased discrepancy during 1700–2000. The revision of the N response function in Veg obviously removed the amplification of the impact of differences in the $[NO_3^-]$ on the ground vegetation cover predictions.

Considering 372 species, moderately increases the dissimilarity of the ground vegetation composition produced by VSD(FS)-Veg and ForSAFE-Veg (Figure 4.4C). The CzI for 90% of the sites ranges from 0.62 to 0.93 in the initial simulation phase and falls to 0.59-0.90 towards the year 2000. In the second half of the simulation period the values scatter between 0.67 and 0.93. The median is on average 0.74±0.02 in the first half of the simulation period and increases to 0.83±1 in the second half of the simulation period when the variation in the climate input is less erratic and pollutant deposition levels out.

Figure 4.5 Time series of normalized (A) and straight (B) probabilities ('strength') of ground vegetation species occurrence at Frienisberg, CH. The superimposed black line shows the photosynthetically active radiation (PAR) at the forest floor.



A standard presentation of the temporal evolution of the ground vegetation composition at a site is depicted in Figure 4.5A. The plot is obtained by normalizing the sum of the probabilities of occurrence ('strengths') of the individual species to 1. The graph may lead to the false impression that the forest floor is completely covered by ground vegetation. However, the appearance of ground vegetation depends strongly on the availability of light, i.e. PAR at ground level, and may almost be completely suppressed in periods with a closed canopy (Figure 4.5B), and their very small 'strengths' might be mostly spurious. Furthermore, for the whole simulation period Veg computes for this site occurrences of 356 (out of 372) species. With such a large number of species, the individual species' probability of occurrence may become extremely small. These issues certainly need further discussion to be able to design robust indicators for use in policy support.

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Part 3
NFC Reports

This part brings together the reports by the National Focal Centres documenting their country's submission of data and assessments in response to the Call for Data, issued in 2010. Although Lithuania did not submit any data, their (abbreviated) report is included in the hope that this will encourage a future data submission.

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

Critical loads

In response to the call for data of November 2010 a new dataset of critical loads is provided. Three different approaches for the calculation of critical loads are applied. Critical loads of acidity *(CLmaxN&S)* are calculated using the VSD model and soil data from 496 soil monitoring sites. The calculation of Critical loads of nutrient nitrogen *(CLnutN)* is also done using the mass balance approach, but is based on the CORINE Landcover 2006 dataset and other maps instead of soil monitoring sites. This is possible because of the reduced data requirements of the CLnutN calculation and it allows the production of CLnutN-maps. At least, the Empirical critical loads dataset *(CLempN)* is also mainly based on the CORINE Landcover 2006 dataset. The main difference to the November 2007 Call for Data is the use of the CORINE 2006 dataset and the reference to the new 5×5 EMEP grid.

Dynamic soil-vegetation modelling

In response to the 2010 Call for input data to test dynamic modelling of vegetation changes in selected sites in a country, the dynamic model VSD+ was calibrated for several permanent soil-vegetation plots of the ICP Integrated Monitoring site Zöbelboden. These plots have been used for the 2009 Call so that this year's focus is on the VEG module. This site has been chosen because it represents very important forests in Austria with regard to biodiversity and ecosystem services (e.g. major drinking water resources). Also deposition of N is high in the northern part of the European Alps, where the study site is located. Bedrock materials are carbonates so that soils have a very high base saturation. The focus is thus on eutrophication effects of N and not on acidification. The knowledge of effects of N in such forests is very scarce, though comparable forest sites can be found all over the Alps. Several on-site studies showed that chronic N deposition has already affected soils, forest ground vegetation, epiphytic lichens and mosses (Zechmeister et

Table AT.1 Data description, methods and sources for the CL of acidity calculation.

Variable	Explanation and Unit	Description
CLmaxS	Maximum critical load of sulphur (eq ha^{-1} a^{-1})	calculated by VSD
CLminN	Minimum critical load of nitrogen (eq ha^{-1} a^{-1})	calculated by VSD
CLmaxN	Maximum critical load of nitrogen (eq ha^{-1} a^{-1})	calculated by VSD
nANCcrit	The quantity –ANCle(crit) (eq ha^{-1} a^{-1})	calculated by VSD
crittype	Chemical criterion used	used: molar Al/Bc (1)
critvalue	Critical value for the chemical criterion	used: 1
thick	Thickness of the soil (m)	mostly 0.5 m, sometimes less, depending on soil inventory data
bulkdens	Average bulk density of the soil (g cm^{-3})	Mapping Manual 6.4.1.3 eq. 6.27
Cadep	Total deposition of calcium (eq ha^{-1} a^{-1})	total depositions for forest ecosystems (Van Loon et al. 2005)
Mgdep	Total deposition of magnesium (eq ha^{-1} a^{-1})	total depositions for forest ecosystems (Van Loon et al. 2005)
Kdep	Total deposition of potassium (eq ha^{-1} a^{-1})	total depositions for forest ecosystems (Van Loon et al. 2005)
Nadep	Total deposition of sodium (eq ha^{-1} a^{-1})	total depositions for forest ecosystems (Van Loon et al. 2005)
Cldep	Total deposition of chloride (eq ha^{-1} a^{-1})	Nadep * 1.166 (Nadep from Van Loon et al. 2005)
Bcwe	Weathering of base cations (eq ha^{-1} a^{-1})	Mapping Manual 5.3.2.3, eq. 5.39; Table 5-14 (WRc = 20 for calcareous soils; factor 0.8 for Na reduction)
Bcupt	Net growth uptake of base cations (eq ha^{-1} a^{-1})	[average yearly yield rate * base cation content], data from Austrian forest inventory, base cation contents from Jacobsen et al. 2002 (no uptake from unmanaged protection forests)
Qle	Amount of water percolating through the root zone (mm a^{-1})	Hydrological Atlas of Austria-v.2
lgKAlox	Equilibrium constant for the Al-H relationship (log10)	[9.8602 - 1.6755 * log(OM) for 1.25 < OM < 100; 9.7 for OM < 1.25]; SAEFL 2005 (OM = Organic Matter [%])
expAl	Exponent for the Al-H relationship	used: 3 (gibbsite equilibrium)
pCO2fac	Partial CO_2-pressure in soil solution as multiple of the atmospheric CO_2 pressure (-)	[log10pco2 = -2.38 + 0.031 * Temp (°C)]; atmospheric CO_2 pressure = 0.00037 atm; equation recommended by CCE
cOrgacids	Total concentration of organic acids (m*DOC) (eq m^{-3})	used: 0.01 (recommended by Max Posch)
Nimacc	Acceptable amount of nitrogen immobilised in the soil (eq ha^{-1} a^{-1})	decreasing from 5 kg N in the highlands (< 5°C mean Temp) to 1 kg N in the lowlands (> 8°C mean Temp); see German NFC Report in Posch et al. 2001, p.142, Table DE-7
Nupt	Net growth uptake of nitrogen (eq ha^{-1} a^{-1})	[average yearly yield rate * N content], data from Austrian forest inventory, N contents from Jacobsen et al. 2002
fde	Denitrification fraction (0≤fde<1) (–)	from 0.1 (dry) to 0.7 (wet) according to soil moisture class; information from soil inventory
CEC	Cation exchange capacity (meq kg^{-1})	information from soil inventory; calibrated to pH 6.5 (Mapping Manual 6.4.1.3 eq. 6.29)
bsat	Base saturation (–)	information from soil inventory
yearbsat	Year in which the base saturation was determined	year of soil inventory (1987-1990)
lgKAlBc	Exchange constant for Al vs. Bc (log10)	calibrated by VSD; initial value 0
lgKHBc	Exchange constant for H vs. Bc (log10)	calibrated by VSD; initial value 3
Cpool	Initial amount of carbon in the topsoil (g m^{-2})	[thick * bulkdens * Corg(%) * 10 000]; for mineral topsoil (0–10 cm) + organic layer; information from soil inventory
CNrat	C/N ratio in the topsoil	Cpool / Npool
yearCN	Year in which the CNratio and Cpool were determined	year of soil inventory (1987–1990)
Measured	On-site measurements included?	all sites: ICP-Forests (1)
EUNIScode	EUNIScode of ecosystem	information from soil inventory: G1, G3, G4, G3.1B (unmanaged protection forests)
Protection	Type of nature protection (SAC, SPA...)	status unknown at all sites (-1)
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	CORINE 2006 - total forest area within the EMEP grid cell

al. 2007, Umweltbundesamt 2007, Hülber et al. 2008, Dirnböck et al. 2009, Dirnböck and Mirtl 2009, Diwold et al. 2010, Jost et al. 2011). Moreover, long-term data about N leaching exists (Jost et al. 2011). These results represent valuable evaluations for the VSD+ and VEG outcomes.

Collaboration between NFC and Habitat experts

Collaboration between ICP M&M and Austrian's habitat experts already started in 2010 in the course of the COST Action 729 Nitrogen Deposition and Natura 2000. This collaboration will continue and concrete next steps will be discussed during 2011. Based on national funding, critical loads based nitrogen deposition assessment for Habitats Directive Article 17 reporting (due in 2013) will be targeted for the year 2012.

Critical Loads of Acidity

Data sources

Data sources remain unchanged compared to the 2007-call for data, except the reference to the new EMEP grid and the ecosystem area.

Soils: Soil information is based on the Austrian Forest Soil Inventory from the Austrian Federal Office and Research Centre for Forests (Forstliche Bundesversuchsanstalt 1992). About 500 sample plots were investigated in an 8.7 x 8.7 km grid between 1987 and 1990. Most of the soil input parameters to calculate critical loads and target loads were taken from this dataset. The data are part of the Soil Information System BORIS, maintained at the Federal Environment Agency.

Nutrient uptake: Information on biomass uptake is derived from data of the Austrian Forest Inventory, sampled by the Austrian Federal Office and Research Centre for Forests - BFW (Schieler and Schadauer 2001). Mean harvesting rates for the years from 1986 to 1996 were aggregated on EMEP grid cell basis. Grid cells with too few sample points were combined with neighbouring cells. Base cation and nitrogen contents were taken from Jacobsen et al. (2002). No nutrient uptake takes place at unmanaged protection forests.

Ecosystem: CORINE 2006 - total forest area within the EMEP grid cell.

Depositions: New sulphur and nitrogen deposition time series provided by the CCE 2008 ('Review of the 1999 Gothenburg Protocol', Executive Body for the Convention (2007), ECE/EB.AIR/WG.5/2007/7); Base cation depositions: Van Loon et al. (2005).

Each record of the *inputs/CLdata*- and the *EmpNload*-tables has a unique link to the *ecords*-table with information describing the location (one-to-one relation). As overlapping areas of the three approaches do not point to a common location record, summing up ecosystem areas is meaningful only within one of the three approaches.

Calculation method

The calculations and assumptions are generally in accordance with the Mapping Manual (ICP M&M 2004) and the CCE Status Reports. A detailed description of the parameters and the data and methods used for their derivation is given in Table AT.1.

The Access version of VSD was used for critical loads calculation and dynamic modelling. For the cation exchange the Gapon model was used, the exchange constants were calibrated. Theta was set to be 0.3, CNmin and CNmax were set to be 10 resp. 40. Oliver constants for the organic acid dissociation model were set to 4.5, 0, 0. Base cations were lumped together in the Ca column for weathering and uptake. Due to the lack of spatial distributed information on organic acids, default values for all records were used.

Calcareous soils occur at 30% of the sample points representing about 40% of the ecosystem area.

Critical Loads of Nutrient Nitrogen

Data sources and calculation method

The calculation of CLnutN is primarily based on the forest patches of the Austrian CORINE Landcover 2006 dataset. Generally calculation methods are in accordance with the methods suggested in the mapping-manual, but some changes were necessary due to the spatial approach, the data availability and the specific situation of alpine ecosystems with high precipitation surpluses.

Denitrification: The denitrification fraction is based on the soil type units of the soil map 1:1,000,000 of the Hydrological Atlas of Austria, as no better spatial distributed information on soil moisture in forests is available. The assignment of fde-values to soil types is based on an analysis of soil moisture classes within soil types of the Austrian forest soil inventory dataset.

Leaching: The acceptable leaching is decreasing from 4 kg N in the lowlands (500 m a.s.l.) to 2 kg N at 2000 m a.s.l. (see Swiss NFC Report in Posch et al. 2001). As the acceptable leaching does not depend on the precipitation surplus and the critical nitrogen concentration but on the altitude, the cNacc is back-calculated from the acceptable leaching and the precipitation surplus Qle, leading to very high (at low Qle values) and very low (at high Qle values) acceptable nitrogen concentrations.

Table AT.2 Assignment of fde-values to soil type units.

Soil type unit	fde
Rock outcrop, glacier	0.0
Rendzina, Lithosol, orthic Luvisol	0.3
Chernosem, Cambisol, gleyic Luvisol, Regosol, Podzol, Solonetz	0.4
Fluvisol, Planosol	0.5
Histosol	0.7

Table AT.3 Data description, methods and sources for the CLnutN calculation.

Variable	Explanation and Unit	Description
CLnutN	Critical load of nutrient nitrogen (eq ha^{-1} a^{-1})	Mapping Manual 5.3.1.1, eq. 5.5
cNacc	Acceptable (critical) N concentration (meq m^{-3})	back-calculated from Nleacc and Qle
Nleacc	Acceptable nitrogen leaching (eq ha^{-1} a^{-1})	decreasing from 4 kg N in the lowlands (500 m a.s.l.) to 2 kg N at 2000 m a.s.l. (see Swiss NFC Report in Posch et al. 2001)
Qle	Amount of water percolating through the root zone (mm a^{-1})	Hydrological Atlas of Austria-v.2
Nimacc	Acceptable amount of nitrogen immobilised in the soil (eq ha^{-1} a^{-1})	decreasing from 5 kg N in the highlands (< 5°C mean Temp) to 1 kg N in the lowlands (> 8°C mean Temp); see German NFC Report in Posch et al. 2001, p.142, Table DE-7
Nupt	Net growth uptake of nitrogen (eq ha^{-1} a^{-1})	[average yearly yield rate * N content], data from Austrian forest inventory, N contents from Jacobsen et al. 2002
fde	Denitrification fraction (0≤fde<1) (-)	from 0 (dry) to 0.7 (wet) according to the soil type of the soil map 1:1 Mio. of the Hydrological Atlas of Austria-V.2
Measured	On-site measurements included?	all sites: no measurements (0)
EUNIS code	EUNIS code of ecosystem	CORINE Landcover 2006; G1, G3, G4
Protection	Type of nature protection (SAC, SPA, ...)	status unknown at all sites (-1)
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	CORINE Landcover 2006 patch size

Table AT.4 Ecosystem, CORINE 2006 code, EUNIS code, recommended CL range and applied CLempN value.

Ecosystem	CLC2000	EUNIS	CLNrange	CLemp(N)
Mire, bog and fen habitats	412	D	5-15	5
Raised and blanket bogs	a)	D1	5-10	5
Oligotrophic fens	a)	D2.1	10-15	10
Mesotrophic fens	a)	D2.2	10-15	10
Eutrophic fens	a)	D4.1	15-30	15
Dry grassland	b)	E1.7	10-15	10
Pastures	231	E2.2	20-30	20
Mountain hay meadows	321	E2.3	10-20	10
Moss and lichen dominated mountain summits	333	E4.2	5-10	5
Broadleaved deciduous woodland	311	G1	10-20	10
Coniferous woodland	312, 322	G3	10-15	10
Mixed deciduous and coniferous woodland	313, 324	G4	10-20	10

a) Ecosystem information from Austrian mire conservation database

b) Ecosystem information from Austrian inventory of dry grassland

Table AT.5 Data description, methods and sources for the CLempN calculation.

Variable	Explanation and Unit	Description
CLempN	Empirical critical load of nitrogen (eq ha^{-1} a^{-1})	values used: see table AT.4
EUNIS code	EUNIS code of ecosystem	CORINE Landcover 2006; see table AT.4
Protection	Type of nature protection (SAC, SPA, ...)	status unknown at all sites (-1)
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	CORINE Landcover 2006 patch size

Nutrient uptake: Information on biomass uptake is derived from data of the Austrian Forest Inventory 2000/02, sampled by the Austrian Federal Office and Research Centre for Forests - BFW (Schadauer 2004). Uptake information is spatially distributed on basis of forest districts.

Empirical Critical Loads

Data sources and calculation method

The Austrian CORINE Landcover 2006 dataset is the main data source for this study. Additionally, the Austrian mire conservation database (Steiner 1992) and the Austrian inventory of dry grassland (Holzner 1986) are used to update the small-scale CLC2006 data with mire, bog, fen and grassland habitats.
EUNIS-codes are applied and CLempN values are assigned to the habitats according to the recommendations made at the "Workshop on the review and revision of empirical critical loads and dose-response relationships" (Noordwijkerhout, 23-25 June 2010). The minimum value of the recommended range is used as CL (table AT.4), no further adaptation to abiotic factors is done.

Dynamic Soil-Vegetation Modelling

Data sources

Dynamic models were calibrated for the ICP Integrated Monitoring site Zöbelboden. The site is characterized by a very high variability of soil properties. In order to get a grip on this variability separate models were calibrated for 5 sites (called permanent plots thereafter) within the 90 ha catchment area. Two sites, which were used for the 2009 Call were not considered because of spurious modelling results. There, and on 50-60 further plots, long-term soil physical and chemical data as well as vegetation data is available. Soil water information and deposition was taken from two intensive plots, which are typical for the two gross site types of the area and was allocated to the respective permanent plots. Long-term meteorological data is available on site (clearing area) (Table AT.6, Figure AT.1).

Site description

The Austrian ICP Integrated Monitoring site has a size of 90 ha and is situated in the northern part of the national park "Northern Limestone Alps" (N 47°50'30", E 14°26'30") (www.umweltbundesamt.at/im). The altitude ranges from 550 m to 956 m a.s.l.. The main rock type is Norian dolomite (Hauptdolomit), which is partly overlain by limestone (Plattenkalk). Due to the dominating dolomite,

Figure AT.1 Overview of the ICP IM site Zöbelboden with the location of the main meteorological measurements, the two intensive plots, and the permanent plots (=soil sampling points). Contour lines are shown every 50 m a.s.l.

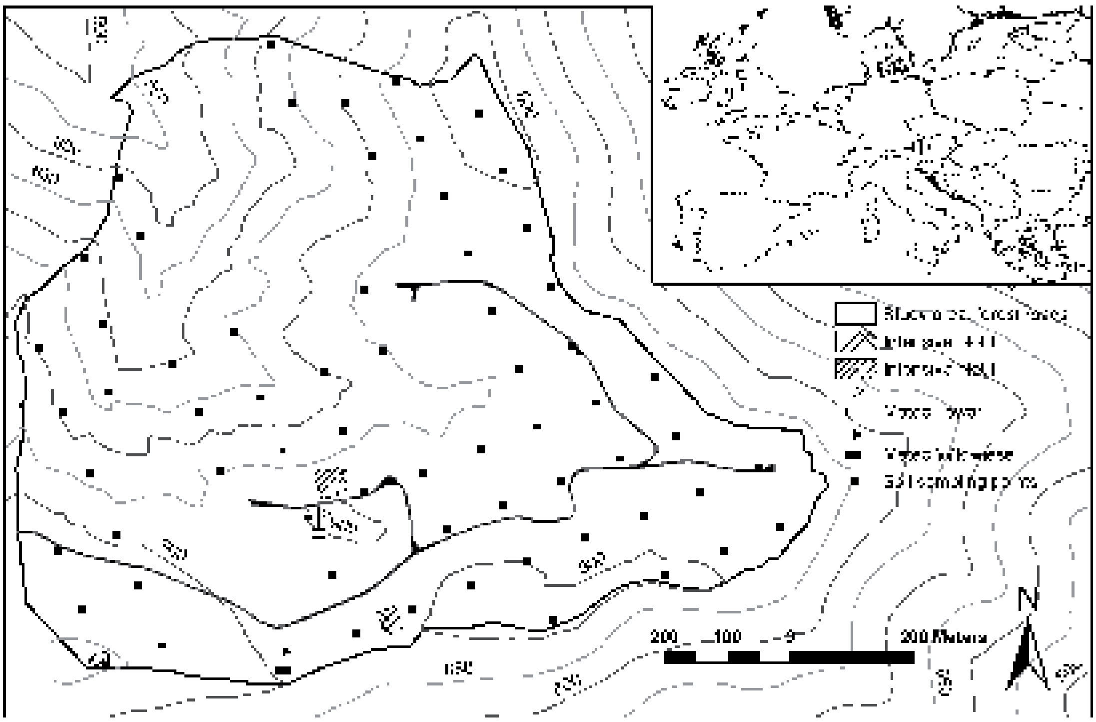

Table AT.6 Forest and soil characteristics of intensive plot 1 (IP I) and intensive plot 2 (IP II) at the ICP IM site Zöbelboden. Soil chemistry is taken from 16 locations (each 4 soil pits) on a 4 x 4 m grid adjacent to the intensive plots in the year 2004. Mean values and standard deviations in parenthesis. [a] Net mineralization (Nnet min) and gross consumption (Ngross cons) of ^{15}N labelled NH_4^+ applying pool dilution experiments with 37 (IP I) and 39 (IP II) samples acquired on a 5x5 m grid in August in the year 2007 adjacent to the intensive plots.

		IP I	IP II
Actual forest type		Spruce dominated forest	Mixed beech, spruce, maple and ash forest
Potential natural vegetation		*Cardamino trifoliae-Fagetum* sensu Willner 2002	*Adenostylo glabrae-Fagetum* sensu Willner 2002
Soil types		Chromic Cambisols and Hydromorphic Stagnosols	Lithic and Rendzic Leptosols
aspect [°]		0-5	25-35
average soil depths [cm]		51	12
pH_{CaCl2}	organic layer	5.3 (0.6)	5.7 (0.4)
	0-10 cm	6.3 (0.6)	6.7 (0.3)
	10-20 cm	6.6 (0.3)	6.9 (0.1)
C_{org} [%]	organic layer	36 (9.2)	44 (6.1)
	0-10 cm	10.1 (3.5)	20.3 (6.6)
	10-20 cm	5.1 (1.6)	12.7 (1.7)
N_{ges} [%]	organic layer	1.3 (0.2)	1.5 (0.2)
	0-10 cm	0.6 (0.2)	1.2 (0.2)
	10-20 cm	0.4 (0.1)	0.8 (0.2)
[a]$N_{net\ min}$ [$mg\ kg^{-1}d^{-1}$]	0-5 cm	−3.2 (5.2); max 5.8; min −26.0	−1.7 (2.1); max 1.8; min −10.9
[a]$N_{gross\ cons}$ [$mg\ kg^{-1}d^{-1}$]	0-5 cm	15.1 (11.0); min −1.9; max 59.5	5.3 (4.4) ; min −1.2; max 23.0

the watershed is not as heavily karstified as limestone karst systems, but shows typical karst features such as conduits and sink holes. The long-term average annual temperature is 7.2° C. The coldest monthly temperature at 900 m a.s.l. is –1°C (January), the highest is 15.5°C (August). Annual rainfall ranges from 1500 to 1800 mm. Monthly precipitation ranges from 75 mm (February) to 182 mm (July). Snowfall occurs between October and May with an average duration of snow cover of about 4 months.
The watershed can be divided into two distinct sites: A very steep slope (30–70°) from 550–850 m a.s.l. and an almost flat plateau (850-956 m.a.s.l.) on the top of the mountain. The plateau is dominated by Norway spruce (*Picea abies*) following plantation after a clear cut around the year 1910, whereas a mixed mountain forest with beech (*Fagus sylvatica*) as the dominant species, Norway spruce (*Picea abies*), maple (*Acer pseudoplatanus*), and ash (*Fraxinus excelsior*) covers the slope. At the plateau and the slope, one intensive plot has been selected for in-depth measurements of hydrochemical processes. Intensive plot I (IP I) is located on the plateau where Chromic Cambisols and Hydromorphic Stagnosols are found. Intensive plot II (IP II) is located on the slope and is dominated by Lithic and Rendzic Leptosols (FAO/ISRIC/ISSS, 2006). Mull and moder humus forms that indicate quick turnover of the forest floor predominates both plots. Mor humus can be found. The soils of IP II are generally richer in N and exhibit lower mineralization rates than the soils of IP I. See Table AT.6 for the description of soil characteristics.

Permanent plots exist along a 100 x 100 m grid across the watershed totalling to 64 (Figure AT.1). For VSD+ dynamic models a representative part of these plots were chosen because they capture the full variability of the site. Soil and tree layer information is derived from surveys in the years 1992 and 2004. Vegetation was recorded in the years 1993, 2004, 2008 and 2010.
From the start of the project in 1992 onwards forest management has been restricted to single tree harvesting in case of bark beetle infestation (the IP I has been exposed to bark beetle infestation in the year 2004, impaired deposition samplers were excluded, no lysimeter was affected).

Parameter setting for VSD+

In general, the same data as in the year 2009 was used to run VSD+ soil module. Only the parameters which are necessary for the VEG module are new (see below). A regional species pool was generated by using the species list from CCE and by selecting those species which occur with more than 5% cover in one of the observation years (all permanent plots).
Table AT.7 describes all parameters and methods which were used for VSD+. The following parameters were calibrated with VSD studio: lgKAlBC, lgKHBC, lgKAlox, CNrat_o, Ca_we and Mg_we. For all parameters not listed the default values of the last VSD+ version were taken. Two or three permanent plots covering the C/N ratio within each soil type (Stagnosols, Cambisols, Leptosols)

Table AT.7 Methods for the derivation of parameter values for VSD+and VEG input. Changes made since the last call are shaded in grey.

Keyword	Unit	Value/Filename	Method
SiteInfo	–	ZOE[plot number]	
period	yr yr	1980 to 2100	
thick	m	input*.dat	total depth of the mineral soil; summation of the depths of the mineral soil horizons of which a soil sample and therefore the bulk density has been calculated
bulkdens	g/cm	input*.dat	the bulk density of a soil sample is the ratio of the oven dried weight (105°C) of the fine soil (<2mm) to the volume of the respective sample - the mean bulk density of the profile was calculated by eq.6.22 in Mapping Manual 2004
Theta	m^3/m^3	input*.dat	mean values taken from continuous volumetric water content measurements at two intensive plots (differentiated into soil types)
pCO2fac	–	18	[$\log_{10}pCO_2 = -2.38+0.031*$Temp (°C)]; atmospheric CO_2 pressure = 0.00039 atm; (equation recommended by CCE)
CEC	meq/kg	input*.dat	as the CEC has not be analysed in the subsoil in 2004, the data of the first soil inventory in 1992 has been used - to scale the measured CEC to a value at pH = 6,5, eq.6.29 in Mapping Manual 2004 has been used - the CEC at pH = 6.5 was calculated by eq.6.28 in Mapping Manual 2004 - the mean CEC of the profile was calculated with the eq.6.23 in Mapping Manual 2004
Excmod	–	1	Gaines-Thomas
lgKAlBC		input*.dat	calibrated with VSD+
lgKHBC		input*.dat	calibrated with VSD+
lgKAlox	$(mol/l)^{1-a}$	input*.dat	9.8602–1.6755*log(organic matter [%])
Cpool_0	g/m^2	input*.dat	best guess using observed values
CNrat_0	g/g	input*.dat	calibrated with VSD+
RCOOmod	–	1	mono-protic
RCOOpars	–	4.5	according to Mapping Manual
cRCOO	mol/m^3	0.32	according to Mapping Manual: *m*=0.029; the DOC concentration taken as the mean value of continuous measurements at two intensive plots: 11 mg/l
TempC	°C	input*.dat	mean values taken from continuous measurements at two intensive plots (differentiated into soil types)
percol	m/yr	wabil*.dat	values between 1993 and 2006 taken from a Brook90 calibration for two intensive plots (differentiated in conifer and deciduous forest; for mixed forests the mean has been used)
Ca_we	$eq/m^3/yr$	input*.dat	calibrated with VSD+
Mg_we	$eq/m^3/yr$	input*.dat	calibrated with VSD+
SO_2_dep	$eq/m^2/yra$	dep*.dat	throughfall deposition from continuous measurements at two intensive plots (differentiated into conifer and deciduous forest; mixed forest taken as the mean value); 1980 values were taken from the EMEP grid and multiplied by a receptor specific constant
NO_x_dep	$eq/m^2/yra$	dep*.dat	
NH_3_dep	$eq/m^2/yra$	dep*.dat	
Ca_dep	$eq/m^2/yra$	dep*.dat	
Mg_dep	$eq/m^2/yra$	dep*.dat	
K_dep	$eq/m^2/yra$	dep*.dat	
Na_dep	$eq/m^2/yra$	dep*.dat	
Cl_dep	$eq/m^2/yra$	dep*.dat	
rf_min	–	input*.dat	Taken as one minus moisture related rf_denit minus temperature related reduction, which was calculated according to equation R4 in the VSD+ manual taking data from the intensive plots
rf_nit	–	input*.dat	
rf_denit	–	input*.dat	denitrification potential is very low in these sites, so we set rf_denit = 0.1
age_veg	yr	input*.dat	age in the year 1980
growthfunc		input*.dat	2 parameter model: annual growth rate was taken from inventories in the years 1993 and 2005; annual litterfall was measured continuously at two intensive plots
veg_type		input*.dat	spruce forest=1; beech forest=4; mixed forest =4

Table AT.7 (continued).

Keyword	Unit	Value/Filename	Method
VEG parameters:			
PARtop	µmol/m²/s	input*.dat	Above canopy PAR was calculated using GLA Version 2.0 (hemiphotograph software)
ThetaWP	m^3/m^3	input*.dat	Estimated from soil water measurements from cores of the intensive plots
ThetaSat	m^3/m^3	input*.dat	Soil water measurements from cores of the intensive plots
Observations:			
Cpoolobs	g/m^2	bodchem*.obs	available for the years 1992 and 2004; topsoil is defined as organic layer, mineral soil horizon (0-5 cm) and mineral soil horizon (5-10cm) - Cpool is calculated as: Cpool = depth of soil horizon (cm) * bulk density of soil horizon (g/cm^3) * Corg (%) *100
CNratobs	g/g	bodchem*.obs	available for the years 1992 and 2004; topsoil is defined as organic layer, mineral soil horizon (0-5 cm) and mineral soil horizon (5-10cm) - C:N ratio in topsoil was calculated as C:N-ratio = Cpool/Npool - the Npool was calculated in the same way as the Cpool
bsatobs		bodchem*.obs	available for the years 1992 and 2004; as the BS has not be calculated in the subsoil in 2004, the data of the first soil inventory in 1992 has been used - the mean BS of the profile was calculated with the eq.6.24 in Mapping Manual 2004
pHobs		bowaObs*.obs	available between the years 1998 to 2008; continuous soil water data (plate lysimeter) of the two intensive plots were allocated to plots according to their soil type
cSO_4obs	eq/m^3	bowaObs*.obs	
cNO_3obs	eq/m^3	bowaObs*.obs	
cBcobs	eq/m^3	bowaObs*.obs	
cNaobs	eq/m^3	bowaObs*.obs	
cClobs	eq/m^3	bowaObs*.obs	
cAlobs	eq/m^3	bowaObs*.obs	

were selected, totalling to 7 plots. It is assumed that these plots are representative for the study area with regard to soil and forest characteristics.
For testing the VEG module we used only the baseline deposition scenario. All models were run from 1970 to 2050. The 1980 deposition was taken from the respective EMEP grid cell and multiplied by a receptor specific factor (mean of the ratio of bulk deposition/throughfall deposition from 1996 to 2008). Future deposition was taken to be constant from now onwards. Initial base saturation was assumed to be in steady state (bstat_0 set to -1).
We used all species which occur with > 5% cover in any observation year (all permanent plots of the study site, totalling to 123 species) AND which are included in the CCE species list (grndveg363_tcm61-49259.txt). In total 64 species were used, which means that almost half of the regional plant species pool was excluded.
For evaluation of model runs observation data was used from the years 1992, 2004, 2008 and 2010 including all occurring species together with their cover.

Results and Discussion

Dynamic soil modelling

The focus is on eutrophication due to nitrogen deposition because acidification is not a big issue for the carbonate soils of the IM site Zöbelboden. However, the model results of parameters relevant for acidification (e.g. pH of the soil solution) did well match with observed values.
In the previous modelling tasks (see report to the last ICP M&M call) we found that the sensitivity of sites to N leaching in the study area increases from Leptosols to Cambisols to Stagnosols corroborating earlier results. However, comparison of the model results with measured and modeled N leaching shows that the calibrated models predict much lower N leaching than was observed.
Long-term observations between the years 1993 and 2007 show that 7 to 34 kg/ha/yr inorganic N (0.05 - 0.23 $eq/m^2/yr$) leaches with the soil water to the ground water (Jost et al. 2011). With VSD+ such values are only predicted to occur in the long term and under higher deposition of N than today. In addition, all models show significantly lower NO_3 concentrations than we observed in lysimeter samples between the year 1996 and 2008. After adapting some details of the parameterization the results in general are the same. There are a number of possible explanations for further improvements:

1. N processes exhibit very strong seasonal variation so that annual means might not be very representative.
2. Preferential flow through macropores is common in the soils found at the IM site Zöbelboden (and many other sites as well). Since hydrological processes are very important for the long-term trends of C and N in soils preferential flow could be addressed in further development of VSD+.

3. By using throughfall deposition alone other important deposition pathways - or part of it - are ignored, namely dry and occult (fog and cloud) deposition. It is known for the IM site Zöbelboden (measurements of fog samples and application of fog and dry deposition models) that total deposition might be double the throughfall deposition, particularly in stands with a high proportion of conifers such as spruce. These deposition pathways could be incorporated in future.
4. In further modelling efforts an age dependent growth function should be parameterized because of the prime importance of growth for long-term N immobilisation. Presently we used only a constant function with the growth rate taken from the difference of only two time points (1992 and 2004). It is probable that week predictions result from this rough approximation.

Dynamic vegetation modelling

The vegetation development could only be modelled for a part of the plots which were used last year (see above). Some plots with Leptosols could not be modelled due to inconsistencies in the soil water budget. These soils are very shallow and stony. VSD is predicting too many values below wilting point for the majority of the species. This issue should be tackled during further activities because vegetation on Leptosols shows relatively strong changes as a response to N deposition (Hülber et al. 2007).
Overall, the tree layer composition at the IM site Zöbelboden is strongly influenced by management. Since management is not included in the VEG module we do not evaluate tree species.
Permanent plot ZOE1: The soil is a chromic Cambisol. The tree layer was changed from beech dominance to spruce dominance. Only the first observation year in 1992 can be used to evaluate the VEG outcomes because thereafter the plot was severely disturbed by bark beetle. Until 1992, the plot was quite dark and showed a very sparse ground layer. The dominant species, which are predicted to occur, are not found in the observation data.
Permanent plot ZOE28: The soil is a hydromorphic Stagnosol. The site is relatively flat. The forest floor is dark. Accordingly, ground layer cover is low. The naturally dominant beech tree layer was changed by management to a spruce monoculture. Although the related effects on the ground layer plants are severe, the pool of species predicted fit quite well the records. The predicted cover of the species does not coincide with the records.
Permanent plot ZOE40: The soil is a mixture of shallow chromic Cambisols and rendzic Leptosols. The tree layer is characterized by *Fagus sylvatica, Acer pseudoplatanus,* and *Picea abies*. The site is steep and radiation income to the forest floor is high. The ecological species pool is characterized by many basiphilous species (*Carex alba, Calamagrostis varia,* etc.). Many of the species are not parameterized for the VEG module. VEG predicts *Rubus fruticosus* to be dominant, which is not so in reality, followed by a number of subordinate species. *Carex a*. and *Calamagrostis v*. are within this pool but with much lower than recorded cover values.
Overall, the results of vegetation modelling compared with existing observations shows that the VEG module is, for some plots, capable to predict the correct species pool but it never predicts the dominance structure correctly. The prediction of the species pool could be improved with a more comprehensive suite of species which are accurately parameterized. It is not very surprising that the cover of species is not well predicted since many other ecological processes apart from the soil characteristics drive ground layer species composition. This latter issue is more difficult to solve. Next steps should include
1. Parameterization of those species of the site which occur more frequently, i.e. optimizing the regional species pool;
2. Pooling of a number of plots with comparable biogeochemistry and forest management in order to minimize random population processes;
3. Improving the biogeochemistry module (see above).

Several model shortcomings and bugs have been reported to the CCE …

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CLC, 2010, 2006 - Corine Land Cover, © EEA, Copenhagen

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Mapping Procedure and Maps Produced – Wallonia

Critical load maps have been produced for coniferous, deciduous and mixed forests in Wallonia.
Digitized maps with a total of 29,000 ecosystems were overlaid by a 5 × 5 km² grid to produce the maps. In Wallonia, the critical value given for a grid cell represents the average of the critical values weighted by their respective ecosystem area (coniferous, deciduous or mixed forests).

Calculation methods
Critical loads for forest soils were calculated according to the methods described in UBA (1996) and the Dynamic Modelling Manual (Posch et al. 2003):

$$CL_{max}(S) = BC_{we} + BC_{dep} - BC_u - ANC_{le(crit)}$$
$$CL_{max}(N) = N_i + N_u + CL_{max}(S)$$
$$CL_{nut}(N) = N_i + N_u + N_{de} + Q_{le} \cdot cN_{acc}$$
$$ANC_{le(crit)} = -Q_{le} \cdot ([Al^{3+}] + [H^+] - [RCOO^-])$$

where:
$[Al^{3+}] = 0.2$ eq/m³
$[H^+]$ = concentration of $[H^+]$ at the pH critique
$[RCOO^-] = 0.044$ mol_c/molC x $DOC_{measured}$

Table BE.1 Aluminium equilibrium constants and weathering rates used for Walloon soils.

Sites	Soil type	K	BCwe eq ha^{-1} yr^{-1}
Bande (1-2)	Podzol	140	610
Chimay (1)	Cambisol	414	1443
Eupen (1)	Cambisol	2438	2057
Eupen (2)	Cambisol	25	852
Hotton (1)	Cambisol	2736	4366
Louvain-la-Neuve (1)	Luvisol	656	638
Meix-dvt-Virton (1)	Cambisol	2329	467
Ruette (1)	Cambisol	5335	3531
Transinne (1)	Cambisol	3525	560
Willerzie (2)	Cambisol	2553	596

(1) deciduous; (2) coniferous forest

The equilibrium K = $[Al^{3+}]/[H^+]^3$ criterion: The Al^{3+} concentration was estimated by (1) experimental speciation of soil solutions to measure rapidly reacting aluminium, Alqr (Clarke et al. 1992); (2) calculation of Al^{3+} concentration from Alqr using the SPECIES speciation software. The K values established for 10 representative Walloon forest soils (Table BE.1) were more relevant than the gibbsite equilibrium constant recommended in the manual (UBA 1996). The difference between the estimated Al^{3+} concentrations and concentration that causes damage to root system (0.2 eq Al^{3+}/m^3; De Vries et al. 1994) gives the remaining capacity of the soil to neutralise the acidity. Tables BE.1 and BE.2 summarise the values given to some of the parameters.

Table BE.2 Constants used in critical loads calculations in Wallonia.

Parameter	Value
N_i	5.6 kg N ha^{-1} yr^{-1} coniferous forest
	7.7 kg N ha^{-1} yr^{-1} deciduous forest
	6.65 kg N ha^{-1} yr^{-1} mixed forest
cN_{acc}	2.5 mg N L^{-1} for coniferous forest
	3.5 mg N L^{-1} for deciduous forest
	3 mg N L^{-1} for mixed forest
N_{de}	fraction of $N_{dep} - N_i - N_u$

The minimum recommended values are applied for the calculation of CLnutN (Table BE.2).

Soils: In Wallonia, 47 soil types were distinguished according to the soil associations map of the Walloon territory, established by Maréchal and Tavernier (1970). Each ecosystem is characterised by a soil type and a forest type.

Weathering rates: In Wallonia, the base cation weathering rates (BC_{we}) were estimated for 10 different representative soil types (Table BE.1) through leaching experiments. Increasing inputs of acid were added to soil columns and the cumulated outputs of lixiviated base cations (Ca, Mg, K, Na) were measured. Polynomial functions were used to describe the input-output relationship. To estimate BC_{we}, a acid input was fixed at 900 eq ha^{-1} yr^{-1} in order to keep a long term balance of base content in soils.

The flux of drainage water, Q_{le}: from the soil layer (entire rooting depth) was estimated with the EPICgrid model (Faculté Universitaire des Sciences Agronomiques de Gembloux). The results of the EPICgrid model are illustrated in Figure BE.1.

The critical (acceptable) N concentration (cN_{acc}) comes from De Vries et al. (2007):
Coniferous forests: 2.5–4 mgN L^{-1}
Deciduous forests: 3.5–6.5 mgN L^{-1}

Net growth uptake of base cations and nitrogen: In Wallonia, the net nutrient uptake (equal to the removal in harvested biomass) was calculated using the average growth rates measured in 25 Walloon ecological territories and the chemical composition of coniferous and deciduous trees. The chemical composition of the trees *(Picea abies, Fagus sylvatica, Quercus robus, Carpinus betulus)* appears to be linked to the soil type (acidic or calcareous) (Duvigneaud et al. 1969, Unité des Eaux et Forêts 2001). The net growth uptake of nitrogen ranges between 266 and 822 eq ha^{-1} yr^{-1}, while base cations uptake values vary between 545 and 1224 eq ha^{-1} yr^{-1} depending on trees species and location.

Base cation deposition: In Wallonia, actual throughfall data collected in 8 sites, between 1997 and 2002, were used to estimate BC_{dep} parameters. The marine contribution to Ca^{2+}, Mg^{2+} and K^+ depositions was estimated using sodium deposition according to the method described in UBA (1996). The BC_{dep} data of the 8 sites was extrapolated to all Walloon ecosystems as a function of the location and the tree species.

Figure BE.1 Flux of drainage water at 50 cm depth in Wallonia for the 2001-2005 period.

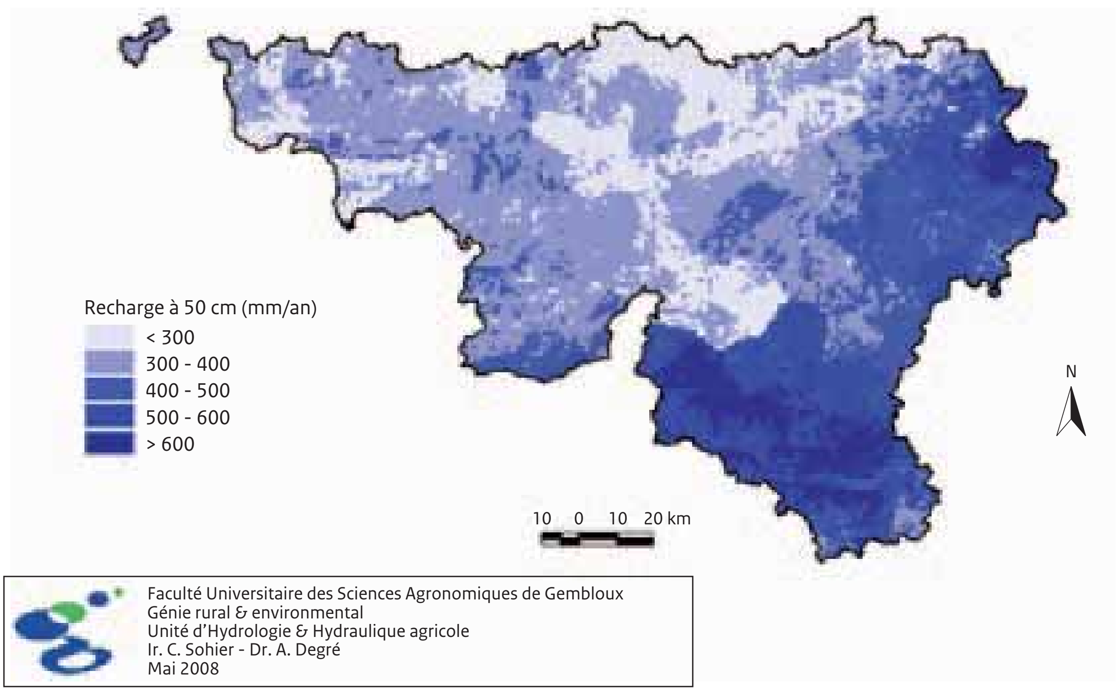
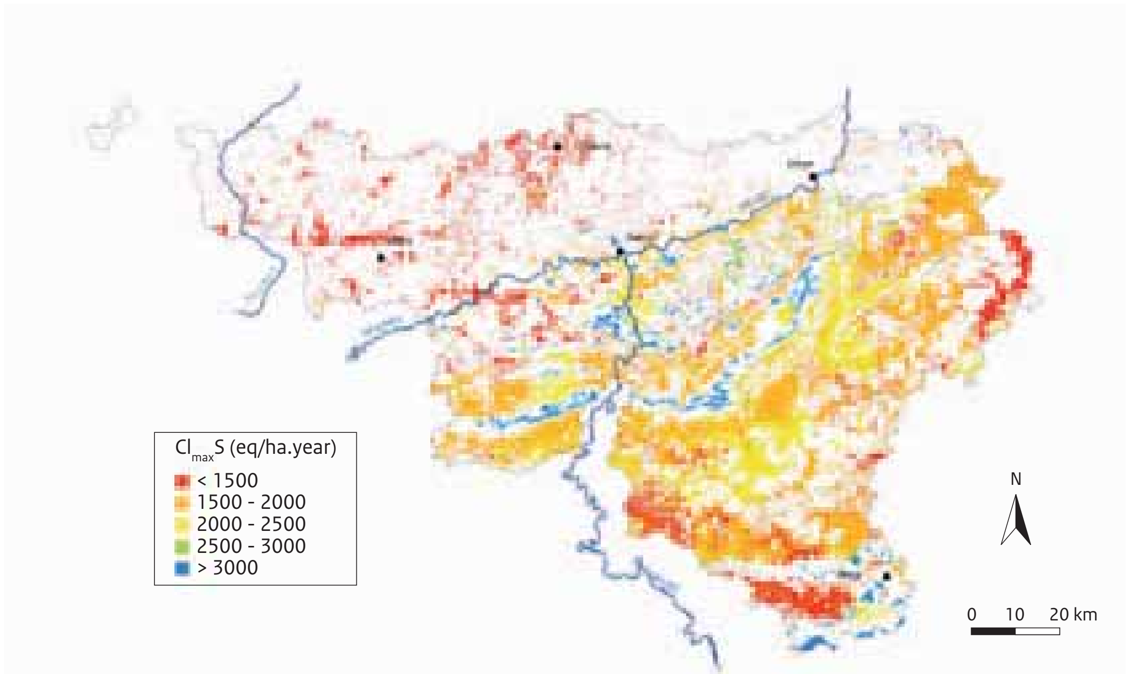


Figure BE.2 Maximum critical loads of sulphur for forests, $CL_{max}(S)$.



Results

Results are shown in Figures BE.2 through BE.4. In Wallonia, the highest CL values were found for calcareous soils under deciduous or coniferous forests. The measured release rate of base cations from soil weathering processes is high in these areas, and thus provides a high long-term buffering capacity against soil acidification.

Figure BE.3 Maximum critical loads of nitrogen for forests, $CL_{max}(N)$.

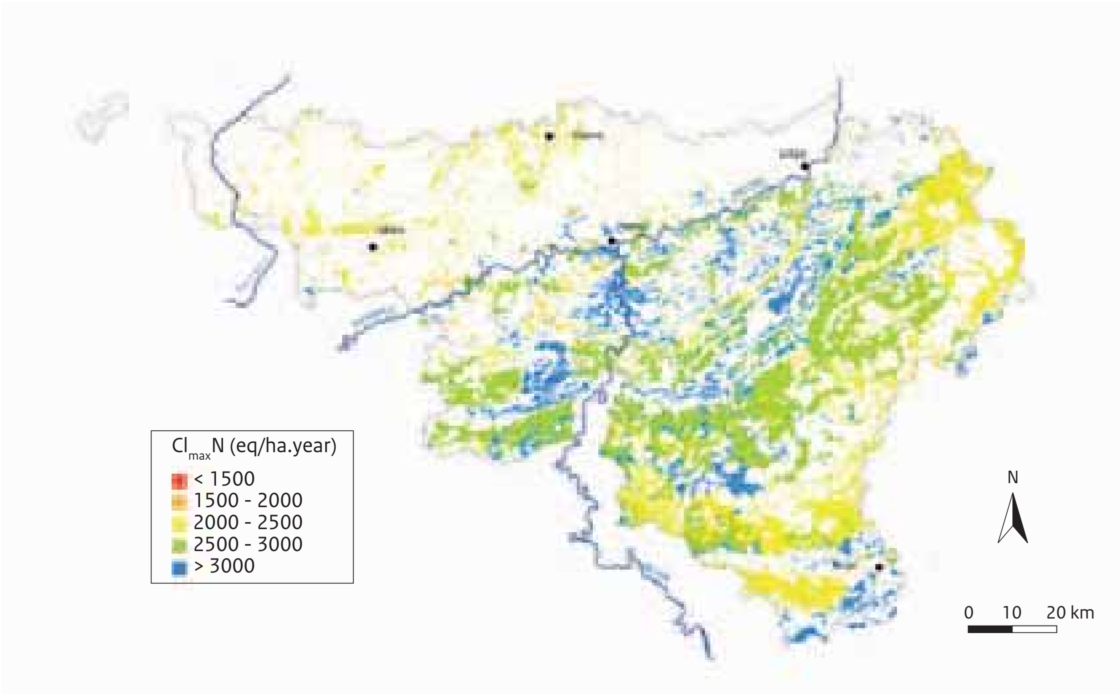
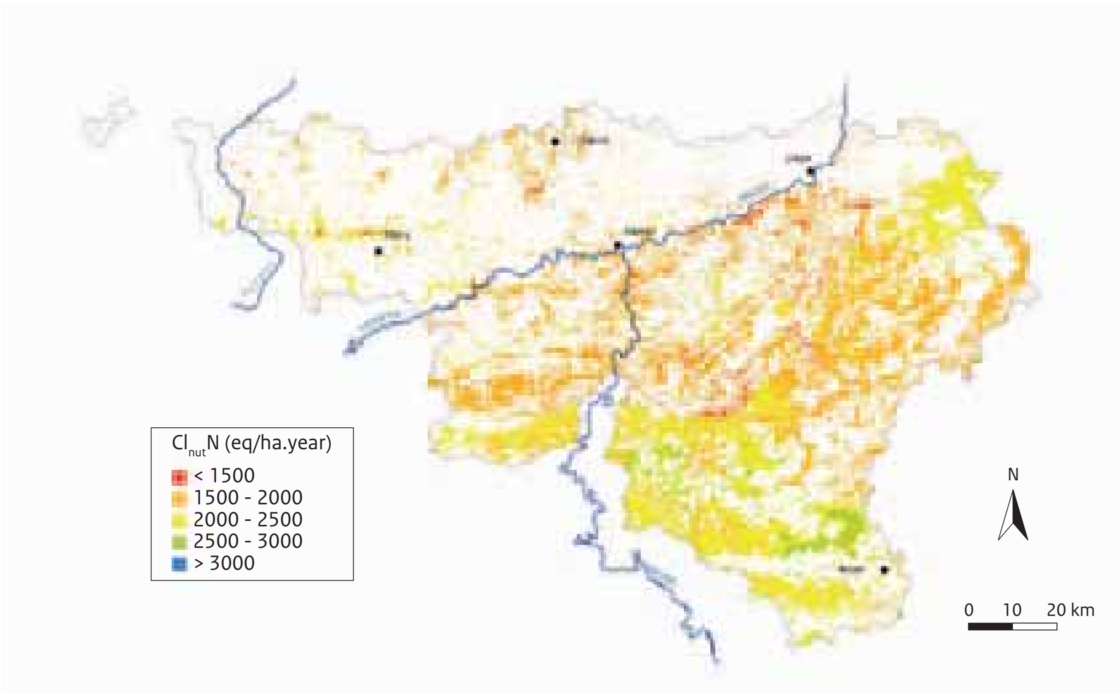


Figure BE.4 Critical loads of nutrient nitrogen for forests, $CL_{nut}(N)$.



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Calculated Critical Loads and Dynamic Modelling

Data sources

National maps:
- FAO soil map of Bulgaria 1:400,000;
- Geological map of Bulgaria 1:500,000;
- Vegetation map of Bulgaria 1:500,000;
- Mean annual temperature map 1:500,000;
- Mean annual precipitation map 1:500,000;
- Corine Land Cover 2006 (GIS data) 1:100,000.

The monitoring of the soil is in 11 years at Jundola, Vitinya and Staro Oryahovo.

Ecosystems: Two forest ecosystem types have been investigated according to EUNIS classification: G1 *(Fagus sylvatica, Quercus fraineto, Quercus cerris)*; G3 *(Picea abies, Abies alba)*.

Runoff: of water under root zone has been measured in grid cells of 10 × 10 km² for the entire country (Kehayov 1986).

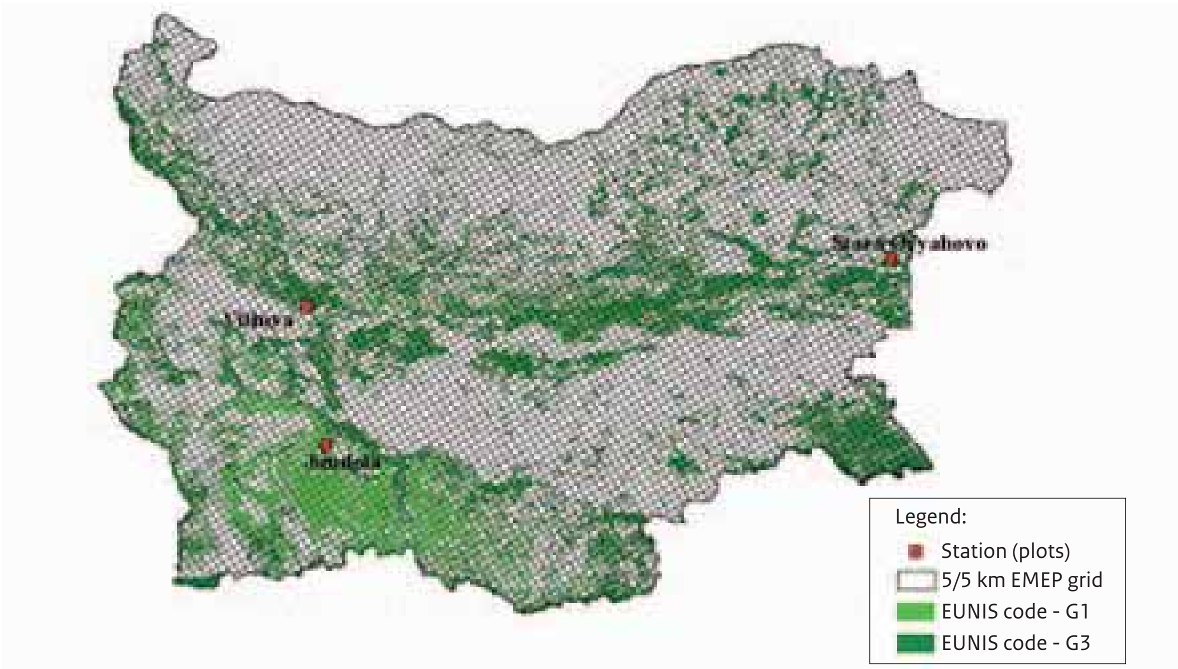
Deposition: Sulfur and Nitrogen deposition time series provided only by Bulgarian Air Immissions Data. Since 2005 no such measurements in Jundola, Vitinya and Staro Oryahovo.

Receptors: Coniferous and deciduous forests in 3 EMEP 5 × 5 km² network stations (Table BG.1 and Figure BG.1).

Table BG.1 Bulgarian stations and their locations.

Station name	Longitude	Latitude	50×50 EMEP grid		5×5 EMEP grid		
			ID	Gridcode	I5	J5	IJ5
Jundola	23° 53' 40"	41° 55' 34"	8409	96051	951	503	9510503
Vitinya	23° 55' 48"	42° 55' 39"	8296	94052	935	511	9350511
Staro Oryahovo	27° 03' 52"	43° 03' 52"	7633	97058	968	576	9680576

Figure BG.1 Map of investigated areas by the 5×5 km^2 EMEP grid.



This research project includes three work packages aiming at:

- Adapting and application of dynamic modelling for critical loads of acidity for three stands in Bulgaria: Jundola, Vitinya and Staro Oryahovo;
- Calculation and mapping of actual critical acidity, sulphur and nitrogen loads as well as their exceedances for selected forest ecosystems in collaboration with other expert teams at the same monitoring stands (Table BG.2)

Dynamic Modelling

The Very Simple Dynamic (VSD) model (Posch and Reinds 2009) has been selected as the base dynamic modelling method.

Calculation Methods

Critical loads of nitrogen as a nutrient, maximum values for the critical loads of sulphur and acidifying nitrogen; minimum critical load of nitrogen have been calculated according to the 1996/2004 Manual (UBA 1996, ICP Mapping 2005) using the steady-state mass balance method. In the absence of more specific data on the production of basic cations through mineral weathering for most of the study regions, weathering rates have been calculated according to the dominant parent material obtained from the lithology map of Bulgaria and the texture class taken from the FAO soil map for Europe, according to the clay contents of the Bulgarian forest soils (UBA 1996). The gibbsite equilibrium constant K_{gibb} for the Al-H relationship (m^6/eq^2) has been estimated in accordance with the soil organic matter in % and type of soils using the manual (UBA 1996).

Results and comments (CL)

Table BG.3 and Figures BG.2 and BG.3 present results for coniferous and deciduous species in the three stations.

Due to insufficient data, critical loads data from the year 2007/2008 were used. Calculated values for CLmaxS vary between 4192 and 9772 eq ha^{-1} a^{-1} for coniferous, and

Table BG.2 Monitoring plots and their characteristics.

Name	SiteID	5×5 EMEP grid		Type	Tree species	Tree age	Altitude
		I5	J5			(yr)	(m)
Jundola	1	951	503	1	Picea abies, Abies alba	170	1600
Vitinya	2	935	511	2	Fagus sylvatica	140	950
Staro Oryahovo	3	968	576	2	Quercus frainetto, Quercus cerris L.	156	250
Vitinya	2002	935	511	1	Pinus nigra		950
Staro Oryahovo	2003	968	576	1	Pinus nigra		250

Table BG.3 Values of critical loads of sulphur and nitrogen for deciduous and coniferous forests in Bulgaria (in eq ha^{-1} a^{-1}).

CL	Coniferous			Deciduous	
	Jundola SiteID 1	Vitinya SiteID 2002	Staro Oryahovo SiteID 2003	Vitinya SiteID 2	Staro Oryahovo SiteID 3
CLmaxS	6909	4192	9771	3791	3356
CLminN	266	375	426	367	319
CLmaxN	7174	4567	10197	4158	3675
CLnutN	277	381	430	374	324

Figure BG.2 Map of the critical loads of S, N and nutr.N (eq ha^{-1} a^{-1}) - Coniferous.

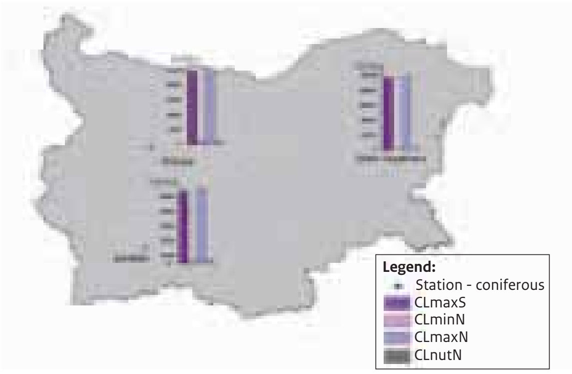
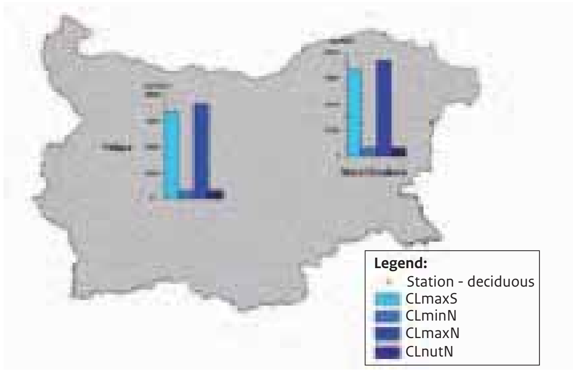


Figure BG.3 Map of the critical loads of S, N and nutr.N (eq ha^{-1} a^{-1}) - Deciduous.



between 2774 and 6909 eq ha^{-1} a^{-1} for broadleaved forests. For CLmaxN they vary between 4567 and 10197 eq ha^{-1} a^{-1} for coniferous, and between 3275 and 6243 eq ha^{-1} a^{-1} for broadleaved forests. Critical load values for nutrient nitrogen are lower and ranged between 770 and 930 eq ha^{-1} a^{-1} for coniferous, and between 324 and 776 eq ha^{-1} a^{-1} for deciduous forests. The lowest critical loads are calculated for CLminN (between 573 and 926 eq ha^{-1} a^{-1} for coniferous, and between 266 and 926 eq ha^{-1} a^{-1} for deciduous forests). In general, calculated critical loads values for the whole country are higher for coniferous forests than for broadleaved ones, due to the lower mean values of critical loads parameters used (base cation weathering, deposition and uptake).

Results and comments (dynamic modelling)

The most important additional soil parameters needed for the VSD model have been the carbon content in the soil, carbon/nitrogen ratio, soil bulk density, clay and sand content, as well as the soil pH. Typical VSD+Veg model output for the three sites (see Tables BG.1 and BG.2) is shown in Figures BG.4 through BG.9.

Figure BG.4 Flux of drainage water at 50 cm depth in Wallonia for the 2001-2005 period.

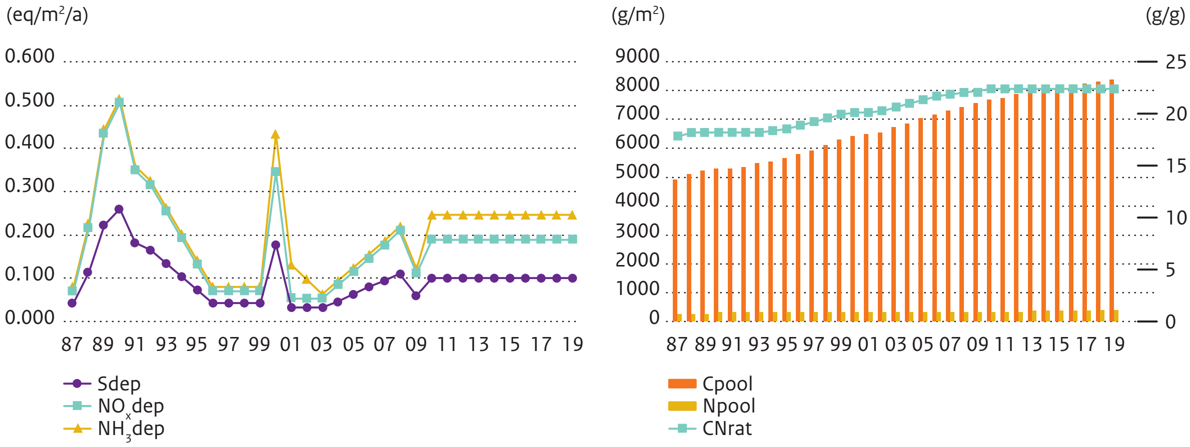


Figure BG.5 Results of the VSD+Veg modelling for Jundola.

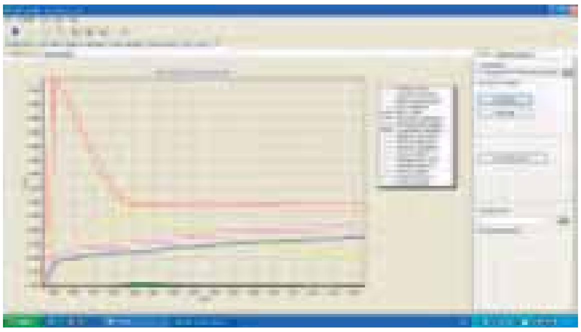


Figure BG.6 Results of the VSD+ modelling for the Vitinya site for the period 1960-2020.

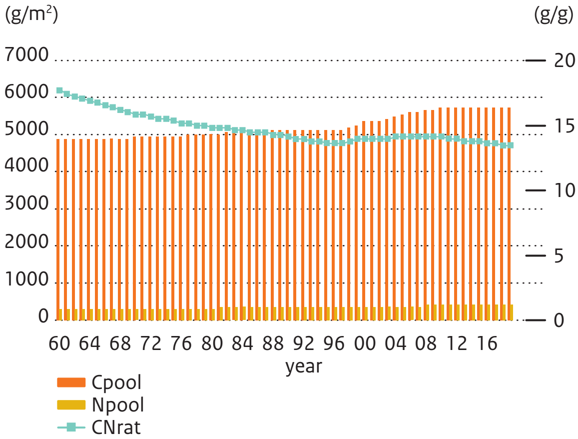


Figure BG.7 Results of the VSD+Veg modelling for Vitinya.

Figure BG.8 Results of the VSD+ modelling for the Staro Oryahovo site for the period 1998–2020.

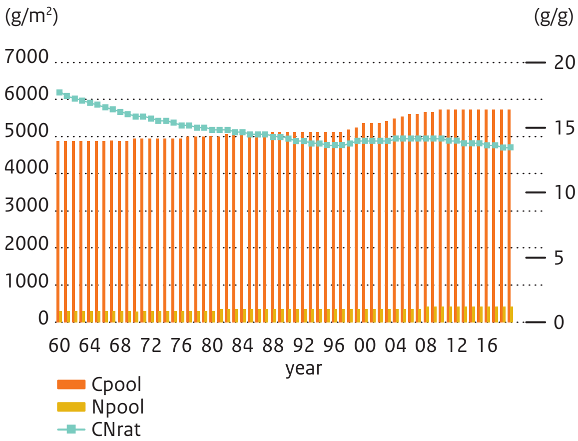


Figure BG.9 Results of the VSD+Veg modelling for Staro Oryahovo (Simpson Index).

Empirical Critical Loads of Nutrient Nitrogen

Data sources: The empirical critical loads of nitrogen for habitat groups treated have been determined in accordance with the Mapping Manual chapter 5.2.1 (UBA 2004) and ECE/EB.AIR/WG.1/2010/14 using suggested empirical critical loads for nitrogen deposition as follows (CCE and ICP M&M 2010, Annex 1) (all in kg N $ha^{-1} a^{-1}$):

Forest habitats (G):
- **G1.6**: 10-20; **G1.8**: 10-15; **G1.A**: 15-20; **G3.1**: 10-15; **G3.5**: 15

Heathland, scrub and tundra habitats (F):
- **F2**: 5-15 (for alpine and subalpine scrub habitats); **F4.11**: 10-20 ('U' Calluna and 'L' Erica tetralix)

Grasslands and tall forb habitats (E):
- **E2.2**: 20-30; **E2.3**: 10-20

Mire, bog and fen habitats (D):
- **D1**: 5-10 (for raised and blanket bogs)

Inland surface water habitats (C):
- **C1.16:** 10-20 (for dune slack pools)

Coastal habitats (B):
- **B1.3:** 10-20 (for shifting coastal dunes); **B1.4:** 8-15 (for coastal stable dune grasslands); **B1.5**: 10-20 (for coastal dune heaths)

Marine habitats (A):
- **A2.54** and **A2.55**: 20-30 (for pioneer and low-mid salt marshes)

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Introduction

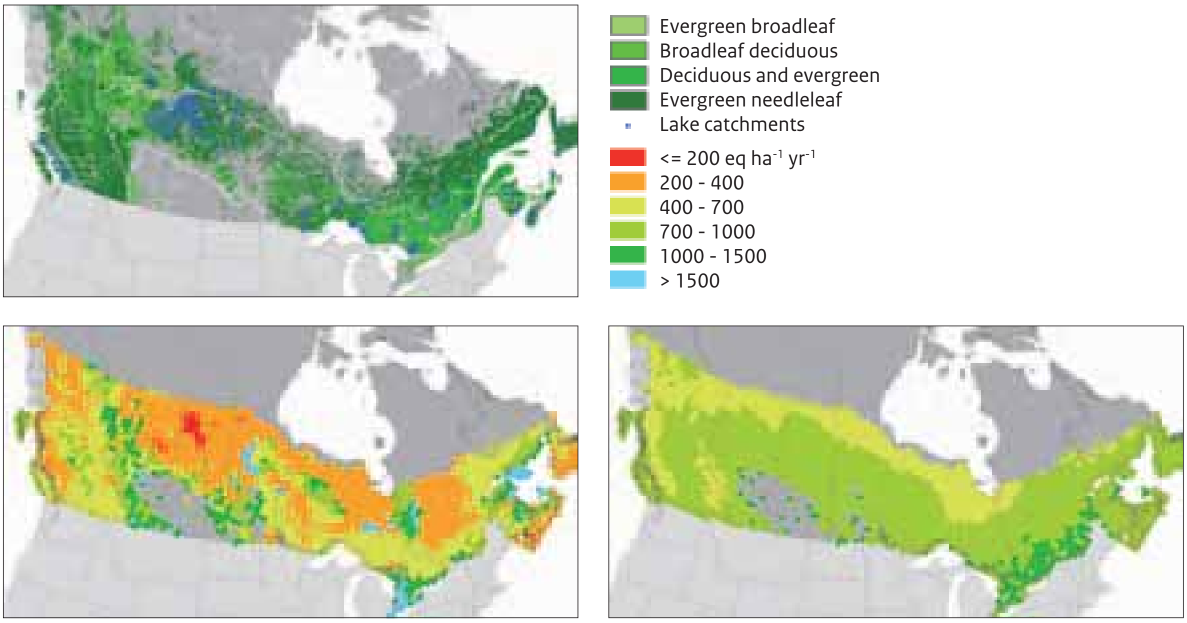
The 2010 Call for Data was composed of four objectives: to (a) increase the resolution of (existing) critical loads, (b) apply revised empirical critical loads following the 'Workshop on the Review and Revision of Empirical Critical Loads and Dose-response Relationships' held in Noordwijkerhout (the Netherlands), June 2010, (c) continue work on an extended very simple dynamic model (VSD+) and vegetation modelling, and (d) encourage NFCs to relate to national habitat experts. The Canadian NFC submitted a response on three components (a, b and c) as outlined below.

Critical loads of acidity and nutrient nitrogen

There were significant updates to the Canadian NFC critical loads database in response to the 2010 CCE call for data. The database currently holds terrestrial (forest soil) critical loads data for all provinces in Canada (below 60°N) and surface water (lake) critical loads for approximately 3000 catchments across Canada, representing approximately 20 % of the total area of Canada (Figure CA.1). The data submission included new data for lake catchments and empirical critical loads of nutrient nitrogen for forest ecosystems. Critical loads of acidity for surface waters, based on the Freshwater Acidity Balance model, was only determined for lakes with catchment area estimates (n = ~3000, see Figure CA.1).

Empirical critical loads of nutrient nitrogen were assigned to forest ecosystems (Figure CA.1) based on Bobbink and Hettelingh (2011). Forest ecosystem were defined by combing ecological regions of North America (URL: www.epa.gov/wed/pages/ecoregions.htm) with land cover types (URL: edc2.usgs.gov/glcc/na_int.php).

Figure CA.1 Top left: Map of receptor ecosystems (forest soils and lake catchments) used in acidity and nutrient nitrogen critical loads. Top right: legends for receptor ecosystem and critical load maps. Bottom left: fifth percentile of critical loads of acidity (CLmaxS) for forest soils and lake catchments (eq ha^{-1} yr^{-1}) summarised on the EMEP50 grid. Bottom right: fifth percentile of empirical critical loads of nutrient nitrogen (CLempN: eq ha^{-1} yr^{-1}) for terrestrial (forest) ecosystems (see receptor ecosystems [top left]) summarised on the EMEP50 grid.



Very simple dynamic (VSD+) model and vegetation modelling

The VSD+Veg model was applied to three forest plots in Alberta, Canada (Table CA.1). The study sites were located within the Boreal Plain Ecozone and are dominated by the following tree species: Paper Birch (PB), Lodgepole Pine (LP) and Black Spruce (BS).

Model input data and observations were derived from several sources (Table CA.1). Soil (i.e., thickness, bulk density, cation exchange capacity [CEC], base saturation [BS], carbon pool [C_poolobs], nitrogen pool [N_poolobs], and carbon to nitrogen ratio [CN_ratioobs]) and forest stand characteristics (e.g., stand age, growth function parameters) were estimated from soil and forest inventory databases (Shaw et al. 2005). Digital maps were used to estimate total deposition (Environment Canada [GEM grid: 35 km × 35 km]), soil weathering (Soil Landscapes of Canada v3.0; 1:1,000,000), and climate and hydrological variables (long-term [1961–1990] normals of annual precipitation [rainfall, m], runoff [m], air temperature [°C]; New et al. 1999 [GEM grid 35 km × 35 km]). Atmospheric deposition (centred on 1996) was scaled according to past emission scenarios (period 1900–2000) following Whitfield et al. (2010). In general, anthropogenic deposition values are low at the Alberta sites, compared with regions in Eastern Canada.

Soil characteristic were depth (i.e., bulk density) and bulk density weighted (i.e., CEC, BS, C_poolobs, N_poolobs, CN_ratioobs) for topsoil (rooting depth, assumed to represent horizons LFH, A, and B). Soil physical data (bulk density, organic carbon, and particle size fractions) were used in the MetHyd model to estimate soil water content (Theta), reduction factors (of mineralization [rf_min], nitrification [rf_nit] and denitrification rates [rf_denit]), percolation (precipitation surplus), water content at saturation (ThetaSat), water content at wilting point (ThetaWP), and photosynthetic active radiation (PARtop).

The Veg-module was tested using the vegetation table for a full list of European species and a selected list of species (comparable to those sampled at the study sites compiled from both the European and Rocky Mountain species list). Based on the European vegetation list in the Veg-module, *Lonicera xylosteum* dominated the understory composition at the PB site (~90% throughout the simulation), with the remaining species constituting less than 1% of total composition (e.g., *Hedera Helix, Rubus Fruticosus* [Figure CA.2]). Although several modelled species at the PB site corresponded to those observed, their areal coverage was minimal (i.e., *Epilobium angustifolium* <0.1%, *Vaccinium vitis-idaea, Pleurozium schreberi*, and *Hylocomium splendens* <0.05% throughout the simulation) in contrast to their suggested dominance based on field observations. Similarly, the species composition at LP and BS did not correspond well to those observed; using the European vegetation list appeared to produce somewhat unrealistic results in terms of species composition for the Canadian ecosystems.

Table CA.1 Input parameters and methods of estimation for VSD+Veg simulations (1900–2000).

Keyword	Unit	PB	BS	LP	Estimation method
Thick	m	0.60	0.87	0.51	Site measurement: LFH through to B
Bulkdens	g/cm^3	1.12	1.32	1.26	Site measurement: LFH through to B (depth weighted)
Theta	m^3/m^3	0.3663	0.3111	0.3069	Estimated using MetHyd (from soil physical characteristics)
CEC	meq/kg	292	237	294	LFH through to B (depth and bulk density weighted)
bsat_0	%	-1	-1	-1	Estimated by the model
Excmod	-	2	2	2	Gapon
lgKAlox	$(mol/l)^{1-expAl}$	9.1	9.8	10.1	Estimated using eqn. 9.8602-1.6755*Log(%OC)
Cpool_0	g/m^2	2590	685.48	1190.9	Best estimates to fit data
CNrat_0	g/g	20	9	6.4	Best estimates to fit data
RCOOmod	-		0		Organic acid model: 0=Oliver, 1=mono-protic
RCOOpars			0.96 0.9 0.039		Original Oliver et al. (1983) model values used
Percol	m/yr	0.098	0.174	0.180	Estimated using MetHyd
Ca_we	$eq/m^3/yr$	0.035	0.024	0.024	Estimated from digital soil database
K_we	$eq/m^3/yr$	0.012	0.008	0.008	Estimated from digital soil database
Na_we	$eq/m^3/yr$	0.012	0.008	0.008	Estimated from digital soil database
Deposition	$eq/m^2/yr$		From file		Environment Canada
cCa_min	eq/m^3	0.0001	0.0001	0.0001	VSD default
cMg_min	eq/m^3	0.0001	0.0001	0.0001	VSD default
cK_min	eq/m^3	0.0001	0.0001	0.0001	VSD default
Nfix	$eq/m^2/yr$		0.1		VSD default, if missing set to 0
!ctCast	%		0		VSD default
!ctMgst	%		0		VSD default
!ctKst	%		0		VSD default
rf_min	-	0.5143	0.6192	0.5642	Estimated using MetHyd
rf_nit	-	0.5143	0.6192	0.5642	Estimated using MetHyd
rf_denit	-	0.1020	0.0135	0.0305	Estimated using MetHyd
veg_type	-	4	1	2	Stand type
age_veg	yr	28	40	38	Stand age (at beginning of simulation, 1900)
growthfunc	kg/m^2 yr^{-1} yr $kg/m^2/yr$	9.38 0.1 45.0 0.092	16.03 0.1 54.0 0.239	18.77 0.1 38.0 0.199	Estimated using forest database, maximum amount of stems (kg/m^2) logistic growth rate constant (yr^{-1}) time at which amount of stems is half of maximum (yr) maximum amount of litterfall ($kg/m^2/yr$)
Cpoolobs	g/m^2	3325	1489	857	Site measurement; LFH through to B horizon, Measurements were available from 1977 for paper birch site, 1981 for lodgepole pine, and 1978 for black spruce site
Npoolobs	g/m^2	186	155	216	Site measurement; LFH through to B horizon
CNratobs	%	16	9.3	6.4	Site measurement; LFH through to B horizon
bsatobs	%	0.25	0.9	0.55	Site measurement; LFH through to B horizon
ThetaSat	m^3/m^3	0.4815	0.476	0.451	Estimated using MetHyd
ThetaWP	m^3/m^3	0.2707	0.170	0.178	Estimated using MetHyd
PARtop	$\mu mol/m^2/s$	469.5	505.7	506.7	Estimated using MetHyd

Running the Veg-module using a smaller subset of species (selected from the European and Rocky Mountain species list based on sampled species at sites) produced a more realistic species composition for the study sites (Figure CA.3). The herb species (*Epilobium angustifolium*) appeared to dominate the understory composition at the PB site throughout the simulation period, and at the LP and BS sites up to ~1920s. Moss species (i.e., *Pleurozium schreberi*) dominated the understory composition at the LP and BS sites, particularly post ~1920s; this species was also the 2nd most dominant at PB site (Figure CA.3). In general, the modelled species composition was similar for the two sites

Figure CA.2 VAS+ VEG simulation results for the Paper birch site (with dominating species: *Lonicera xylosteum* [left] and without [right]) using the European vegetation list.

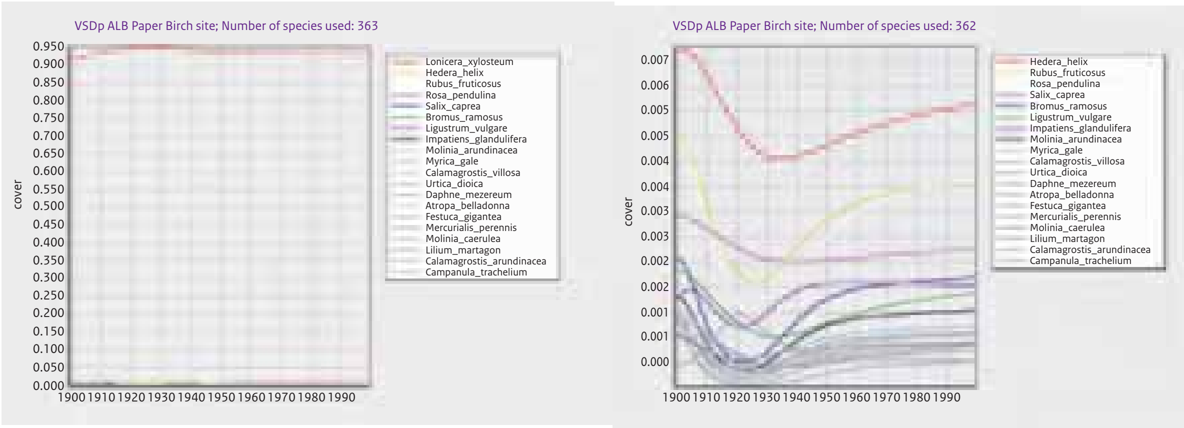
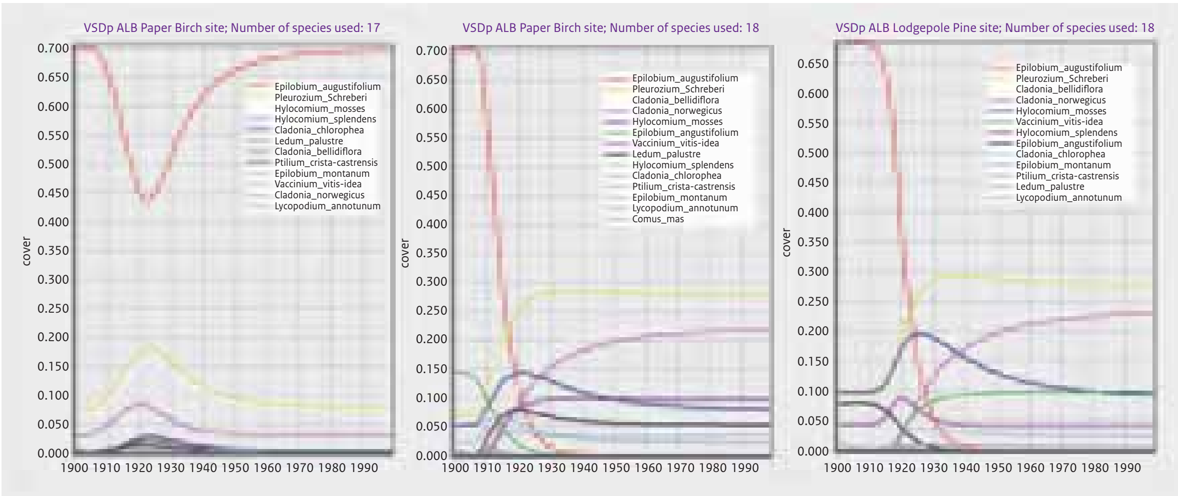


Figure CA.3 VSD+ VEG simulation results for the three study sites; species were selected to reflect occurrence in the forest inventory database (based on both the European and Rocky Mountain species list).



dominated by coniferous forest stands; these sites were closer in proximity and thus had similar characteristics.

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The national database of critical loads

The evaluation of critical loads of nitrogen and sulphur and empirical critical loads for nitrogen was carried out for forest ecosystems. The SEI map provided by the CCE was applied for mapping of the critical loads. Results of maximum and minimum critical loads of sulphur and maximum, minimum and nutrient critical loads of nitrogen are summarized in the 'Cldata' and 'EmpNload' tables. Additional information on localities you can find in the table "ecords". All these localities belong to forested areas with broadleaved deciduous forest ecosystems – G1 *(Fagus sylvatica, Quercus robur, Quercus petraea, Carpinus betulis)*, coniferous forest ecosystems – G3 (*Picea abies, Pinus sylvestris, Larix decidua)* and mixed forest ecosystems – G4. The table 'inputs' presents the input data needed for calculating critical loads.

Forest localities and their data belong to different monitoring programmes. They are monitoring of surface waters and forest soils, the ICP Vegetation (Sucharova and Suchara 2004) the ICP Forests (Boháčová et al. 2007, Boháčová et al. 2009) and Natura2000 (www.biomonitoring.cz). Soil parameters given in "inputs" table were provided directly by monitoring programmes for forest soils (the monitoring of the national level) and the ICP Forests. Soil characteristics for next sites were derived from the measured ones. The Mapping Manual (UBA 2004) and the Manual for Dynamic Modelling (Posch et al. 2003) are the main methodological sources for the evaluation of critical loads for sulphur and nitrogen and related soil data. Empirical critical loads elaborated in 2009 were updated according to the new results of the workshop in Noordwijkerhout (Bobbink and Hettelingh 2011).

Calculation of critical loads for acidity, nutrient nitrogen, and empirical critical loads

Maps (GIS layers) of soil properties, atmospheric depositions, temperatures and precipitations have been the base for the evaluation of the critical loads. Biotope map SEI has been used for describing three main types of forest ecosystems (broadleaved, coniferous and mixed).

Table CZ.1 Contents of N, Ca, Mg and K in stems of main forest types.

	Contents (g/kg) in stems (incl. bark)			
Forest type	N	Ca	Mg	K
coniferous	1.22	1.41	0.18	0.77
broadleaves	1.82	2.14	0.22	1.05
mixed	1.52	1.78	0.20	0.91

Table CZ.2 Temperature-dependent N immobilisation rates for soils with C/N ≥ 20.

Temperature (°C)	N immobilisation rate (eq ha^{-1} a^{-1})
4.5	357.1
5.5	285.7
6.5	214.3
7.5	142.9
8.5	107.1
9.5	71.4

Protection programmes for localities have been selected from the protection area maps. Runoff represents the amount of water percolating through the soil profile. The relationship between temperatures and precipitation amounts used for the assessment of "precipitation surplus" has been taken from the Mapping Manual (2004, chapter 5.5). The uptake of nitrogen, N_{upt}, and nutrients such as K_{upt}, Ca_{upt} and Mg_{upt}, represents average annual wood increments (in 2005, data from the Forest Management Institute, Brandys nad Labem) multiplied by stem contents given in Table CZ.1. Data on average annual wood increments have been divided to 6243 municipalities in the territory of the Czech Republic and elaborated into the GIS layer. Immobilisation rates of nitrogen in the soils of C/N ≥ 20 have been differentiated in the relation to the long-term annual temperatures (Table CZ.2). Immobilisation was set equal to zero for soils with C/N rate lower than 20 (De Vries et al. 2003).

The classification of soils according to their ability for bounding soil water has determined the denitrification factor in the range of 0 and 0.8. A new critical limit for nitrogen in the soil solution has been used in the calculation of nutrient nitrogen critical loads. 1.5 mg N l^{-1} (107.1429 meq m^{-3}) has been selected as the critical (acceptable) N concentration in soil solution (Hettelingh et al. 2008). This value, presenting the impact of N to vegetation species, corresponds to the vegetation change from blueberry to grass (1–2 mg N l^{-1}).

The critical load of nutrient N for forest ecosystems has been calculated by the following equation:

$$CL_{nut}(N) = N_{upt} + N_{im,acc} + Q_{le} \cdot [N]_{crit} / (1-f_{de})$$

with $N_{upt} = k_{gr} \cdot \rho_{st} \cdot ctN_{st}$

where

N_{upt} = uptake of N

$N_{im,acc}$ = (acceptable) immobilisation rate of N

f_{de} = denitrification fraction

Q_{le} = water runoff

$[N]_{crit}$ = critical N concentration (=1.5 mg l^{-1})

k_{gr} = average annual growth rate (m^3 ha^{-1} a^{-1})

ρ_{st} = density of stem wood (kg m^{-3})

ctN_{st} = nitrogen content in stems (see Table CZ- 1)

Empirical critical loads of nitrogen were compiled in 2010 (Skořepová 2010). The values of empirical critical loads were taken from Achermann and Bobbink (2003). At the end of the last year they were updated according to the new results of the workshop in Noordwijkerhout (Bobbink and Hettelingh 2011). The SEI map provided by the CCE was applied for mapping of empirical critical loads of nitrogen. Resulting map is shown in Figure CZ.1 (including grasslands). With data on nitrogen deposition (in 2008), kindly provided by the Czech Hydrometeorological Institute, exceedances of empirical critical loads could be elaborated as well (Figure CZ.2).

The maximum critical load of sulphur was calculated with the SMB model (UBA 2004):

$$CL_{max}(S) = BC_{dep} - Cl_{dep} + BC_w - Bc_{up} - ANC_{le,crit}$$

where

BC_{dep} = base cation deposition (Ca, Mg, K, Na)

BC_w = base cation weathering rate (Ca, Mg, K, Na)

Bc_{up} = base cation uptake (Ca, Mg, K)

Cl_{dep} = background deposition of Cl

$ANC_{le,crit}$ = critical alkalinity leaching

Chloride deposition on the background level was assessed on the base of data from the small forest catchments measured in 1994–2008. The value 1.58 mg l^{-1} Cl^- (as the median of all measurements) was used for the calculation of the background Cl^- deposition. Critical leaching values for alkalinity were computed according to the following equation:

$$ANC_{le,crit} = -Q \cdot (([Al]_{crit} / K_{gibb})^{1/3} + [Al]_{crit})$$

with

$[Al]_{crit}$ = critical limit for the forest soil solution (=0.2 mg l^{-1})

K_{gibb} = gibbsite constant

For estimating the CO_2 partial pressure and the organic acid concentration in the forest soils the methods described in Posch et al. (2005) were used.

Data sources

Table CZ.3 Spatial data used in the calculation of nutrient nitrogen critical loads.

Map	Source
SEI map of biotopes (2002)	CCE. Bilthoven
EMEP 5×5 km^2 grid (2010)	CCE. Bilthoven
Annual mean temperature (1960-1990)	Czech Hydrometeorological Institute, Prague
Annual mean precipitation (1960-1990)	Czech Hydrometeorological Institute, Prague
Annual mean deposition of base cations on a 2×2 km^2 grid (1995, 2001)	Czech Hydrometeorological Institute, Prague
Annual mean deposition of N on a 2×2 km^2 grid (2000-2008)	Czech Hydrometeorological Institute, Prague
Protected landscape areas and national parks (2006)	Agency for Nature and Landscape Protection, Brno (Ministry of the Environment)
Nature2000 areas. SPA and SAC Directives (2009)	Agency for Nature and Landscape Protection, Brno (Ministry of the Environment)
Soil map of the Czech Republic	Czech Agricultural University, Soil and Geology Dept., Prague

Figure CZ.1 Empirical critical loads for nitrogen for forest ecosystems including grassland.

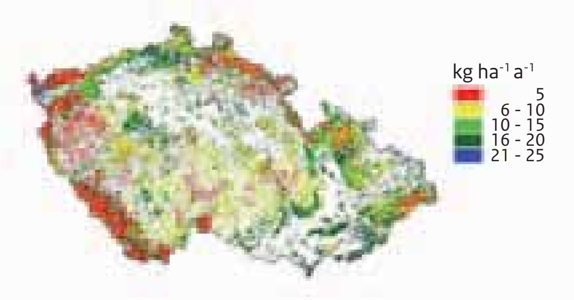
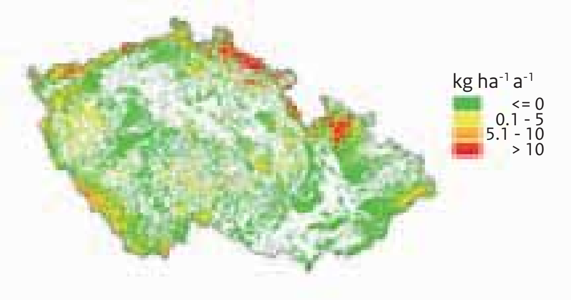


Figure CZ.2 Exceedances of empirical critical loads by atmospheric depositions of nitrogen in 2008.



Comments and Conclusions

The evaluation of critical loads of nitrogen and sulphur and empirical critical loads for nitrogen was carried out for forest ecosystems. The SEI map provided by the CCE was applied for mapping of the critical loads. The present database contents 6971 localities representing forest ecosystems. In comparison to the previous elaboration the database of critical loads is different mainly in using new nitrogen critical limits of soil solution, critical aluminium content in soils and background value for atmospheric deposition of Cl^-. Empirical critical loads for nitrogen have changed as well. Critical loads of nutrient nitrogen given by empirical critical loads are in the range from 5 to 20 kg $ha^{-1} a^{-1}$ (up to 25 kg $ha^{-1} a^{-1}$ including grassland). Atmospheric deposition of nitrogen exceeds the values of empirical critical loads for forest ecosystems in about half of the territory of the Czech Republic.

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Methods and data

Critical loads of nitrogen were determined for different habitat types within the Finnish Natura 2000 sites (Airaksinen and Karttunen 2001, Natura 2000, Metsähallitus 2010). A distinction was made between sites protected within the Birds Directive (SPA), the Habitats Directive (SCI) or by both directives simultaneously (SPA and SCI). The forming of Special Areas of Conservation (SAC) from the Sites of Community Interest (SCI) is under way in Finland. There are 468 sites reported to the Birds Directive and 1,713 sites for which the Habitats Directive applies. The SPA and SCI sites overlap to a large extent. Excluding double-counting because of the overlap, the SCI and SPA areas cover about 49,000 km^2 (12.5 % of Finland's area).

Landcover information for Finnish Natura 2000 sites was obtained from the 25m Corine2006 database (CLC2006-Finland 2009). Only area features of the Natura 2000-areas were included, not linear or point features. The landcover classes of the Corine 2006 database were interpreted to EUNIS habitats using expert judgment, in combination with indicative cross-references (Moss and Davies 2002).To distinguish between different mire habitats, the mire database of Metsähallitus, a Finnish forestry enterprise, was used. Information on freshwater nutrient status was also utilized, in accordance with the database of the Finnish Environment Institute for reporting within EU Water Framework Directive.

The landcover information was combined with the EMEP5 grid, provided by CCE. There are 6,308 EMEP5 grid cells covering Finnish territory. Within each EMEP5 grid cell, the

Table FI.1 Empirical CL N values used for Finnish Natura 2000 sites and total area per protection type.

	CLN_{emp}	SPA	SCI	SPA and SCI	Total area in Natura 2000 sites	Area CLN_{emp} exceeded (NAT2000)	AAE (NAT2000)
EUNIS code	**kg ha⁻¹ yr⁻¹**	**km²**	**km²**	**km²**	**km²**	**km²**	**kg ha⁻¹ yr⁻¹**
A2 Littoral sediments	20	8	3	61	72	0	0
B1Coastal dune and sand habitats	10			0.01	0.01	0	0
B1.3 Shifting coastal dunes	10		1	1	1	0	0
B1.4 Coastal stable dune grassland (grey dunes)	8		0.57	0.24	0.81	0	0
B1.5 Coastal dune heaths	10		0.22	0.06	0.28	0	0
B1.7 Coastal dune woods	10		0.82	0.23	1.05	0	0
B1.8 Moist and wet dune slacks	10		0.02	0.07	0.09	0	0
C1 Surface standing waters	3	14	105	122	241	52	0.30
C1.1 Permanent oligotrophic lakes	3	27	2,893	1,582	4,501	2,233	0.62
C1.3 Permanent eutrophic lakes	3	12	8	11	31	23	1.82
C1.4 Permanent dystrophic lakes	3	100	1,186	235	1,521	1,242	0.87
D1 Raised and blanket bogs	5	28	1,773	2,995	4,796	2	0
D3.2 Aapa mires	5	11	1,536	4,000	5,547	0	0
D4.1 Rich fens	15		4	1	5	0	0
E4.3 Acid alpine and subalpine grassland	5		1	100	101	0	0
F2 Arctic, alpine and subalpine scrub habitats	5		1,506	4,123	5,629	0	0
G1 Broadleaved deciduous woodland	10	4	950	1,389	2,342	1	0
G1.9 Non-riverine woodland with Betula	5		930	1,567	2,497	0	0
G3 Coniferous woodland	5	36	5,770	5,738	11,544	1,046	0.16
G4.2 Mixed taiga woodland with Betula	5	15	674	1,296	1,984	178	0.14
Total area		254	17,340	23,221	40,815	4,776	0.16

area for each protection category (SPA, SCI, SPA and SCI) was summed separately for each EUNIS habitat type. Areas smaller than 1 ha were not included. The total areas of each protection category in each EUNIS habitat are given in Table FI.1. Twenty different EUNIS habitat types were identified in the Finnish Natura 2000 sites.

Critical loads of nutrient nitrogen for Natura2000 areas

The values of empirical critical loads of nutrient nitrogen were based on the recommendations by the 2010 meeting in Nordwijkerhout (Bobbink and Hettelingh 2011, UNECE 2010). The lower values of the suggested ranges were used to reflect the sensitivity of northern boreal ecosystems.

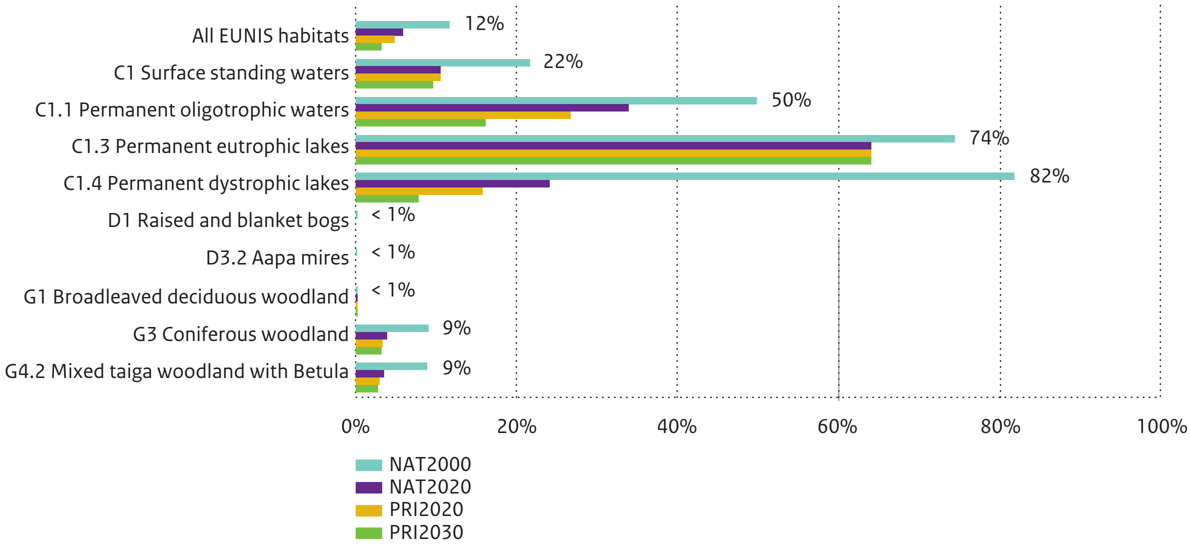
The translation of the Corine land cover classes into EUNIS habitats and the assignment of critical load values involved some challenges. The reasons were that not all habitat types in the Finnish Natura 2000 sites are well defined in the EUNIS classification, and recommendations for critical loads were not available for all habitats found in Finland. For example, no recommendations were given by Bobbink and Hettelingh (2011) for aapa mires. As we were not able to find evaluations or expert judgments of the nitrogen sensitivity of this habitat, we used the same critical load value 5 kg as was suggested for raised and blanket bogs (D1).

Peatland habitats were classified as D1 (raised and blanket bogs) unless they could be identified as aapa mires (D3.2) or rich fens (D4.1). Thereby habitats in class D1 in this exercise include unidentified open peatland habitats, and their total area is about threefold the total area of raised bogs in Finland.

Sites growing Mountain birch *(Betula pubescens ssp. czerepanovii)* were in this exercise classified as G1.9 Non-riverine woodland with Betula. We assigned a lower critical loads value (5 kg) than for other deciduous sites (G1 10 kg) because the Mountain birch sites experience short growing seasons, their biomasses are low and their decomposition rate slow.

Surface waters were classified as C1 (Surface standing waters) if there was not enough information on their trophic status to assign them to the subclasses (C1.1

Figure FI.1 Area at risk of eutrophication in Finnish Natura sites, expressed as percentage of total Natura 2000 protected area in each EUNIS class. NAT2000, NAT2020, PRI2020, PRI2030 represent comparisons with different deposition estimates.



oligotrophic, C1.3 eutrophic or C1.4 dystrophic). In the Natura 2000 sites, most waters are oligotrophic (4,501 km^2 in C1.1), distributed over the whole country. A small portion of protected lakes (31 km^2) are naturally eutrophic (C1.3), occurring mainly in clay soils in southern Finland. Natura 2000 sites include also many dystrophic lakes (1,521 km^2 in C1.4). These waters, which are rich in humic substances and often with a brown colour, are found in regions rich in peatlands. They occur throughout the country, with an emphasis on the central eastern parts. All surface waters were assigned the same empirical critical load (3 kg ha^{-1} yr^{-1}), which is proposed in Bobbink and Hettelingh (2011) for oligotrophic and dystrophic boreal, sub-Arctic and alpine lakes. Although Bobbink and Hettelingh (2011) did not discuss naturally eutrophic lakes, in this first Finnish analysis of empirical critical loads of nitrogen at Natura 2000 sites, these lakes were assigned the same low critical load (3 kg ha^{-1} yr^{-1}) as other boreal lakes. 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 nitrogen than other lakes.

Empirical critical loads of nitrogen of the Finnish Natura sites were compared to deposition estimates obtained from the CCE. The exceedance was calculated as the difference between the deposition and the empirical critical load, and assigned the value zero if the deposition was smaller than the critical load. The average accumulated exceedance (AAE) was calculated separately for each EUNIS class, by summing the area weighted exceedance values and dividing by the total area of the specific habitat type (Tables FI.1, FI.2).

The deposition estimates had been generated with the Source Receptor matrices used in integrated assessment under the LRTAP convention (Amann et al. 2010) according to NAT2000, NAT2020, PRI2020, PRI2030 and MFR2020 emission scenarios. The NAT2000 represents historic emissions and the NAT2020 national information about future economic projections as reported by the countries under the LRTAP convention, while the PRI2020 and PRI2030 are based on economic projections by the PRIMES model and MFR2020 assumes all feasible technologies being implemented.

In the comparison with the historic deposition (NAT2000), empirical critical loads were exceeded at 12% (4,776 km^2) of the area of the Finnish Natura sites (Table FI.1, Figure FI.1). The average accumulated exceedance (AAE) was 0.16 kg ha^{-1} yr^{-1} for all EUNIS classes together. The highest AAE (0.62–1.82 ha^{-1} yr^{-1}) values were obtained for surface waters, since they were assigned the lowest empirical critical loads. The high average exceedance for surface waters is accentuated in the case of eutrophic lakes, which are primarily located in the southern parts of the country, where also the nitrogen deposition is highest. Empirical critical loads are lower than the historic nitrogen deposition at dystrophic lakes over an area of 1,242 km^2. Of all habitat types in Finnish Natura 2000 sites, dystrophic lakes show the highest percentage of area exceeded (82%) (Figure FI.1).

Future status of protection against eutrophication is improving, judging by the comparison of empirical critical loads with estimated nitrogen deposition according to the emission scenarios NAT2020, PRI2020, PRI2030 and

Table FI.2 AAE Average accumulated exceedance (in kg ha^{-1} yr^{-1}) for empirical critical loads assigned per EUNIS class in Finnish Natura 2000 areas due to deposition scenarios NAT2000, NAT2020, PRI2020, PRI2030 and MFR2020.

EUNIS	NAT2000	NAT2020	PRI2020	PRI2030	MFR2020
C1	0.30	0.11	0.10	0.08	0
C1.1	0.62	0.14	0.11	0.08	0
C1.3	1.82	0.85	0.77	0.68	0
C1.4	0.87	0.09	0.07	0.06	0
D1	< 0.01	0	0	0	0
D3.2	< 0.01	0	0	0	0
G1	< 0.01	0	0	0	0
G3	0.16	0.05	0.05	0.04	0
G4.2	0.14	0.04	0.03	0.03	0
Total	0.16	0.04	0.03	0.02	0

Table FI.3 Area exceeded (in km^2) for empirical critical loads assigned per EUNIS class in Finnish Natura 2000 areas due to deposition scenarios NAT2000, NAT2020, PRI2020, PRI2030 and MFR2020.

EUNIS	NAT2000	NAT2020	PRI2020	PRI2030	MFR2020
C1	52	26	26	23	0
C1.1	2,233	1,523	1,198	721	0
C1.3	23	20	20	20	0
C1.4	1,242	367	240	117	0
D1	1.6	0	0	0	0
D3.2	0.03	0	0	0	0
G1	0.7	0	0	0	0
G3	1,046	461	399	373	0
G4.2	178	69	61	54	0
Total	4,776	2,466	1,942	1,309	0

Table FI.4 Area exceeded (in % of total area in each EUNIS class in Finnish Natura 2000 sites) for empirical critical loads due deposition scenarios NAT2000, NAT2020, PRI2020, PRI2030 and MFR2020.

EUNIS	NAT2000	NAT2020	PRI2020	PRI2030	MFR2020
C1	22	11	11	10	0
C1.1	50	34	27	16	0
C1.3	74	64	64	64	0
C1.4	82	24	16	8	0
D1	< 1	0	0	0	0
D3.2	< 1	0	0	0	0
G1	< 1	0	0	0	0
G3	9	4	3	3	0
G4.2	9	3	3	3	0
Total	12	6	5	3	0

MFR2020 (Figure FI.1, Tables FI.2 and FI.3). The NAT2020 and PRI2020 result in rather similar AAE (Table FI.2) and exceeded areas, while PRI2030 is quite close to these, entailing, however, somewhat further decrease in AAE and exceeded areas. Compared to NAT2000, the area where deposition is higher than empirical critical loads is almost halved by decreasing deposition to NAT2020. Only MFR2020 deposition is low enough to protect the habitats of all EUNIS classes in the Finnish Natura 2000 sites.

Nitrogen effects on biological diversity

In the European perspective, nitrogen deposition to Finnish natural conservation areas is low (Vuorenmaa 2004). In the Finnish vegetation zones, nitrogen is a limiting nutrient and nitrogen fertilization experiments have mostly been carried out primarily to investigate the response of forest growth and wood biomass to high doses of nitrogen addition, or to examine the effect on nitrogen on soil and tree nutrient status (Saarsalmi and Mälkönen 2001, Derome et al. 2009).

Vegetation responses to additions of low levels of nitrogen have been reported for Finnish conditions mainly in combination with the analysis of acidification (Shevtsova and Neuvonen 1997). In these studies, an increase in the amount of grasses and a decrease in the amount of lichens were observed in response to the addition of nitrogen. There was also an impact on the berries, especially *Vaccinium vitis idae* carried fewer berries. Changes in soil microbiota were also recorded (Pennanen et al. 1998). Mäkipää (1998) found that the biomass of mosses decreased and their nitrogen concentration increased due to the addition of ammonium sulphate.

The first assessment of threatened habitat types in Finland concluded that 188 of the studied total 381 habitat types and complexes were threatened (Raunio et al. 2008). The most significant reasons for habitat types being threatened were forestry, drainage for forestry, eutrophication of water bodies, clearing of agricultural land and water engineering. Eutrophication due to nitrogen in deposition was considered a contributing threat for Baltic coastal sand beaches, coastal dune types, Baltic esker islands, barren heath forests, xeric and sub-xeric heath forests, esker forests, inland dune forest, and rock and dry meadows. An increase in vegetation biomass has been observed in these habitat types, as well as a decrease in plant species typical to nutrient-poor sites (Raunio et al. 2008).

In a publication that describes the application to Finland of the red list Criteria issued by the International Union for Conservation of Nature, Rassi et al. (2010) report that 10.5% of the evaluated species were classified as threatened. The overgrowing of open habitats is a cause of threat and threat factor especially for species living in open and semi-open areas in esker forests. The slopes of eskers have been taken over by forest, and open sun-exposed areas have been badly invaded by higher vegetation, which has forced more narrow-niche flora and fauna to make way for them. Nitrogen deposition and the paucity of forest fires are considered to increase the nutrient level in such areas. Air pollution, including nitrogen deposition, is also considered a threat for slow-growing, rootless bryophytes and lichens on rock outcrop surfaces (Rassi et al. 2010).

In the preliminary results from a survey of understorey vegetation in a subset of Finnish ICP Forests Level I plots, Salemaa et al. (2010) report a slight increase in the number of species in herbs and graminoids in Southern Finland. They compared species richness and their percentage cover in 1985-86, 1995 and 2006 on plots in 443 forested mineral soil sites across three biogeographical zones in Finland. The report indicates a decrease in the cover of ground lichens on nutrient-poor and xeric sites in the whole country (Salemaa et al. 2010). The accumulation of low annual loads of nitrogen deposition during the last decades may have caused some eutrophication in vegetation, while the main causes for the vegetation changes are found in forest management practices and in natural succession of the stands. In Northern Finland reindeer grazing has probably contributed to the decrease in lichen cover (Salemaa et al. 2010).

Heino and Paasivirta (2008) examined patterns in the biodiversity of non-biting midges across a boreal drainage basin. They found that species diversity generally increased with stream size, macrophyte cover and suspended solids, and decreased with increase in particle size and moss cover. Although the species diversity was primarily accounted for by stream size, the physical and chemical principal components, including nitrogen, also explained significant variation (Heino and Paasivirta 2008).

In a fertilization experiment to examine methane and nitrous oxide fluxes from a boreal *Sphagnum fuscum* pine bog, Nykänen et al. (2002) observed an increase in percentage coverage of cotton grass (Eriophorum vaginatum) with nitrogen addition 30 or 100 kg NH_4NO_3-N ha^{-1} (Nykänen et al. 2002).

Manninen et al. (2011) showed that N-fertilization (four levels) increased the relative biomass of evergreen dwarf shrubs and graminoids whereas *Vaccinium myrtillus* decreased in the field experiment in a subarctic mountain birch forest. The N response of graminoids was higher in disturbed than in undisturbed plots.

In their comparison of historic plant species lists from surveys in the 1930s and1940s to lists compiled in 1996–2004, von Numers and Korvenpää (2007) report a strong influence of succession and environmental change on the flora in the SW Finnish archipelago. Shade-tolerant and perennial species preferring high nitrogen and water availability, but with less requirement for cultural impact have increased over the study period. Increased eutrophication has influenced the floristic composition of the islands in the study region by favouring species of productive habitats (Von Numers and Korvenpää 2007). The eutrophication of the Baltic Sea has led to increasing shore species occurrences (Hannus and Von Numers 2010).

Summary

Critical nitrogen load values were assigned to Finnish Natura 2000 sites. The total area for which critical nitrogen load values were assigned was about 40,000 km^2. Not all habitat types in the Finnish Natura 2000 sites are well defined in the EUNIS classification, and recommendations for critical loads were not available for all habitats found in Finland. There are many Finnish studies that report impacts of nitrogen on soil and vegetation but these results are not easily interpreted to support or refute specific critical load values to protect biodiversity. In general the Finnish nitrogen addition studies or vegetation surveys indicate that nitrogen, together with changing climate and land use has had an impact on the biodiversity. National assessments list nitrogen in deposition as a threat to habitats and species in nutrient-poor sites (Raunio et al. 2008, Rassi et al. 2010). In this exercise the critical load values were chosen in accordance with evaluations reported by Bobbink and Hettelingh (2011) in combination with considerations to account for the northern conditions of short growing season and slow decomposition rates.

Empirical critical loads are exceeded at 12% of the area of Finnish Natura 2000 sites, with deposition according to NAT2000. Emission scenarios NAT2020, PRI2020 and PRI2030 would decrease the AAE to below 0.1 kg $ha^{-1} yr^{-1}$ as well as the area exceeded to below 10% of the total area of the habitat types in the Natura 2000 sites in this analysis. Only the MFR2020 scenario would protect all Natura 2000 sites in Finland.

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Introduction

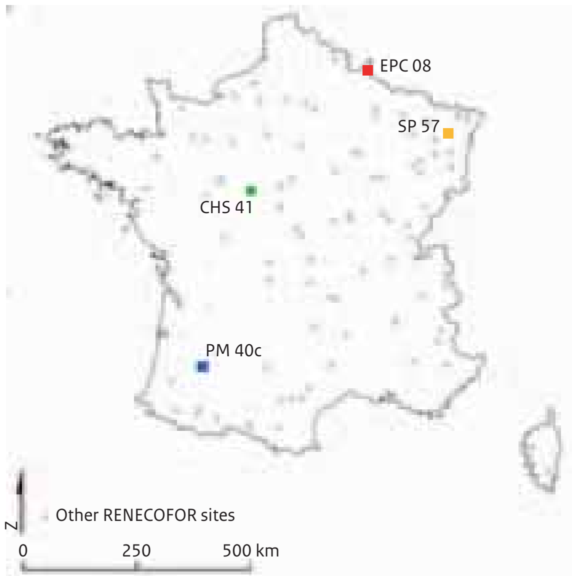
The objectives of the 2010 Call for Data were: (i) to run coupled biogeochemical-vegetation models: VSD+Veg and ForSAFE-Veg, (ii) to submit updated modelled and empirical critical loads values for nitrogen on the 5×5 km² EMEP grid, (iii) to report preliminary results about connecting NFC's to the Natura 2000 national network.
The French NFC currently test the feasibility of applying two dynamic models (ForSAFE and the new version of VSD+) on various forest sites conditions (characterized by different climatic conditions, soil physico-chemical properties such as C/N ratio and pH, nitrogen deposition, vegetation types, ...). The VSD+ and ForSAFE models are coupled to the plant-list Veg-table in order to evaluate the plant responses to nitrogen deposition and to calculate the nitrogen critical loads. In this way, a French Veg-table (233 species) has been set up by French and international experts to take into account the diversity of plant species in French ecosystems. This modelling approach was applied in complement to empirical methods for assessing the vulnerability of French ecosystems to nitrogen deposition.
The VSD+ and ForSAFE-Veg models were performed on four well documented forest sites belonging to the French ICP Forest network (RENECOFOR, National network of heath forest survey from the National Forest Office): CHS41, EPC08, SP57 and PM40c (see Figure FR.1 and Table FR.1). The main N deposition and climatic characteristics are presented in Table FR.2.

Methods and Data

The VSD+ model

The data of the four intensively documented forested sites from the RENECOFOR (belonging to the ICP-Forest) were computed according to the VSD+ methodology. The VSD+ model requires data for a lot of parameters (see Annex FR.1). VSD+ is especially made for use on a regional/national scale (Bonten et al. 2009) and includes modelled carbon and nitrogen cycles.

Figure FR.1 Location of the selected sites.



The inputs data for VSD+ were mainly extracted from the French RENECOFOR network and the French critical loads databases. To ensure regional application of VSD+, the EMEP deposition data (NO_x, NH_y, S) have been used. Base cations deposition data (Ca, Mg, K and Na) were from the RENECOFOR sites.
The initial state of the model corresponds to the early state of the present-day woodland. At this stage, the model needs data for the following parameters: C/N ratio, C and N pool, BS etc. Since no measured initial data were available, the model generated those data using a Bayesian calibration method. The factor of mineralization (rf_min), nitrification (rf_nit) and denitrification (ref_denit) due to moisture and temperature have been evaluated using the MetHyd model developed with VSD+. Mean vegetation growth and litter production were considered as constant over time to calculate vegetation growth. Indeed, a growth function can be calculated in different ways depending on data available on biomass production and harvest. In the future, a logistic growth function might be used as described in the VSD+ manual to take into account human activities like uptake and harvest of wood, and tree growth.

Figure FR.2 shows the trends in C and N pool, C/N ratio, Base Saturation, Al^{3+}, Al/BC ratio and pH over 200 years (1900-2100) depending on the early state of the present-day woodland in the sites.
As can be seen, C and N pool trends are well predicted for the four selected sites if we refer to the good agreement between observed and predicted values. The C and N pool are both increasing continuously despite the decreasing in N deposition by the nineties; nevertheless for two sites (EPC08 and PM40c, the youngest forest), the C pool

Table FR.1 Input data for the selected sites.

Parameter	CHS41	EPC08	SP57	PM40c
Period simulated	1900-2100	1960-2100	1941-2100	1980-2100
Thick cm	0.3	0.3	0.3	0.3
Bulkdens $g.cm^{-3}$	1.183	1.004	1.38	1.024
Theta m/m*	0.3051	0.3776	0.2279	0.2133
CEC $meq.kg^{-1}$	39.6	52.22	26.67	32.56
bsat_0 %	-1	-1	-1	-1
Cpool_0 $g.m^{-2}$	1853.1206	3004.0530	556.2957	3756.3945
CNrat_0 g/g	14.241	13.313	14.241	24.544
TempC °C *	11.05	8.609	8.307	12.87
Percol $m.yr^{-1}$ *	0.1759	0.586	0.3729	0.584
Ca_we $eq.m^{-3}.yr^{-1}$	0.00774	0.00304	0.00026	0.00016
Mg_we $eq.m^{-3}.yr^{-1}$	0.0018	0.00038	0.0018	0
K_we $eq.m^{-3}.yr^{-1}$	0.00146	0.00042	0.0013	0.00014
Na_we $eq.m^{-3}.yr^{-1}$	0.00988	0.00766	0.00048	0.00012
Bsaobs $eq.m^{-3}.yr^{-1}$ **	0.1854	0.039	0.1348	0.3402
Cpoolobs $g.m^{-2}$ **	5732	4937	2240	4544
Npoolobs $g.m^{-2}$ **	299.8	294.4	119.472	179.52
CNratobs g/g **	19	17	18.75	26
pHobs **	4.4	4.1	4.1	4.45
dominant species	*Quercus petraea* (L.)	*Picea abies* (L.)	*Abies alba* (Mill.)	*Pinus pinaster* (Ait.)

* Calculated with the MetHyd model; ** Measured values in 1995

Table FR.2 Mean annual N depositions ($meq.m^{-2}.yr^{-1}$), precipitation ($mm.yr^{-1}$) and air temperature (°C) for the selected sites.

Site	NO_x-N mean 1993–2008	NH_y-N mean 1993–2008	Precipitation mean 1993–2007	Air temperature mean 1993–2007
CHS41	3.8	18.8	679	11.4
EPC08	16.17	53.74	1262	8.8
SP57	8.26	17.72	1256	9.0
PM40c	3.8	11.4	993	13.0

increases faster in relation to the rapid growth of the coniferous stimulated by the "fertilizer input" (high nitrogen deposition corresponding to the period of trees plantation). This increasing pattern corresponds to that described by Bonten et al. (2009). However, this result could also be related to some specific input such as modifying factors of mineralization (rf_min), nitrification (rf_nit) and denitrification (ref_denit). These parameters are probably not well estimated and they largely affect the C/N ratio. Further studies are needed in order to improve these input estimations, especially by using adapted French meteorological data (missing sunshine data) to calibrate these parameters using MetHyd model.
In all sites, the C/N ratio is increasing at the beginning of the simulations and even before the period of increasing N deposition. This may be interpreted as a significant N uptake by the young vegetation for growing. In PM4oc, the increase is less significant may be in relation to available N content in soil following the high N deposition at this period (1981). In agreement with the significant increase in C pool, C/N is increasing in EPC8 and PM4oc, but the ratio decreases by 1980 in CHS41 and SP57, which are characterized by soils with a low nitrogen mineralization (Brêthes et al. 1997).
The increasing N deposition leads to the acidification of the four soils, as shown by the simulated pH and BS pattern. Regarding acidification process, the impact of N deposition seems more important than the influence of the vegetation and the soil type, as already shown by Moncoulon et al. (2007). With a lower deposition level, PM4oc shows the lowest perturbations. Indeed, the model underestimates the soil pH values for all sites (except for PM4oc), but base saturation remains well predicted.
The first runs of VSD+ on the selected sites show rather well calibrated and realistic results. However, it is needed (i) to improve the estimation of some of the key input parameters, like the "growth function" for accurate prediction of C and N dynamics in soil-plant system; (ii) the meteorological inputs adapted to French conditions to determine reduction functions for mineralization and (de) nitrification using MetHyd; (iii) soil pH calibration. For that purpose, new calibration data will be available soon since

Figure FR.2 VSD+ simulation output (continuous lines) for the selected sites and corresponding simulated EMEP nitrogen deposition. Circles indicate measured data (1995).

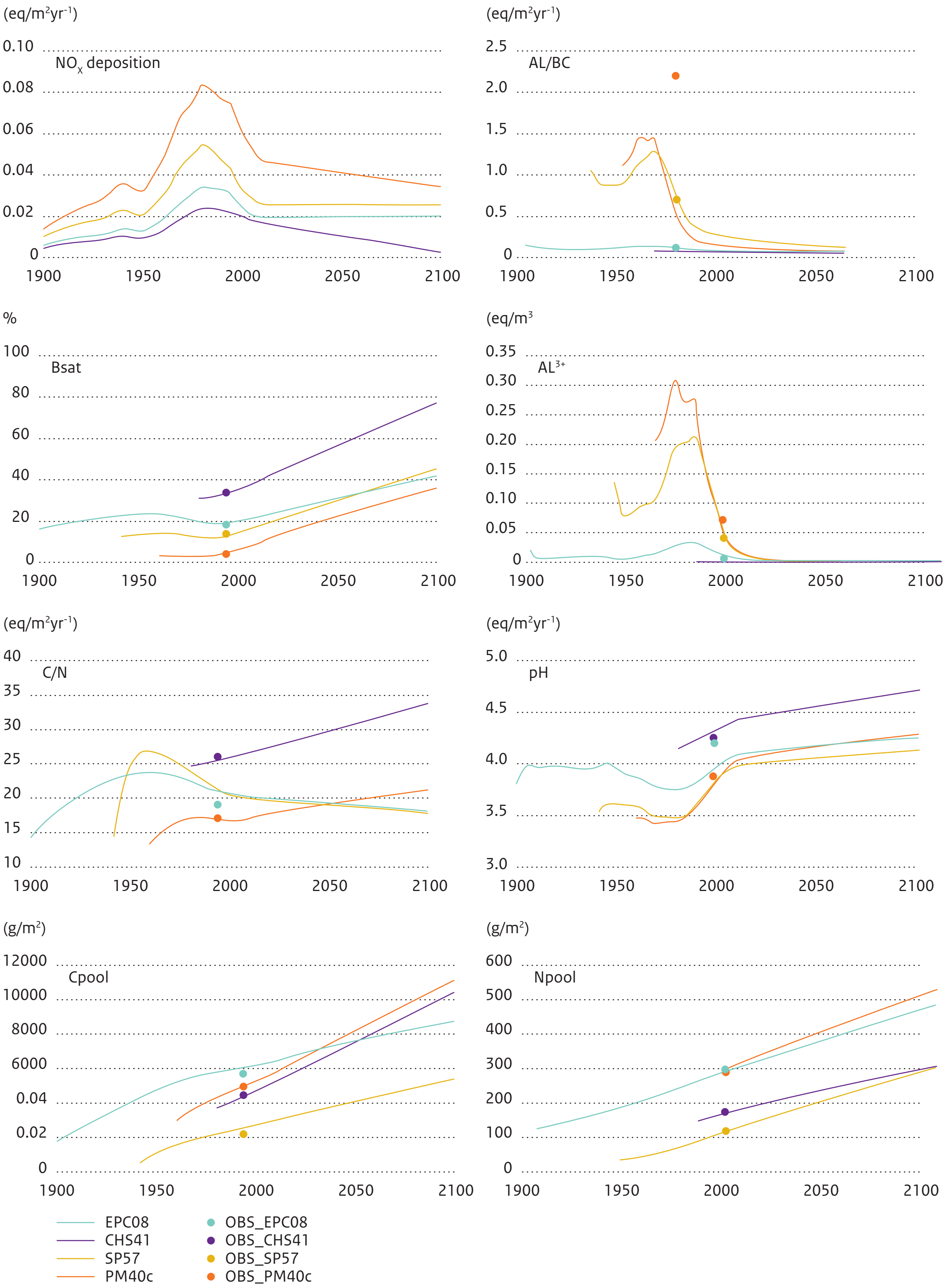
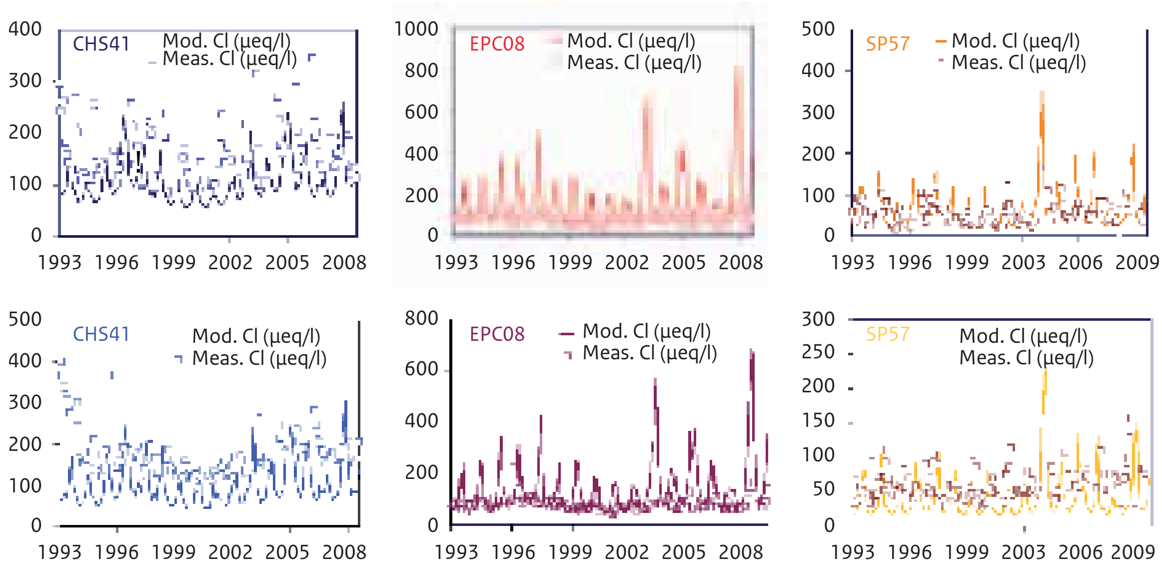


Figure FR.3 Predicted (continuous lines) and measured (squares) Na and Cl concentrations in soil solutions between 1993 and 2009 for the selected RENECOFOR Sites (CHS41, EPC08 and SP57).



recent samplings have been done on the ICP Forest network. We must keep in mind that the underestimation of simulated soil pH may influence the VSD+Veg outputs presented below.

ForSAFE

The French NFC has run ForSAFE model for the previously selected sites (except for PM40c because of the lack of data on soil solutions) in collaboration with Swedish researchers. ForSAFE-Veg was then applied using the French Veg-database to perform trials on one of the forested sites.

Before applying the ForSAFE-Veg platform, it was needed to calibrate ForSAFE on the French forest sites. The assessment of model performance consists in the comparison between predicted and observed values (Belyazid et al. 2006, 2010). The concentrations of Na^+ and Cl^- (µeq/l) were used to calibrate the hydrological ForSAFE module since they are powerful tracers in those types of soils (Figure FR.3). Calibration was performed on the first 20cm of soil depth. Measured input data and soil solutions data from the sites are available since 1993. The main results of this calibration procedure is that the model is quite well calibrated for base line data but despite some model improvements, overestimations of concentrations peaks (EPC08 and to a lesser extent SP57) or some underestimations (i.e. for CHS41) are still observed. Moreover, for some data, there is still a lag time between modelled and measured data. If this delay remains a problem to be solved at a seasonal scale, it can be admitted for year and longer time scale simulations. The discrepancy between site behaviours might be explained by the differences in deposition levels (i.e. in EPC08, Na and Cl deposition was twice that measured in CH41). Some improvements, are still needed in ForSAFE to better constraint the hydrological processes linked to water horizontal fluxes, topography, and the mineralization of twigs and barks supposed to influence the low BC predicted values (data not shown).

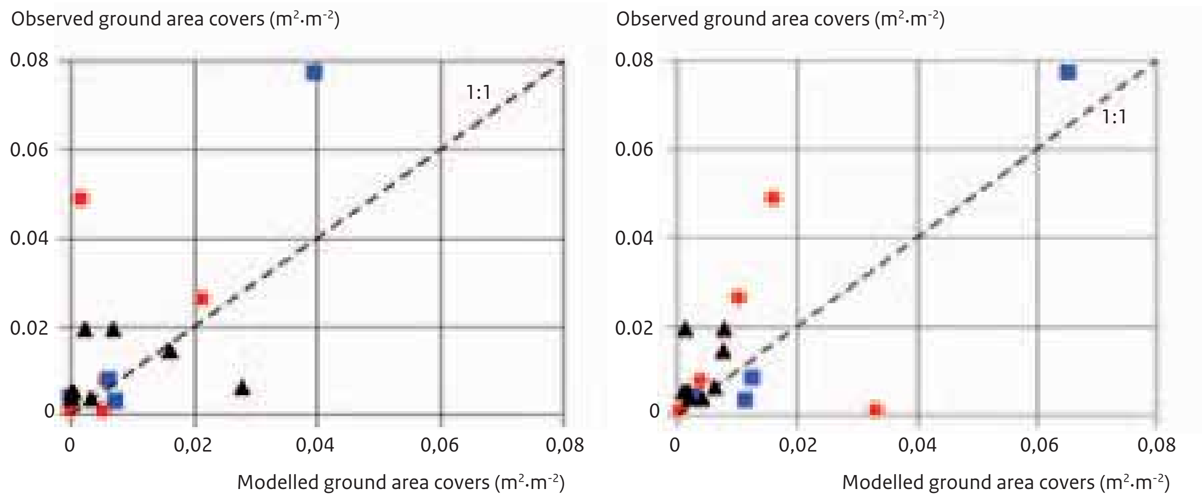
The French vegetation database

The French scientists have contributed greatly to the development of the species list "Veg table". More than 230 species were added to the initial Sweden and Switzerland plant list in order to represent the vegetative diversity of French ecosystems. This database is now included in the Veg-European database.

The extension of the species list for France was set up during a dedicated workshop with vegetation experts in October 2009. Relevant species were chosen to represent the various French forest ecosystems on the basis on expert knowledge. The objective was to have a good representation of common and/or characteristic species of the main French ecosystems. For each plant added to the plant list already documented for Sweden and Switzerland, the Veg-parameters have been completed compiling several sources of data. For some parameters, the link between existing databases and the Veg-parameters needed a scale calibration (such as "nitrogen classes based on C/N ratio", "pH" and "temperature", which were obtained from Ecoplant database, Gégout et al. 2005).

- The delay time done in years, based on average generation time and lifespan was drawn from the French Flora (Rameau et al. 1989, 1994, 2008) and expert opinions.

Figure FR.4 Modelled and observed ground area cover of plant groups: grasses (red dots), herbs (blue squares), and mosses (black triangles) for CHS41 site using FORSAFE-Veg (left) and VSD+Veg (right).



- The promoting nitrogen classes were based on C/N values extracted from the Ecoplant database (Gégout et al. 2005) and adapted to the Veg classes. For the missing species of Ecoplant, the information was found in the French Flora (Rameau et al. 1989) and using the Ellenberg parameter N (Julve 1998).
- The retarding nitrogen, the water and the light response classes were deduced from the French flora (Rameau et al. 1989).
- The lowest pH value was from Ecoplant database and from the French Flora when missing (Rameau et al. 1994).
- The temperature minimum: the lowest annual average temperature when the plant can start taking ground, was extracted from the Ecoplant database and from the French Flora when missing (Rameau et al. 1994).
- The effective shading height was deduced from the French Flora (Rameau et al. 1989). For trees and shrubs, the height was considered only for seedling with a standard height of 0.1.
- The browsing based on the food palatable classification was extracted from literature, pastoral floras (Dorée 1995, Morelleta and Guibert 1999, Bruneton 2001, Gusmeroli et al. 2007, Boulanger et al. 2009) and expert advice.

Comparison of observed and simulated data for ForSAFE-Veg and VSD+Veg

Plants from the French Veg-table have been classified into main group types (grasses, herbs, mosses and lichens). As a comparison purpose, ForSAFE-Veg and VSD+Veg were run on the CHS41 site. The observed and modelled data of the ground area covers of the different plant groups are compared in Figure FR.4. Among all the species predicted by ForSAFE, only 17 species are observed in the site relevés. More than 80 species predicted by ForSAFE are indeed not observed in the field. Unlike ForSAFE-Veg, VSD+Veg model predicts only the percentage of occupancy of plant species and not the number of species that are matched by the model and observed in the site. For this reason, only the 17 species predicted by ForSAFE were used to compare to the VSD+Veg model outputs. The results indicate that the two models underestimate the occurrence of certain herbs (such as *Hedera helix L.* and grasses (such as *Holcus mollis L.*). Moreover, the presence of certain mosses (such as *Dicranella heteromalla Hedw.*) is overestimated by ForSAFE-Veg, whereas others are underestimated by VSD+Veg (such as *Polytrichum formosum Hedw.*) (Figure FR.4).

These results might indicate that some improvements are needed regarding: (i) pH and C/N, which are the main driving parameters for both models influencing the occurrence of vegetation species (Gégout et al. 2005); (ii) the adjustment of some parameters in the Veg-table such as pH and temperature.
A new meeting between French and Swedish experts is planned in order to discuss about improvements of the French Veg-table and of ForSAFE-Veg models. We propose also to test a new modelling approach based on the definition of ecological functional groups. Therefore, the vegetative response of functional groups to N deposition may represent a rigorous method for results interpretation.

Evaluation of simulated vegetation changes by ForSAFE-Veg and VSD+Veg

Figures FR.5 and FR.6 indicate the simulated changes in the ground vegetation plant groups occurrence (% of the total of the whole simulated plant groups) as predicted by the two models between 1900 and 2100 at site CHS41.

Figure FR.5 Evolution of plant group occurrence (% of occupancy) at the RENECOFOR site CHS41 between 1900 and 2100 as simulated by ForSAFE-Veg (left) and VSD+Veg (right).

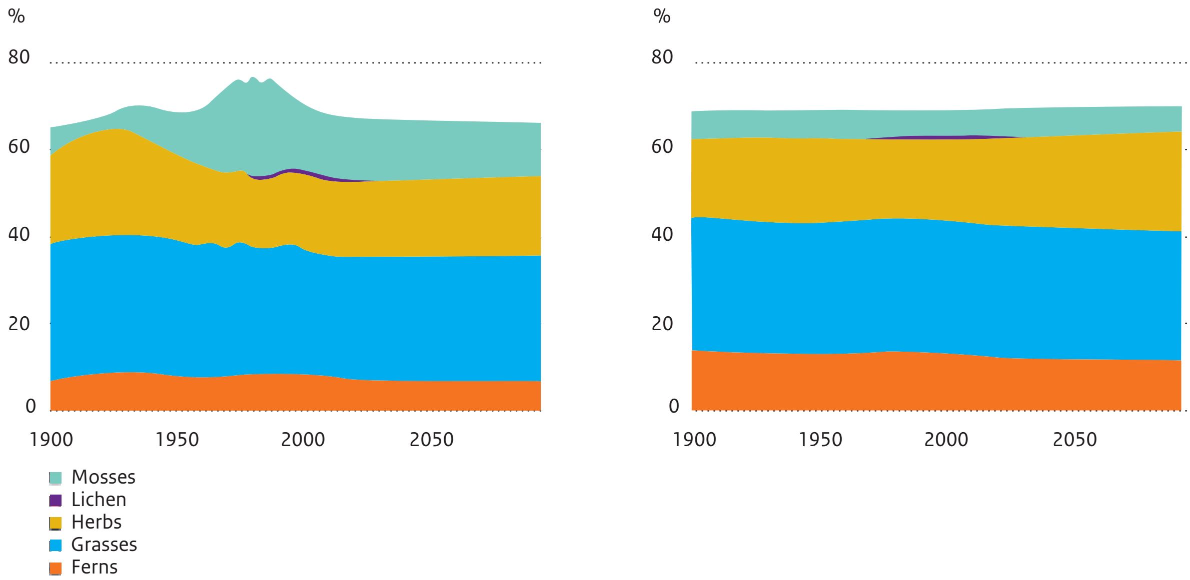
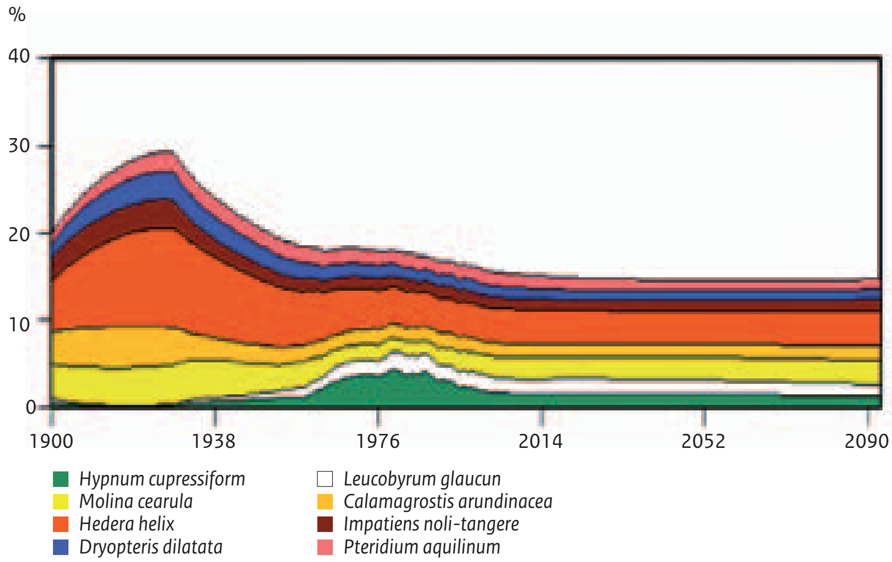


Figure FR.6 Evolution of some species occurrence (% of occupancy) representing the main plant groups at the RENECOFOR site CHS41 between 1900 and 2100 as simulated by the ForSAFE-Veg model.

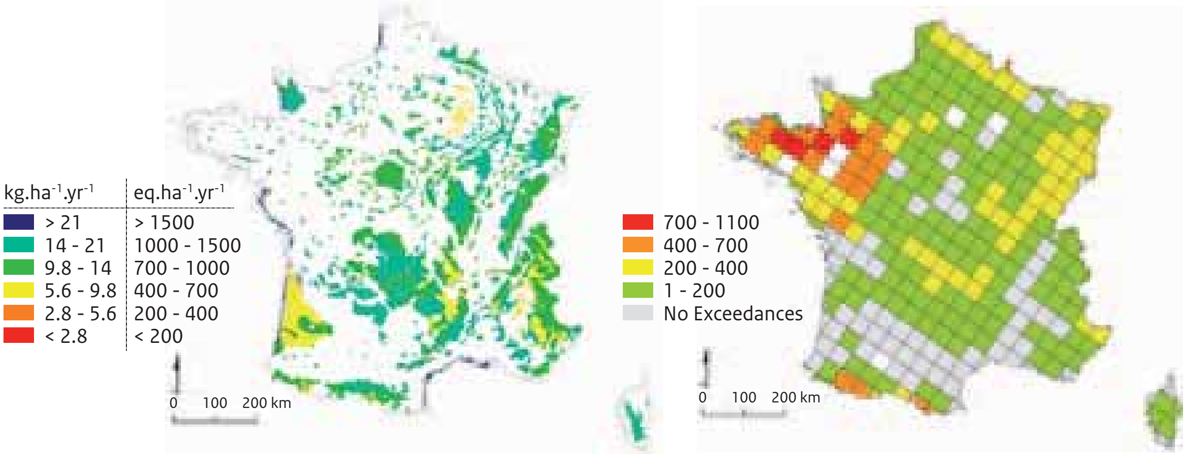


ForSAFE-Veg model indicates some variations in the occurrence percentage of the plant groups between 1968 and 2002. This plant response may be related to the high increase in N deposition between 1960 and 1980 (Figure FR. 1). Particularly, the mosses occurrence has increased significantly from 4% in 1930 to 21% in 1984. This might indicate that this vegetation group is sensitive to N deposition. Thus, it make it appropriate to detect the influence of the variation in N deposition as previously reported in the literature (Armitage et al. 2011, Xiao et al. 2010, Poikolainen et al. 2009).

On the other side, no significant changes in the occurrence percentage of plant groups were observed by running the VSD+Veg model (Figure FR.5). This might indicate that the model is less sensitive than ForSAFE-Veg to simulate tenuous vegetation changes. Further investigations are needed in order to compare the performance of the two models on other sites.

Nevertheless, we have chosen to classify the species according to dominant plant groups. This may have diluted the response to N deposition of certain species in plant groups. Figure FR.6 shows the changes in the occupancy percentage of some selected species belonging to the dominant ground plant groups: mosses (*Hypnum*

Figure FR.7 Empirical critical loads for nutrient nitrogen for French forest sites (left) and average accumulated exceedances (AAE) for Natura 2000 forest sites in 2010 (right).



and *Leucobyrum*), grasses (*Molina* and *Calamagrostis*), herbs (*Hedera* and *Impatiens*) and ferns (*Dryopteris* and *Pteridium*) as simulated by ForSAFE-Veg. Herbs and grasses are dominant between 1920 and 1930. This could be related to the behaviour of nitrogen and carbon pool and to site reforestation (Ponce et al. 1998). We can also spot, the increase of the occurrence of all the species in relation to the increase in N deposition (1960-1980). Particularly the mosses response to N deposition as previously described (Figure FR.5) is very well observed (Figure FR.6). The changes in species occurrence is about 2% for *Leucobyrum* and about 4% for *Hypnum* from 1900 to 1980, which corresponds to the maximum of N deposition.

This testing of the ForSAFE-Veg and VSD+Veg models showed that it is realistic to simulate the link between N deposition and vegetative diversity. More investigations are needed in order to improve the estimation of certain input parameters such as the growth function parameter for VSD+ and BC and some hydrological parameters for ForSAFE (Belyazid et al. 2006). However, ForSAFE-Veg model seems more sensitive at the site scale but since VSD+Veg is supposed to simulate the N deposition impact at the regional/national scale, this step has to be tested. Indeed, the good agreement obtained between simulated and measured soil data is encouraging. The numerous input data needed to run ForSAFE-Veg may be a strike for its application and also it may induce large uncertainties in data output (Wallman et al. 2005). For that reasons, we are currently testing the model robustness by a sensitivity analysis on 15 RENECOFOR sites. The advantage of this modelling approach is obviously the long-term assessment of N deposition impact on the vegetative diversity (Wallman et al. 2005).

Nitrogen effects on biological diversity

Empirical nutrient nitrogen critical loads for French forested ecosystem

Calculation of critical loads for nutrient nitrogen has been updated using the new 5×5 km² EMEP grid. The combination of the 50×50 km² EMEP grid and the French ecosystem map produced about 12,000 entities. The combination with the new 5×5 km² grid leads to 28,336 entities. The precision of exceedances calculations at the national scale will thus be improved.

Calculation of empirical critical loads for nutrient nitrogen for forest ecosystems was extracted from previous investigations done by the French NFC (Party et al. 2001) and adapted in 2008 (Probst and Leguédois 2008). This work (presented in Figure FR.7) was based on the potential vegetation map at the national scale (Party 1999), temperature data, frost period data, and base cation availability data evaluated by expertise. A new vegetation map for France has recently been performed. The empirical loads will be calculated within a few months after having redrawn ecosystem mapping based on the more precise vegetation map. The update criteria defined for Empirical N critical loads for natural and semi-natural ecosystems will be applied (Bobbink and Hettelingh 2011).

Empirical nutrient nitrogen for French Natura 2000 sites

Critical loads for French Natura 2000 sites (forests) have been calculated using empirical loads for French ecosystems and with decision rules to bridge the gap of classifications between EUNIS hierarchical classes, Natura 2000 specific classification and dealing with uncertainties in their relations (Moss and Davies 2002). Because of classification and spatial unit differences, the critical load methodology had first to be adapted for application to Natura 2000 sites to assess and map the sensibility of these forests SACs (Special Area of Conservation under the

Habitat directive). The results indicate that critical loads for Natura 2000 sites are more sensitive to nutrient nitrogen deposition than forest ecosystem units at the country scale. At this stage, Average Accumulated Exceedances calculated for both Natura 2000 and French ecosystems show that Natura 2000 sites are particularly under pressure of nitrogen deposition, particularly in the western part of France and the Pyrénées mountains. Natura 2000 ecosystems are specially threatened habitats; thus, this comparison underlines the differences between protected areas and ordinary ecosystems and of there representativness at the national scale regarding objectives of atmospheric pollution reduction. Indeed these two evaluations correspond to two different levels of environmental risks (ordinary vegetation / protected habitats).

Improvements could be done according to a common methodology and using updated empirical critical loads. Calculation for grasslands ecosystems should be also performed. AAE needs to be calculated according to future deposition scenarios and for all types of ecosystems. The French NFC is in contact with French Natura 2000 administrators, especially with the Ministry of Ecology and the Natural History National Museum (in charge of the mapping and the network database).

Outlook

The French NFC has begun to evaluate the sensibility and applicability of the available biogeochemical soil models and vegetation models. This is done according to the scale of application of the models and considering the available input data in the conditions of the large variety of French forest ecosystems. The aim is to assess the biodiversity response and biogeochemical soil responses to nitrogen deposition, in the way of CCE objectives, at various scales in order to apply the most relevant soil-vegetation chain model at the national scale.

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Critical loads of sulphur and nitrogen for terrestrial ecosystems

The German NFC provided an update of the national critical load data for the steady-state mass balance approach. Critical loads are calculated in accordance to the Call for Data (see Appendix A) and following the methods described in the Mapping Manual (ICP Modelling & Mapping 2010). About 35% of German territory is covered by forests and other (semi-)natural vegetation for which critical loads of acidity and nutrient nitrogen are computed (see Table DE.1). The German critical load database consists of 124,868 records. A source description for updated input data is given in Table DE.2.

As additional information the protection status of all grid cells with critical loads was checked. The European Habitats Directive (SAC) applies to about 37.1% of all mapped grids. SPA areas cover 23.7% of the grid cells and other national nature protection programmes applies at 26.8% of the receptor area (Table DE.3).

Critical loads of acidity, $CL_{max}(S)$ and $CL_{max}(N)$
The calculation of critical loads of sulphur and nitrogen for forest soils and other (semi-)natural vegetation was conducted according to the simple mass balance equations (eqs. 5.22 and 5.26) of the Mapping Manual. For base cation and chloride deposition the 3-year means (2005–2007) were included in order to smooth large

Table DE.1 Selected receptors for critical load computation in Germany ('Others' are EUNIS classes with a proportion of the receptor area below 1%).

EUNIS Code	Proportion of receptor area [%]	Proportion of German territory [%]
G4.6	14.7	5.15
G3.1C	10.2	3.57
G1.91	10.0	3.48
G1.63	9.6	3.34
G1A.16	8.8	3.08
G1.61	8.7	3.05
G3.42	7.8	2.74
G1.87	5.4	1.87
G1.66	5.2	1.81
G4.8	3.6	1.26
G3.1D	3.1	1.09
G4.71	2.0	0.71
G1.41	2.0	0.70
G1.65	1.4	0.50
G4.4	1.1	0.39
G1.221	1.0	0.35
Others	5.4	1.86

variations of this parameter due to meteorological influences.
In comparison with the 2008 data submission only small changes can be observed concerning the critical loads of acidity in terms of sulphur (Figure DE.1) and in terms of nitrogen (Figure DE.2). This is mainly caused by the updated deposition data for base cations and altered weathering rates in the new German soil map. In the new dataset $CL_{max}(S)$ have a wider range of values and show less overall ecosystem sensitivity. Ecosystems with high risk for acidification (sensitivity below 1 keq ha^{-1} a^{-1}) were identified for about 20% of receptor area (30% in 2008).

Critical loads of nutrient nitrogen, $CL_{nut}(N)$

The calculation of critical loads of nutrient nitrogen is described in detail in the Mapping Manual (eq. 5.5). Applying the updated values of acceptable N concentrations in soil solution (update of the Mapping Manual in 2008) a national approach was derived using the vegetation period for assignment of different numbers in the range of concentration values (NFC 2007). The regional distribution of critical loads of nutrient nitrogen is shown in Figure DE.3.

Critical loads exceedances

The critical load values were compared with the national deposition data (at a 1×1 km^2 grid) to determine exceedances and trends over the period 1990–2007 as well as the gap to the protection target of 2020 (MAPESI 2011). A main target of the National Strategy on Biological Diversity (BMU 2007) is to protect all natural ecosystems against acidification and eutrophication.

The positive effects of measures against air pollution within the last two decades are clearly detectable. On more than half (55%) of the receptor area the critical loads of acidification were not exceeded in 2007. Sulphur is no longer the major threat for the ecosystems. On the remaining ecosystems the extent of the critical load exceedance has been significantly reduced compared to the results from the 90's. The critical load exceedances in 2020 are expected to be exclusively caused by nitrogen deposition (Figure DE.5 left).

Table DE.2 Sources of updated input data for critical load computation.

Description	Institution	Reference
Corine Land Cover 2006 (CLC2006)	Federal Environmental Agency (UBA), DLR-DFD	UBA, DLR-DFD 2009
Soil map of Germany, BÜK1000N version 2.3	Federal Institute for Geosciences and Natural Resources (BGR)	BGR 2008
Special conservation areas under Habitats Directive and special protection areas under Birds Directive (NATURA 2000)	Federal Agency for Nature Conservation	BfN 2010
National base cation deposition on a 1×1 km^2 grid	Federal Environmental Agency (UBA)	MAPESI 2011

Table DE.3 Protection status.

Protection program	Covered area of Germany [%]	Proportion of the receptor area [%]
Special Protection Area (SPA), Birds Directive	5.7	9.9
Special Area of Conservation (SAC), Habitats Directive	4.0	23.3
SPA and SAC	4.7	13.8
National Nature Protection Program	29.6	26.8

Figure DE.1 $CL_{max}(S)$.

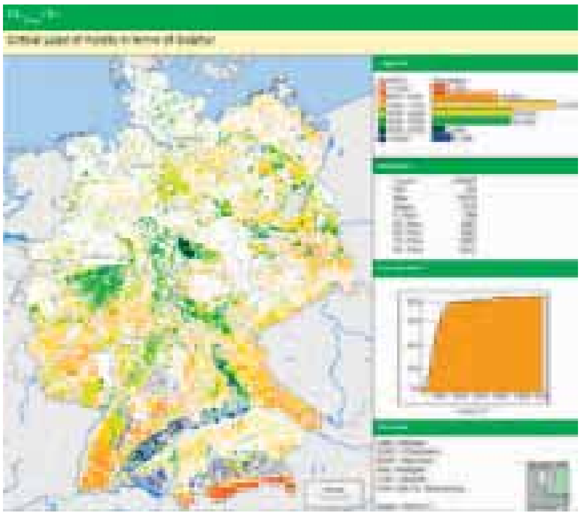


Figure DE.2 $CL_{max}(N)$.

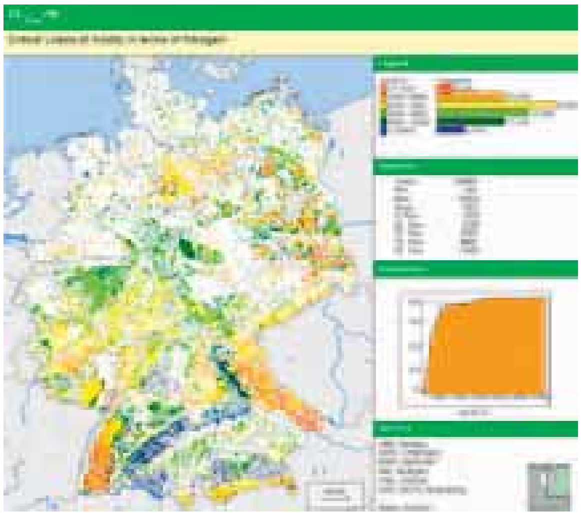


Figure DE.3 $CL_{max}(S)$.

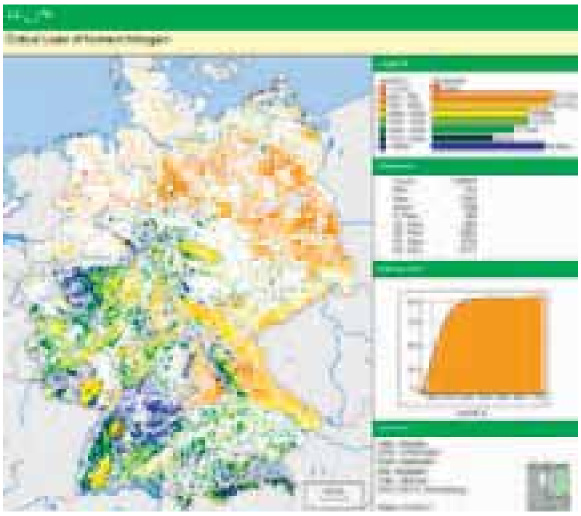


Figure DE.4 $CL_{max}(N)$.

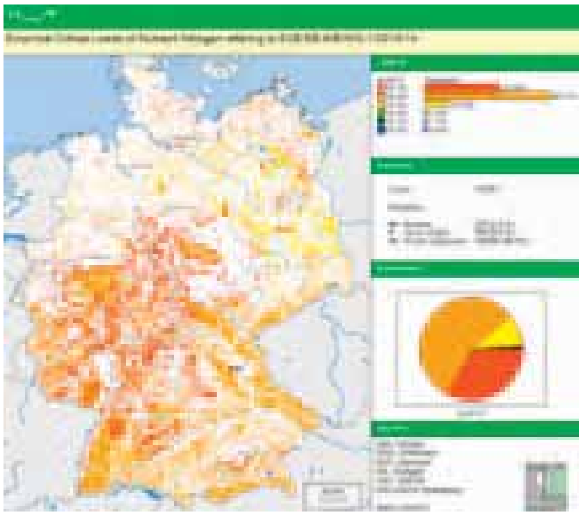
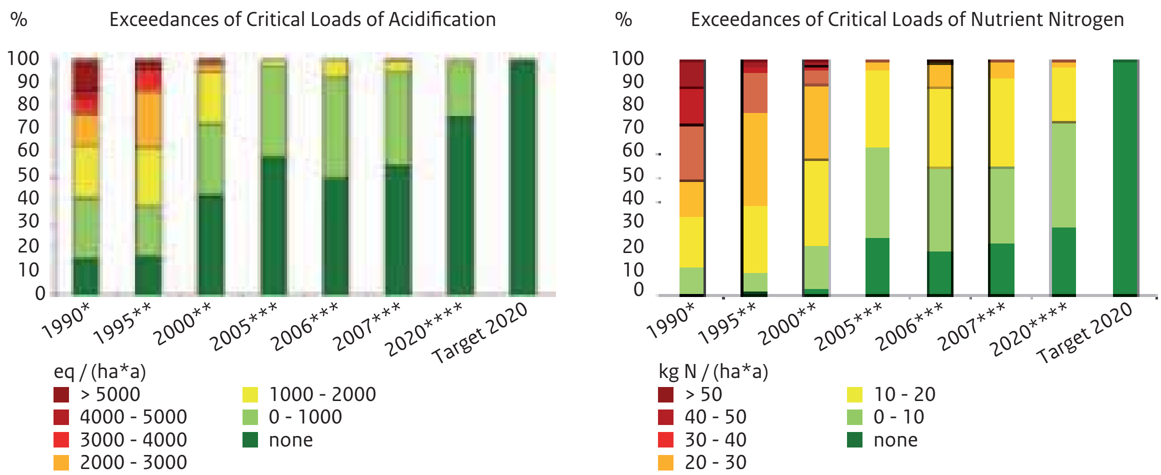


Figure DE.5 Critical load exceedances for acidification (left) and eutrophication (right).



Source: Research projects of the Federal Environmental Agency UBA. * FKZ 200 85 212(2004), ** FKZ 204 63 252 (2008), *** FKZ 3707 64 200 (2011), **** projection FKZ 351 01 081 (2011), protect all ecosystems is a national CBD target for (BMU).

The trend of deposition of nitrogen is also declining, but in contrast to the sulphur deposition the exceedance of critical loads is still evident. A further advance in the protection of ecosystems from acidification and eutrophication can only be achieved by measures to reduce nitrogen inputs. Only 22.5% of the sensitive ecosystems were protected from eutrophication in 2007 and 45% of the receptors were affected by more than 10 kg N ha^{-1} a^{-1}, even 7% by more than 20 kg N ha^{-1} a^{-1} above the critical load value (Figure DE.5 right). The goal to protect all sensitive ecosystems in 2020 against acidification and eutrophication will be accessible only with extreme effort to reduce nitrogen.
The availability of critical loads and critical load exceedances for the NATURA 2000 habitats in Germany are useful tools to determine N effects on biodiversity.

Empirical critical loads of nitrogen

In addition to the calculation of critical loads with the steady-state mass balance approach empirical critical loads of nitrogen, $CL_{emp}(N)$, were assessed for the national dataset. $CL_{emp}(N)$ ranges were derived in accordance to the methods described in the "Overview of empirical critical loads for N deposition to natural and semi-natural ecosystems" (UNECE 2010) and the recommendations of the recently updated background document (Bobbink and Hettelingh 2011). The German empirical critical load database consists of 105,381 records of 1×1 km^2 grids. A regional distribution of this dataset is shown in Figure DE.4. Nearly all (99%) empirical critical loads of nitrogen range between 10 and 20 kg N ha^{-1} a^{-1}.

Site-specific Soil and Vegetation Model Runs on Selected Plots

Description of Selected VSD+ Sites in Germany

The German NFC participated in the test run of the new VSD+ model with its improved nitrogen and carbon cycles (Bonten et al. 2011). The VSD+ model was applied to 16 sites in Germany. All plots are sites of the ICP Forests Level II program.

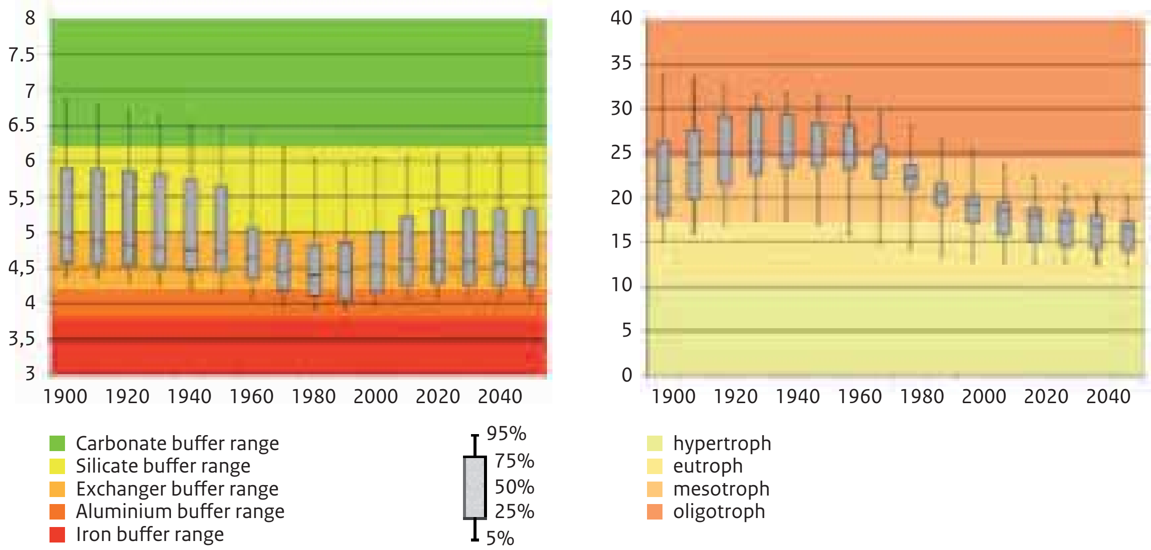
The 16 chosen sites represent 12 different soil classes and 3 different vegetation types (see Table DE.4). They are also located in quite different landscapes and climate regions (see Figure DE.6). The German sites for the VSD+ model application represent not only different ecosystems but also different environmental and soil chemical conditions. The selected plots are also located in regions with different levels of air pollution. The deposition of nitrogen (values for 2007) ranges from 14.1 kg N $ha^{-1}yr^{-1}$ (Site 706) to 41.4 kg N $ha^{-1}yr^{-1}$ (Site 303). The deposition of sulphur varies between 369 eq $ha^{-1}yr^{-1}$ (Site 1302) and 1032 eq $ha^{-1}yr^{-1}$ (Site 303). The deposition of the base cations varies in the same manner (MAPESI 2011).
Since the Level-II plots had measurements for pH values (except plot 507), this parameter was one of the most important factors for the VSD+ internal Bayesian calibration. Eight parameters were calibrated (mainly chemical exchange constants and C:N describing parameters). Where available, the carbon pool, C:N ratio and base saturation were used for the calibration as well.

Figure DE.6 Selected sites for the VSD+ model in Germany.

Table DE.4 Vegetation types of selected sites for testing the VSD+ model in Germany.

Model code (veg-type)	Vegetation type	German test sites (Site ID)
1	spruce	303, 305, 802, 808, 1404, 1605
2	pine	1206
4	broadleaf hardwood	301, 304, 507, 601, 602, 606, 706, 903, 1302

Figure DE.7 pH value (left) and C:N ratio (right) modelled with the VSD+ model.



Input parameters

The data set for deposition was derived by data from the MAPESI project (MAPESI 2011). Even though the project provides several time steps only the values for 2007 were chosen. These values were used to create modelled nitrogen deposition time series, where the originally given times series of the VSD+ model was the reference. The same was done for the sulphur deposition. The parameter 'growth function' was set to include 3 parameters: yearly vegetation growth, yearly litterfall and yearly harvest (all in kg $m^{-2} yr^{-1}$). The values for these 3 parameters were estimated for each vegetation type. The yearly harvest parameter was set to zero since the chosen sites are not harvested.

The estimation of the weathering rates of the base cations was not trivial and should be discussed. Since the original input data (data requests of previous calls) were given in eq $ha^{-1} yr^{-1}$ and now the unit for VSD+ was asked as eq $m^{-3} yr^{-1}$ a transformation of the units was necessary. This transformation was done by using the German soil classification BÜK1000N (BGR 2008) and the soil depths of their reference profiles. The combination of the known depth and the weathering rates (in eq $ha^{-1} yr^{-1}$) produces weathering rates of base cations in eq $m^{-3} yr^{-1}$, as required. The water content of the soil, the percolation and modifying factors of the nitrification, denitrification and mineralization was derived, applying the "MetHyd" (v1.3) tool proposed by the CCE.

Results

The C:N ratio as indicator for nutrient balance shows an interesting trend. In the starting year (1900) two plots were in a eutrophic condition (C:N between 10 and 17), 7 plots mesotrophic (C:N between 17 and 24) and 7 plots in an oligotrophic condition (C:N above 24). The current situation (modelled values for 2010) differs markedly: 6 eutrophic, 9 mesotrophic and one oligotrophic site. The prediction for the year 2050 follows this trend: 9 eutrophic and 7 mesotrophic sites. Figure DE.7 (right) shows that with this decreasing trend also the range will be narrowed in future.

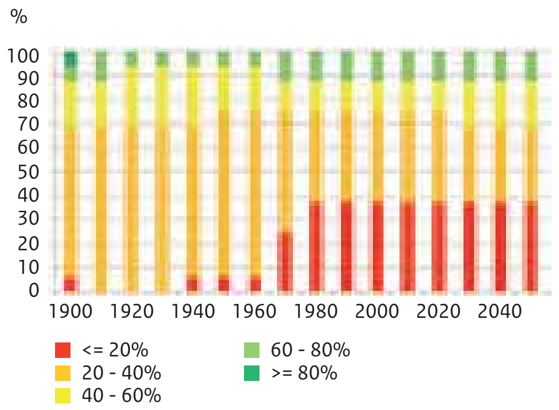
The trend of the modelled pH value can be split into two phases. The first one reaches from 1900 to 1980 and shows decreasing pH values for almost every site. Six plots have a strong decrease, where the pH value in the year 1980 is much lower than in 1900. Nine plots have a rather slight decrease. The change of the pH value on plot 1302 is nearly constant. The second phase of the pH trend reaches from 1980 till 2050 and shows more diverse trends. Two plots seem to recover and have a strong increase of the pH value. Ten plots have only a slight increase of the pH value. There is no change on 3 plots and 1 plot shows further (slight) decrease. The overall trend of decreasing pH values (till 1980) and a recovery (starting 1990) is displayed in Figure DE.7 (left). Of course one should use this overall evaluation carefully since it has to be analysed separately for each plot and each buffer class.

The development of the parameter base saturation (EBc) also shows different results. Figure DE.8 shows cumulated bar charts to illustrate the shift in the proportion of the different base saturation classes. It seems that the major changes happened till 1980 when the class of base saturation below 20% increased a lot. This change happens mostly at the expense of the class above (20–40%). The proportion of base saturation classes doesn't change much between 1980 and 2050.

The BERN model

The modelling results of the VSD+ model were also used to establish a link to a biological response model. The chosen model is the BERN model and C:N ratio and base

Figure DE.8 Base saturation modelled with VSD+.



saturation were used as main drivers for this model. The other possible drivers (soil water content, climatic water balance, vegetation period, solar radiation, temperature) were kept constant for this approach. One plot (606) with the best data availability regarding deposition, soil data and vegetation composition was selected for a case study. Figure DE.9 shows the output of the VSD+ for C:N ratio and base saturation.

The BERN model was used to calculate the possibility of existence for different tree species (Figure DE.10). *Fagus sylvatica* is the dominant species on this plot with coverage over 60% on the top tree layer. *Acer pseudoplatanus* and *Fraxinus excelsior* are also present on the top tree layer on this plot but with a rather small share in the total coverage. *Ulmus glabra* was found in the ground vegetation layer as spontaneous sowing and will be important for the further analysis.

One main approach of the BERN model is to link the current existing plant composition to the natural or pristine plant community of the site under consideration. These plant communities are well defined regarding constant species, characteristic species and their assumed

Figure DE.9 C:N ratio (left) and base saturation (right) modelled with the VSD+ model for plot 606.

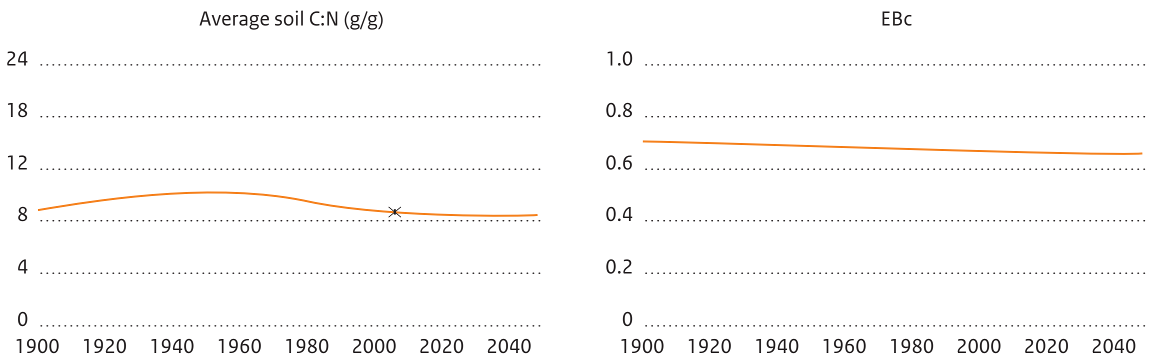


Figure DE.10 BERN modelled values for the possibility of existence for several plant tree species.

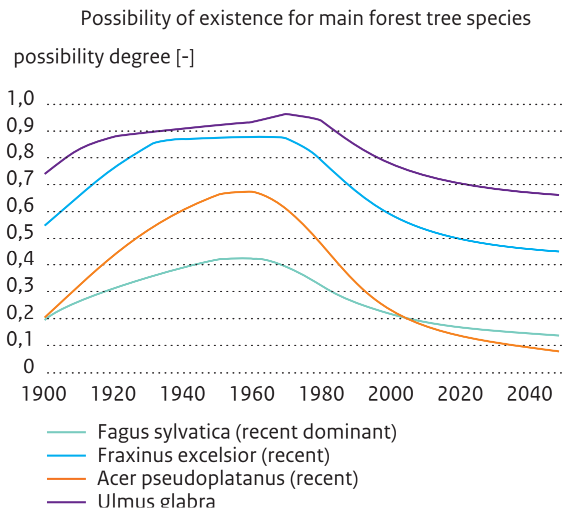
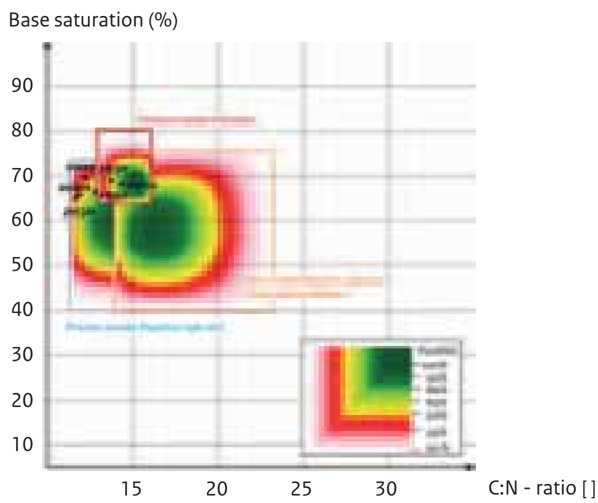


Figure DE.11 Results of the BERN model on plot 606.



occupation on the different vegetation levels. Knowing the ecological niches of obligatory plant species and combining those the BERN model computes values which can be used as indicator for the vitality of the assumed plant community. The results of such computation are shown in Figure DE.11. The change of values for C:N ratio and base saturation derived by the VSD+ model are displayed (marks and modelling year) in combination with the possibility of existence/vitality of three different natural or pristine plant communities that could occur under these conditions. *Fraxino excelsi-Fagetum sylvatici* was selected because its association of plant species is the best match compared to the given plant survey. The plant species listed in the vegetation survey matching with 54% the idealistic plant composition of the chosen plant community. The other plant communities *Mercuriali-Fagetum sylvatici (Convallaria-subass.)* and *Fraxino excelsi-Ulmetum* were selected because they show a response to the current site factor combination and have *Fagus sylvatica* as main tree species as well.

The method described above creates two indicators to evaluate the sustainability of the recent plant composition and therefore the capability of preserving biodiversity and sustaining function and services of the ecosystem. The first indicator is the comparison of the plant survey with a natural or pristine plant community. The better the match the higher is the degree of naturalness. Of course this matching should be weighted so that basic plant species (like main tree species) are more important than other plants with smaller influence on ecosystem functions. The second indicator is the calculation of vitality for the chosen natural plant community. The higher the value the better is the community adapted to the recent or projected site factor configuration. The better the adaptation the better are the capabilities developed to resist short term ecological stress or to adapt to long term ecological stress (e.g. air pollution, climate change).

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The 2010 Call for Data issued by the International Cooperative Programme on Modelling and Mapping was composed of four objectives: to (a) increase the resolution of (existing) critical loads, (b) apply revised empirical critical loads following (UNECE) workshop, Noordwijkerhout (the Netherlands), June 2010, (c) continue work on an extended very simple dynamic model (VSD+) and vegetation modelling, and (d) encourage NFCs to relate to national habitat experts.

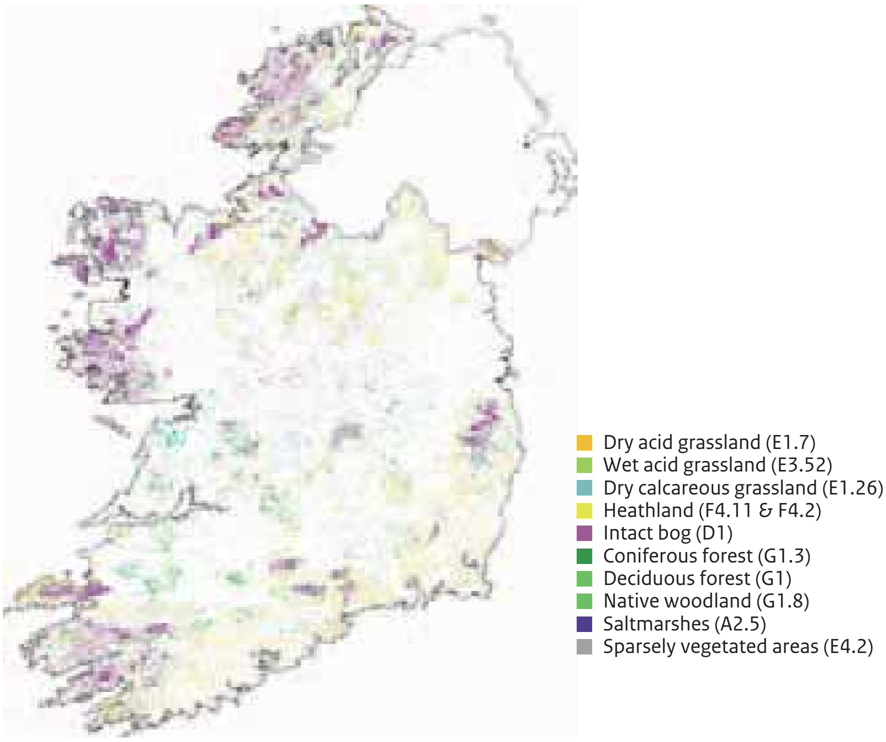
The Irish NFC submitted a response on three components as outlined below.

High resolution critical loads: In response to the 2010 'call for data', national critical loads were completely revised to accommodate newly available high resolution mapping data layers. The national subsoils map (6 themes, 1:50,000) and the indicative soils map (25 classes, 1:100,000–1,150,000) were combined with CORINE 2000 (level 6) and CORINE 2006 (level 3) to derive a new (wet-dry acid-basic) receptor ecosystem habitat map (see Figure IE.1) for mapping critical loads of acidity and nutrient nitrogen for Ireland. The indicative soils and subsoils map underlie the weathering rate and soil process parameters used in the steady-state mass balance critical load models.

Empirical critical loads: Empirical critical loads of nutrient nitrogen were assigned to all receptor ecosystems under the critical load habitat map (see Figure IE.1) based on output from the 'Workshop on the Review and Revision of Empirical Critical Loads and Dose-response Relationships', Noordwijkerhout (The Netherlands), June 2010 (Bobbink and Hettelingh 2011). The revised (mapped) empirical critical loads of nutrient nitrogen have been discussed with the UK NFC during several bilateral meetings (13 August 2010, 16 February 2011 and 17 April 2011).

National habitat experts: On February 14, 2011, a meeting between the National Parks and Wildlife Service (NPWS,

Figure IE.1 Receptor ecosystem habitat map derived from the Teagasc-EPA Soils and Subsoils Mapping Project, and CORINE 2000 and 2006 (URL: gis.epa.ie).



i.e., national habitat experts) and the Irish NFC (David Dodd [EPA] and Julian Aherne [Trent University]) was held to discuss potential linkages between critical load and habitat reporting. The meeting provided a valuable opportunity to discuss linkages with reporting requirements under article 17 of the EU Habitats Directive. However, owing to significant workloads and lack of staff resources, engagement on critical loads is not seen as a priority by NPWS; given advance notice and a specific proposal, future engagement may be possible.

Future activities: The NFC will continue to update the national critical loads database, incorporating revised (updated) base cation deposition, base cation uptake and soil percolation (using MetHyd model) and including critical loads for surface waters based on the freshwater acidity balance model. In addition, activities will focus on developing capacity on nutrient nitrogen and plant diversity, i.e., evaluating statistical relationships between soil chemistry and plant relevé data, and assessment of linked dynamic biogeochemistry-vegetation models.

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Introduction

In response to the Call for Data, Italy submitted mass balance critical loads of acidification and nutrient nitrogen. The methodology adopted for the critical load calculation is the steady-state mass balance approach (UBA 2004).

The critical load calculations have been performed by ISPRA (Institute for Environmental Protection and Research) and ENEA (National Agency for New Technology, Energy and Sustainable Economic Development) that support the Ministry for the Environment. A general revision and upgrading of the critical load database has been carried out, in order to downscale the results to the 5×5 km^2 EMEP grid. A further upgrade is the identification of protected areas by Habitat Directive, Bird Protection Directive and National Directives.

Sources for database compilation

The information about ecosystems distribution was derived from Corine Land Cover 2000 database (APAT 2004) and the National Vegetation Map (Ministero dell'Ambiente 1992). Ecosystems were subsequently classified according to the EUNIS habitat nomenclature (16 first levels and 29 second level classes) (see Table IT.1). Temperature and precipitation data were derived from maps of the Public Work Ministry, and updated to the year

Table IT.1 EUNIS classification for ecosystems.

Level 1	Level 2	Ecosystem description
B1	4	Coastal stable dune grassland
B3	3	Rock cliffs, ledges and shores, with halophytic angiosperms
E1	2	Perennial calcareous grassland and basic steppes
E1	3	Mediterranean xeric grassland
E1	5	Mediterranean mountain grassland
E1	8	Mediterranean dry acid and neutral closed grassland
E2	3	Mountain hay meadows
E4	3	Acids alpine and subalpine grassland
E4	4	Calciphilous alpine and subalpine grassland
F2	3	Subalpine and oroboreal bush communities
F5	2	Maquis
F7	4	Hedgehog-heaths
G1	6	Woodland (Fagus)
G1	7	Thermophilous deciduous woodland
G1	8	Acidophilous (quercus)-dominated woodland
G2	1	Mediterranean evergreen (quercus) woodland
G3	1	Abies and picea woodland
G3	4	Pinus silvestris woodland south of the taiga
G3	5	Pinus nigra woodland
G3	7	Lowland to montane Mediterranean Pinus woodland
G4	6	Mixed Pinus sylvestris – acidophilous Quercus woodland

2000, while base cation depositions were provided by ENEL (Italian Electricity Generating Board). Information regarding soil characteristics was extracted from EUROSOILS European database (JRC, Ispra). Atmospheric depositions were provided by EMEP. The spatial resolution of the critical load maps is the 5×5 km^2 EMEP grid. Italy is fully covered by 6325 cells. Information regarding ecosystem protection was derived from Ispra (2011) (Figure IT.1).

Critical load data sources and methods for ecosystems in Italy

In table IT.2 parameters employed to calculate Critical Load and relative sources and references are shown.

Conclusion

Data point out a low to medium sensitivity of the Italian peninsula to acid deposition, with some more sensitive areas located in the Alpine and in the Appennino regions. Several provinces however show large areas of non-sensitive soils.

Figure IT.1 Protected areas by Habitat Directive (left), Bird Directive (centre) and National Protection Law (right).

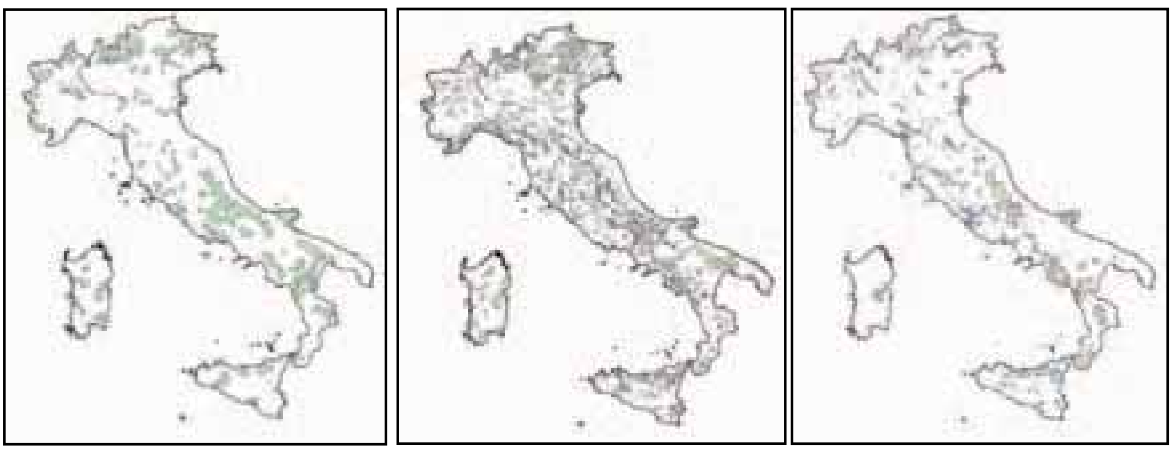

Table IT.2 Parameters and their sources used for critical load calculations.

Parameter	Unit	Method	Reference
Protection		Call for data instruction	ISPRA 2011
EUNISCODE			APAT 2004
cNacc	meq m^{-3}		Bobbink et al. (1998), Berendse et al. (1987)
crittype	1	Assumption	
critvalue	1	Assumption	
thick	m		EUROSOILS (1999)
bulkdens	g cm^{-3}		FAO (1981)
Cadep, Mgdep, Kdep, Nadep	eq ha^{-1} a^{-1}		Nilsson and Grennfelt (1988); De Vries et al.(1993)
Cldep	eq ha^{-1} a^{-1}		EMEP
Cawe, Mgwe, Kwe, Nawe	eq ha^{-1} a^{-1}		EUROSOILS (1999), UBA (2004)
Caupt, Mgupt, Kupt	eq ha^{-1} a^{-1}		Inventario forestale nazionale italiano (IFNI), Giordano (1955)
Qle	mm a^{-1}	$Q_{le,zb} = P-E_i-E-_sf_{Et,zb}\cdot E_t$	DeVries et al. (1991), Michalzik et al. (2001)
lgKAlox	3	Assumption	
expAl	8	Assumption	
pCO_2fac			Brook et al. (1983)
Nimacc	eq ha^{-1} a^{-1}		Rosen et al. (1992), Sogn et al. (1999)
Nu	eq ha^{-1} a^{-1}	$N_u = kgr \cdot r_{st} \cdot (ctN_{st} + f_{r,st} \cdot ctN_{br})$	Kimmins et al. (1985), De Vries et al. (1990), Rosén (1990), Reinds et al. (2001), Jacobsen et al. (2002)
fde			De Vries et al. (1993), Reinds et al. (2001), Carta Italiana dei Suoli

Ecosystem sensitivity to nutrient nitrogen is, for a large extent, comparable to that of acidity. The areas with the highest sensitivity are located in Sardinia and Sicily and their sensitivity is mainly due to low nitrogen uptake rates of forest ecosystems. Some sensitive areas can be observed also in Tuscany although most of the ecosystems in this region are classified as non-sensitive.
Results of the mapping activity point out an overall low sensitivity of Italian soils to acid depositions. On the other hand, large areas with forest ecosystems are sensitive to nitrogen atmospheric deposition, with possible eutrophication risks (nitrogen saturation).

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Introduction

This report presents recent results of the calculations of critical loads and exceedances of nitrogen and sulphur compounds in Lithuania.

Methods and data sources

Critical loads of nutrient nitrogen (N) as well as sulphur (S) and N acidity were calculated with the Simple Mass Balance (SMB) model as described in the Mapping Manual (UBA 2004, chapter 5). Essentially, default values (ranges) described in UBA (2004) have been used for the individual terms in the SMB model. Values for the acceptable N concentration were taken from Table 1 in De Vries et al. (2007).

Critical loads of S and N, both contributing to acidification of ecosystems, and their exceedances were derived and mapped in a large scale exercise for forest soils (deciduous, coniferous and mixed forest), natural grassland, acidic fens, heathland and mesotrophic peat bogs in Lithuania. Each ecosystem has its specific sensitivity against the air pollutants, which is expressed by (the) critical load value(s). To identify this, the geographical information from the CORINE land cover database has to be overlapped with spatial information on soil and climate. In combination with the General Soil Map of Lithuania and climate data conclusions on the vegetation structure of the land cover types can be drawn and the net biomass production can be derived.

The EMEP Eulerian acid deposition model output has been used as deposition of N and S compounds in Lithuania.

Critical load and exceedance maps

Annual critical loads and total (dry and wet) deposition velues of oxidized sulphur, oxidized and nutrient nitrogen were mapped on the 50×50 km^2 EMEP grid. Critical loads for Lithuania ecosystems were evaluated by using GIS

Figure LT.1 Critical loads of sulphur (5th percentile on the EMEP 50×50 km^2, in eq ha^{-1} yr^{-1}).

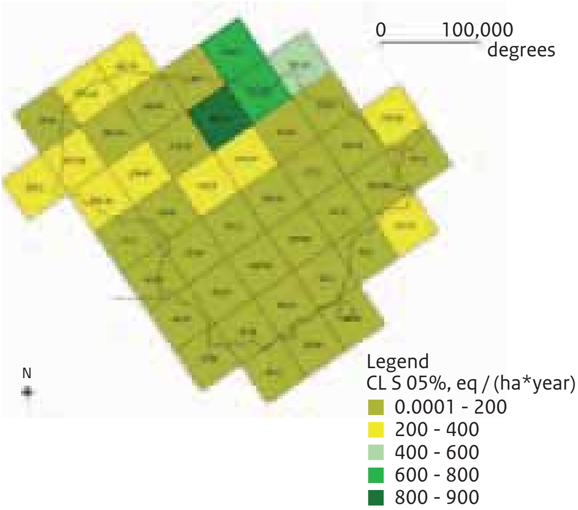
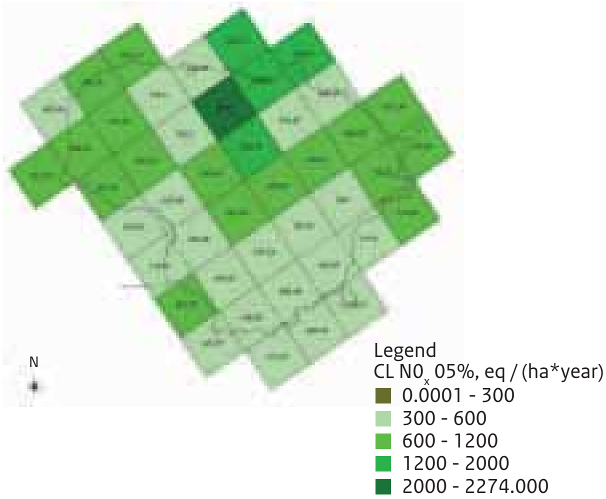


Figure LT.2 Critical loads of oxidized nitrogen (5th percentile on the 50×50 km2 EMEP grid, in eq ha^{-1} yr^{-1}).



model LandUse. During the evaluation of critical loads the ditributions over the teritory of Lithuania of coniferous, deciduous and mixed woods, annual average temperature, average annual precipitation and soil map were taken in to account.

Calculations of critical loads were made for the 5th percentile, i.e. 95% of ecosystem can sustain such load. Oxidized sulphur critical load values varied from 18 to 876 eq ha^{-1} yr^{-1} (Figure LT.1). The highest critical load values of oxidized sulphur were calculated for the northern and central parts of Lithuania, the lowest for southern parts.

Critical load values of oxidized nitrogen varied from 354.9 to 22747 eq ha^{-1} yr^{-1} (Figure LT.2). The lowest critical load values of oxidized nitrogen were obtained for the southern part of Lithuania.

Critical load values of nutrient nitrogen varied from 279.89 to 521.71 eq ha^{-1} yr^{-1}. Figure LT.3 shows, that the highest critical load values of nutrient nitrogen were calculated for the northern and western parts of Lithuania, and the lowest for southern parts.

The difference of critical loads and total depositions of oxidized sulphur, oxidized and nutrient nitrogen was calculated, and negative values represent exceedances of critical load. We calculated the exceedances for the deposition data of the year 2008, because newer deposition data were not available. The calculated

Figure LT.3 Critical loads of nutrient nitrogen (5th percentile on the 50×50 km^2 EMEP grid, in eq ha^{-1} yr^{-1}).

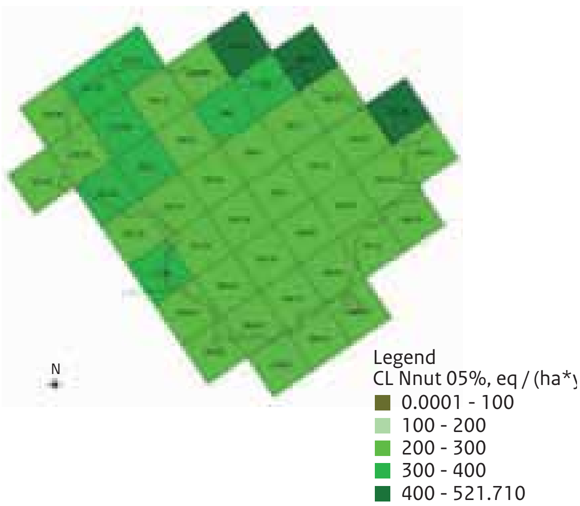


Figure LT.4 Difference of critical loads and deposition of oxidized sulphur; negative values represent exceedances of critical load (in eq ha^{-1} yr^{-1}).

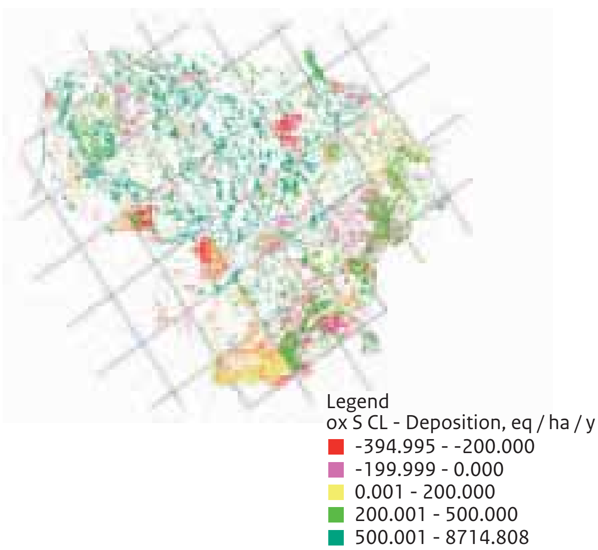


Figure LT.5 Difference of critical loads and deposition of oxidized nitrogen; negative values represent exceedances of critical load (in eq $ha^{-1} yr^{-1}$).

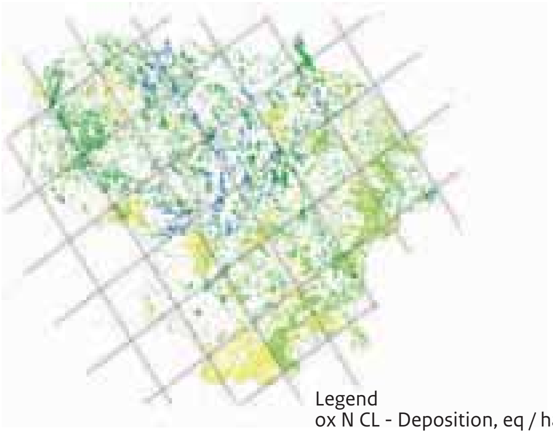
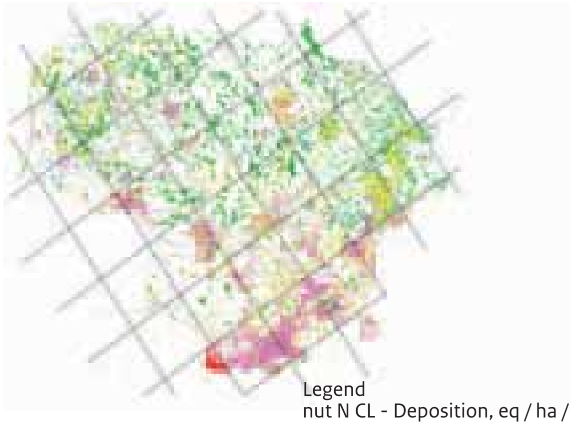


Figure LT.6 Difference of critical loads and deposition of nutrient nitrogen; negative values represent exceedances of critical load (in eq $ha^{-1} yr^{-1}$).



differences of critical loads and deposition of oxidized sulphur (-394.995 – 8714.808 eq $ha^{-1} yr^{-1}$) are shown in the Figure LT.4. As can be seen, critical loads of oxidized sulphur were mostly exceeding in the southern, south-western as well as small northern parts of Lithuania.

The calculated differences of critical loads and deposition of oxidized nitrogen (14.904 – 29979.298 eq·$ha^{-1} yr^{-1}$) are shown in the Figure LT.5. As can be seen, critical loads of oxidized nitrogen were nowhere exceeded in the territory of Lithuania.

The calculated differences of critical loads and deposition of nutrient nitrogen (-248.474 – 519.299 eq $ha^{-1} yr^{-1}$) are shown in the Figure LT.6. As can be seen, the highest exceedances of critical loads of nutrient nitrogen were calculated for the southern part of Lithuania. The lowest exceedances of critical load of nutrient nitrogen were calculated for the northern parts of Lithuania.

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National Critical Load Maps

The Dutch dataset on critical loads of acidity and nutrient nitrogen contains critical loads for the protection of:

- forests (soils) against root damage due to elevated Al/Bc ratios and soil quality, by requiring no depletion of the soils' aluminium pool;
- plant species composition in terrestrial ecosystems (both forests and other semi-natural vegetation) against eutrophication and acidification;
- plant species composition in small heathland lakes against eutrophication.

The methods for calculating these critical loads are described in a report on the evaluation of Dutch acid rain abatement strategies (Albers et al., 2001) and in various CCE reports since 2001. Critical acid loads for the protection of forest soils were calculated with the SMB model. Critical loads for the protection of heathland lakes were calculated with the dynamic model AquAcid (Albers et al. 2001). The critical loads for the protection of terrestrial vegetation were calculated with a steady-state version of SMART2-MOVE. Since SMB and SMART are parameterised for individual 250×250 m^2 grid cells, based on the present combination of vegetation type and soil type, calculated critical loads were assigned to 5×5 km^2 EMEP grids, based on location of the centre of each individual cell.

Empirical critical loads

The new ranges of empirical critical loads were assigned to the different types of nature targets used in SMART-MOVE. Critical loads computed with SMART2-MOVE or AquAcid were used for assigning one value to each target type when the calculated critical load was inside the range of empirical critical loads. When the calculated critical load was outside of the empirical ranges, the nearest limit of the empirical range was used for setting the empirical critical load. No critical loads were set for those types of nature targets for which no empirical ranges were available (i.e. fluvial, riparian or swamp woodlands and reed lands). This procedure has been described in Van Hinsberg and Van Dobben (2011).

Dynamic modelling: application of VSD+ and PROPS

For the dynamic modelling we used the models VSD+ (Very Simple Dynamic model plus C and N dynamics; Bonten et al. 2009)) and PROPS. PROPS is a model similar to MOVE, which uses measured soil characteristics instead of the Ellenberg indicator values used in MOVE. The model VSD+ was applied to three Dutch locations, one location with a dry sandy soil (Zeist), one location with a rich wet soil (Lemselermaten) and one wet location with an acidified wet peaty soil (Korenburgerveen). PROPS was applied for two types of dry vegetation (pine forest and dry heathland) using the VSD+ simulations for the Zeist plot, one wet grassland (Lemselermaten) and one wet heathland (Korenburgerveen). These vegetation types were chosen because they occupy a large part of the Dutch natural area and are protected under the EU Habitats Directive.

Locations

The Dutch forest plot in Zeist has been monitored within the framework of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests; Leeters et al. 2007). The Zeist plot is a 76-year-old forest on dry sandy soil with groundwater levels of below four metres. This location was used to calculate the species composition of dry pine forests and dry heathland.

Lemselermaten is located in the eastern part of the Netherlands (Twente), in the valley of the brook Weerselerbeek. The soil consists of fluvioperiglacial sand deposits, and along the brook umbric gleysols occur. Due to water seepage, a rich fen meadow has developed. This location was used for calculating the species composition of wet grassland.

Korenburgerveen is also located in the east (east Gelderland). The soils have developed in fluvioperiglacial loamy sand deposits. They are influenced by water seepage, but due to groundwater abstraction, the soils have acidified. This location was used to calculate species composition of wet heathland.

Application of VSD+

Model input

Deposition and seepage

For all locations, national deposition trends were used for generating time series of deposition, back to 1900, using the measured deposition as the reference value. For the wet locations of Lemselermaten and Korenburgerveen, supply of base cations via water seepage was added to the deposition, as the VSD+ does not support explicit water supply from seepage.

Measured soil properties

Measured bulk density, theta and cation exchange capacity (CEC) were used as input for the VSD+ model. Per location, soil solution concentrations in the deepest layer were used for estimating the solute concentrations in the seepage water. The depth-weighted average values of the soil solution concentrations were used for calibrating the VSD+ model.
Initial base saturation was set at 0.95 for Lemselermaten, which was assumed to be in equilibrium with depositions of 1900 for the Korenburgerveen and the dry sandy Zeist locations (equilibrium initialisation).

Default values

For the remaining soil and vegetation parameters, we used default values as given in Kros et al. (1995), based on the types of soil and vegetation at these locations. The soil types were peat (PN) for Korenburgerveen, sandy rich (SR) for Lemselermaten, and sandy poor (SP) for Zeist. For vegetation parameters of the wet sites, we used the default vegetation parameters for grass (GRP) (Kros et al. 1995). For the dry site, most vegetation parameters were obtained from site data.

Hydrology

Hydrology (percolation) was calculated with the soil hydrological model SWAP. For these calculations, SWAP used meteorological data (minimum and maximum temperatures, relative humidity, wind speed, precipitation, reference evaporation) from the nearby KNMI meteorological weather station, physical soil characteristics (water holding capacity and conductivity data from the standard Dutch soil series database (Staring Reeks), drainage characteristics calibrated with measured soil moisture and groundwater level), and forest stand characteristics (measured tree height, crop resistance, leaf area index, soil cover, storage capacity of the crown, calibrated with measured soil moisture and groundwater level, and root distribution from literature studies).

Daily SWAP results were not available for the wet locations. We used aggregated results from previous SWAP runs for these locations (Jansen 2000). Average annual fluxes and annual times of aeration were given.

Table NL.1 A-priori distributions and calibrated values of various parameters.

Location	Parameter	Minimum	Maximum	Calibrated value
Zeist	Cpool_0	0	10000	9897
	CNrat_0	10	35	34.8
Hardenberg	Cpool_0	0	10000	2872
	CNrat_0	10	50	16.3
Lemselermaten	Cpool_0	5000	15000	14967
	CNrat_0	15	40	21.0
	lgKAlBC	-2	2	1.978
	lgKHBC	-2	2	1.887
	Ca_we	0.005	0.10	0.056878
	Mg_we	0.005	0.10	0.093043
	K_we	0.005	0.10	0.096507
	Na_we	0.005	0.10	0.099016
Korenburgerveen	Cpool_0	5000	15000	8827
	CNrat_0	15	40	39.8
	lgKAlBC	-2	2	1.408
	lgKHBC	-2	2	0.899
	Ca_we	0.005	0.02	0.016104
	Mg_we	0.005	0.02	0.012081
	K_we	0.005	0.02	0.007555
	Na_we	0.005	0.02	0.013680
Location	**Parameter**	**Mean**	**Standard dev.**	**Calibration**
Zeist	lgKAlBC	0	1	0.3436
Zeist	lgKHBC	2	1	1.85
Zeist	lgKAlox	8	1	8.76

Reduction functions
For Zeist, reduction functions for mineralization, nitrification and denitrification *(rf_min, rf_nit, rf_denit)* were calculated with SWAP, using data on daily temperatures and soil moisture over the whole soil profile (50 cm). The reduction factors for mineralization were divided into three components: reduction due to soil moisture, drought and temperature. The reduction function for nitrification was equal to the reduction function for mineralization, and the reduction function for denitrification is one, minus that for nitrification. The calculated reduction function for denitrification was zero for the dry sandy plot. For calculations with VSD+, the average (over the 2003–2005 period) of the daily reduction factors was used.
Since daily SWAP results were not available for the wet locations, we set the reduction function for denitrification at 0.9, because of the wet circumstances. The reduction functions for nitrification and mineralization were calibrated manually.

Calibration

For all locations, the VSD+ model was calibrated using Bayesian calibration.
At the monitoring locations, we used measurements of carbon pool, C/N ratio, base saturation and soil water concentrations ((Al^{3+}(dry plots only), Ca^{2+}, Mg^{2+}, K^+, NO_3^-, NH_4^+, Na^+, Cl^-) to calibrate:

- the initial values for the carbon pool (Cpool_0);
- the initial value for the C/N ratio in the top soil (CNrat_0);
- exchange constants (lgKAlBc, lgKHBc);
- the equilibrium constant for the Al-H equilibrium (KAlox) (dry plots only);
- the weathering of Ca, Mg, K and Na (wet plots only).

Table NL.1 provides the priori distributions and calibrated values for these parameters.

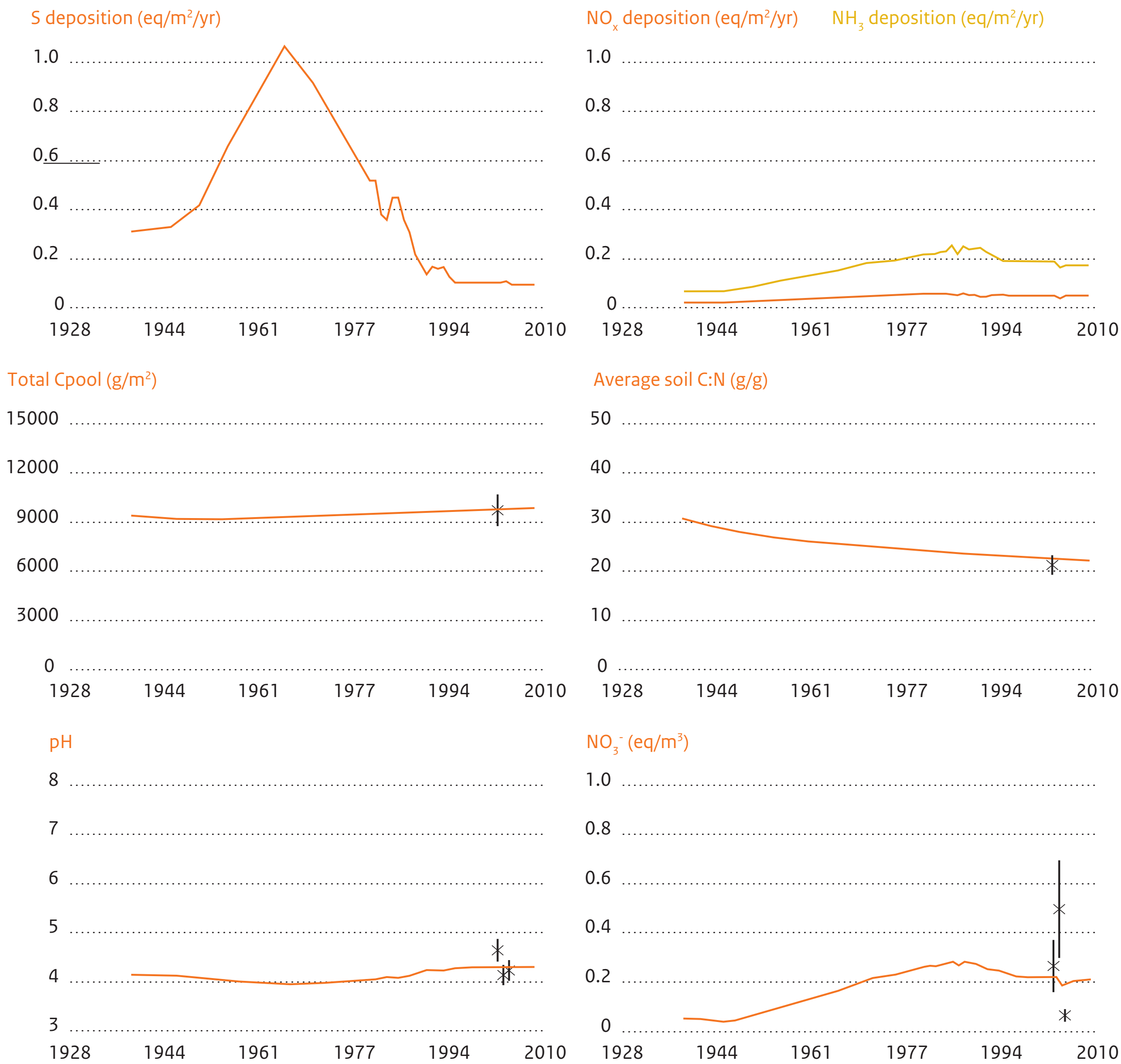
Application of PROPS

PROPS is a vegetation response model which describes plant response functions based on simultaneous measurements of abiotic conditions and plant species occurrence. Compared to MOVE, the use of measured responses means that no conversion between model output and Ellenberg indicator values is needed, reducing the model's uncertainty.

Based on simultaneous measurements of soil chemistry (pH, NO_3) and plant species composition in the Netherlands, response curves were fitted for individual species in the form of:

$$lp = b_{00} + b_{10} . pH + b_{20} . pH^2 + b_{01} . \log NO_3 + b_{02} . \log NO^2_3 + b_{11} . pH . \log NO_3$$

Figure NL.1 Results with calibrated VSD+ model for forest on sandy soil.



with logNO_3 = log(NO_3 + 0.05). From this the occurrence probability *OP* was computed as:

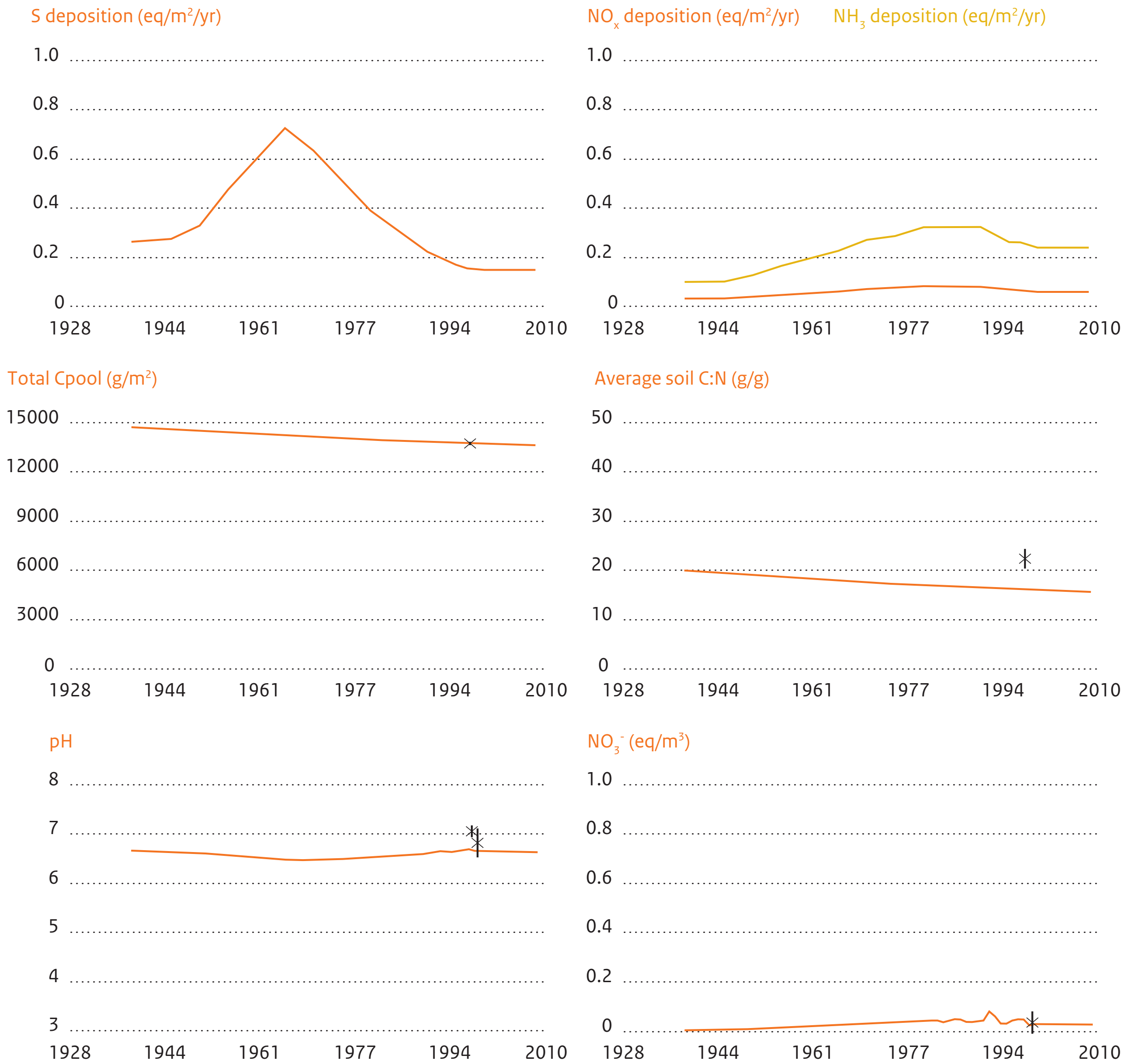
$$OP = \frac{1}{1 + e^{-lp}}$$

For each of the four vegetation types (dry heath, dry pine forest, wet grassland and wet heath), a list of characteristic plant species was composed, based on the vegetation surveys of the Dutch National Vegetation Database. The list of species identifies typical species as well as competing species, given the description of the protected habitat types. Based on the data set, parameters b_{00} to b_{11} could be derived for a number of different species. The occurrence probability of these individual plant species was calculated based on NO_3 concentration and pH. Other biotic and abiotic factors that influence plant species composition were not taken into account.

Based on the output of VSD+, we computed time series of two policy relevant parameters:

- The average occurrence probability of the typical plant species of protected habitat types and of the competing plant species. Both occurrences are used in the European Habitats Directive as an indicator for the conservation status of protected habitat types. Within the context of SEBI en CBD, the average occurrence probability mimics the indicator that focuses on the abundance of selected species (EEA 2007).
- The numbers of typical and competing species, based on occurrence probability: if the occurrence probability of a species is greater than 5% of the maximum occurrence probability (that can be derived from the parameters b_{01} to b_{11} and plausible ranges for pH and NO_3), we assumed the species were be present.

Figure NL.2 Results with calibrated VSD+ model for wet grassland.



Results

Figures NL.1 to NL.3 show that calculated soil solution concentrations were in general, consistent with the measured concentrations. NH_4 concentrations, however, were overestimated. Calculated C pools were consistent with the measurements, but the C:N ratio at the Lemselermaten plot was underestimated. The results gave enough confidence to run the vegetation response model based on modelled pH and NO_3 concentrations.

The results from PROPS are presented in Figures NL.4 to NL.7. The figures show that at all locations changes in soil conditions were large enough to influence occurrence of typical species from Natura 2000 habitats. Changes in probability of species occurrence precede changes in species number, making the former a more sensitive policy-relevant biodiversity indicator. Although at certain locations the number of typical species eventually was reduced by 50%, also showing large effects of acidification and eutrophication.

The occurrence of competing species responded in a less expected way, as the decrease in typical species was not always accompanied by an increase in competing species. In wet grassland and heathland the trend of competing species did mirror the trend of the typical species. However, in dry heathland the occurrence probability of both species reacted similarly to changes in pH and NO_3.

Changes in species composition largely differ among locations. In the pine stand, the increase in the occurrence probability for competing species between 1945 and 1965 was probably due to acidification, as this coincided with a decrease in pH. With the recovery of pH after 1990, the

Figure NL.3 Results with calibrated VSD+ model for wet heathland.

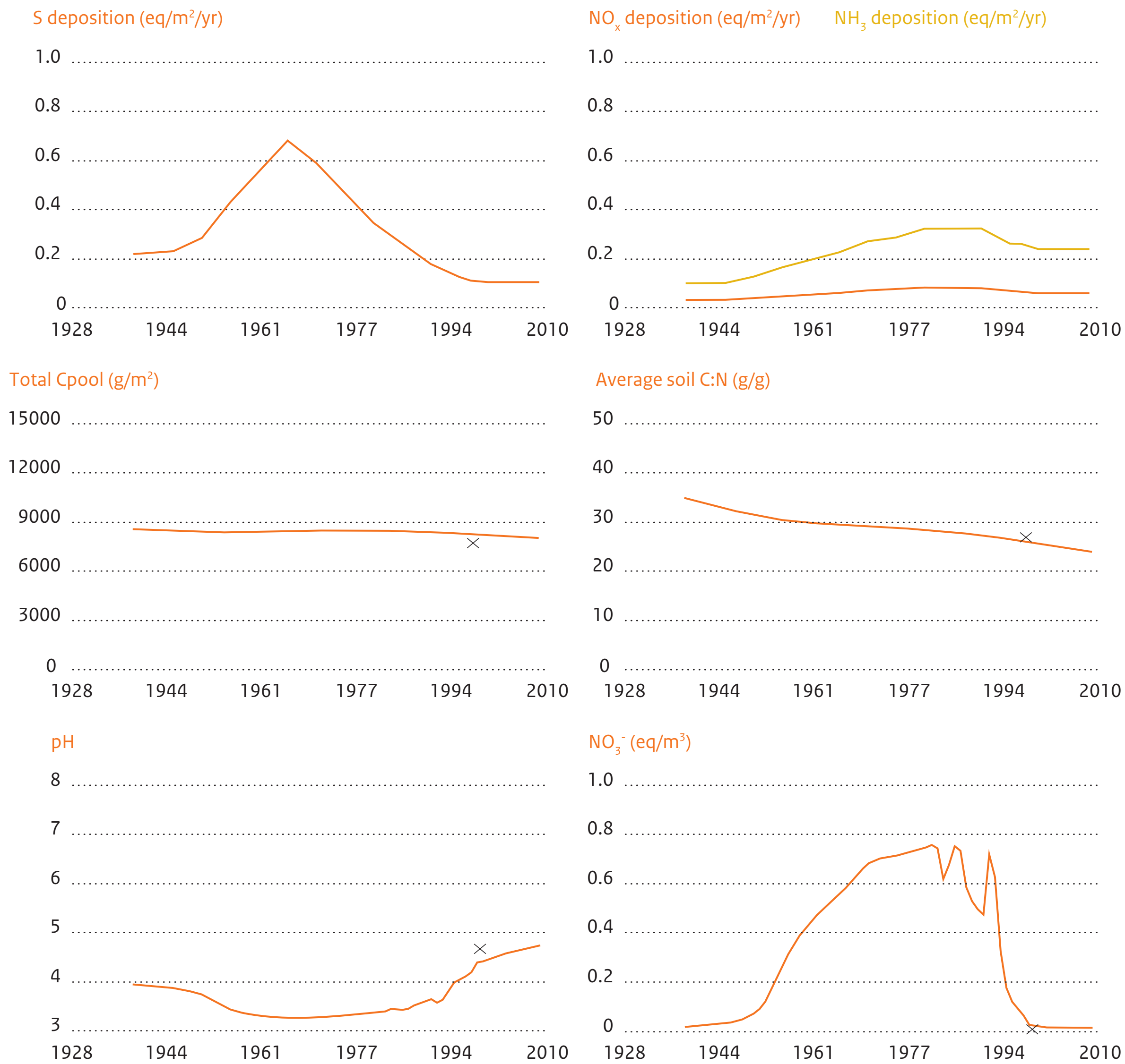


Figure NL.4 Vegetation changes in dry pine forest.

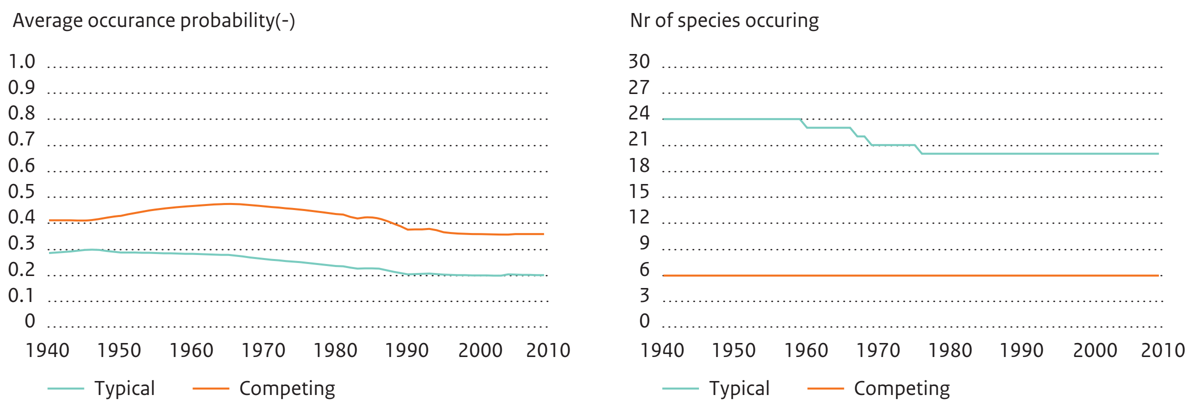


Figure NL.5 Vegetation changes on dry heathland.

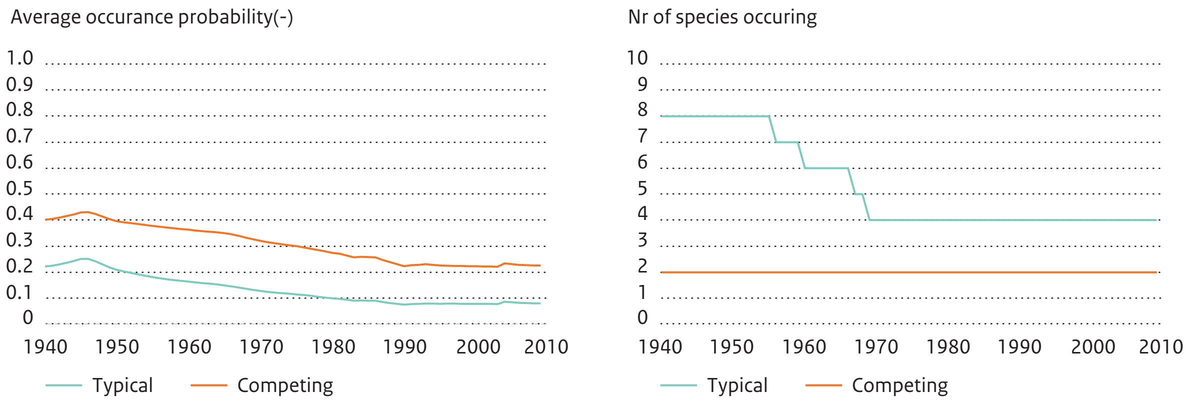


Figure NL.6 Vegetation changes on wet grassland.

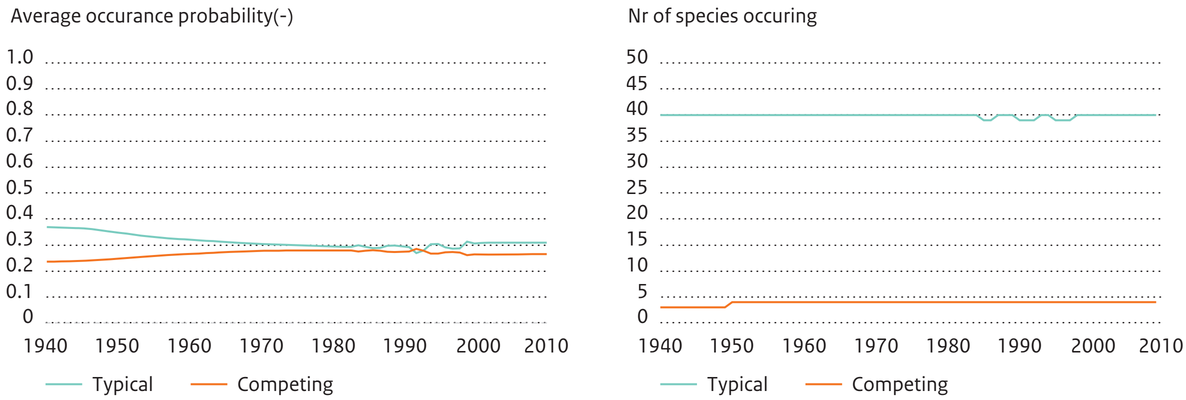
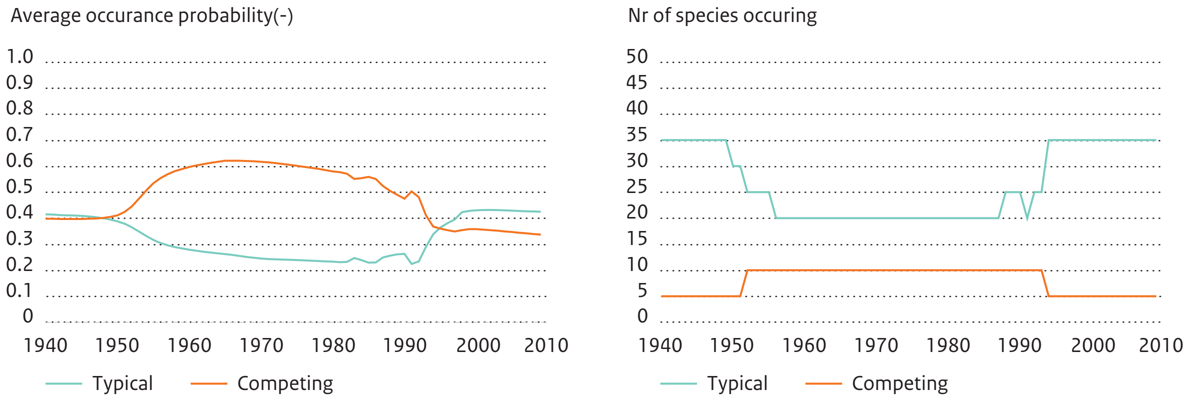


Figure NL.7 Vegetation changes on wet heathland.



occurrence probability of competing species declined. The decrease in typical species followed the increase in nitrate concentration.

In the wet grassland pH changes resulted in an increase in occurrence of competing species and a decrease in typical species. Strong effects of changes in soil chemistry were predicted in wet heath. Here, the occurrence probabilities followed the trend in pH and NO_3. A sharp increase in NO_3 after 1960 (and an associated decrease in occurrence probability and number of typical species) was followed by a recovery after 1995 (and an associated decrease in occurrence probability and number of typical species). These results show that biological models can be used to indicate chances for biological recovery. Whether biological recovery actually occurs at the locations, would depend not only on the changes in soil condition, but also on other factors, such as the presence of seeds.

Overall conclusions

- The current dynamic soil models seemed able to describe current soil conditions. However, due to the lack of long-term soil measurements it is unclear whether the process of change was described adequately.
- Simple vegetation models, such as PROPS, can be used to translate indicators of changes in soil conditions into policy-relevant biodiversity indicators, such as the probability of occurrence of plant species typical to protected habitat types. However, more sophisticated models are needed to really predict the species composition of a vegetation at a particular moment in time. Such models should not only describe soil conditions but also other abiotic and biotic conditions. Important factors, such as presence and dispersal of seeds and viability of plant populations, cannot be computed by most models.
- Simple indicators, such as the probability of occurrence of typical species, seemed more useful to describe effects of deposition changes than, for example, those that indicate number of species or occurrence of competing species. However, species typical to protected habitat types are often rare and difficult to predict with the use of deterministic competition models. Descriptive regression models like PROPS can be used to model such rare species.

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Methods and data

The updates for Norway submitted to the Call for Data are related to two aspects:

- Changing the resolution of the critical loads and dynamic modelling data in the national data base to fit the new EMEP 5×5 km² grid.
- Updating the empirical critical loads according to the report from the "Workshop on the review and revision of empirical critical loads and dose-response relationships" (Noordwijkerhout, 23-25 June 2010, Bobbink and Hettelingh 2011)

Surface water

The EMEP 5×5 km² grid cells were assigned values from national data base which is based on a grid structure of ¼ degree longitude by 1/8 degree latitude. The value from the mid point of the new EMEP grid cell was used for the cell.

Data for dynamic modelling was calculated using the MAGIC model. The modelling procedure and the data sources are described in the CCE Status Report 2008.

Calculations of critical loads for surface waters were carried out with the FAB model in accordance with the Mapping Manual.

Vegetation

The vegetation map of Norway was updated with the new empirical critical loads (Bobbink and Hettelingh 2011). Affected areas were EUNIS codes C1, G3 and G4, in which the empirical critical loads were reduced to 3 kg, 5 kg and 5 kg (N $ha^{-1} yr^{-1}$), respectively. Inside EMEP 55 km² grid cells, each vegetation type was given a unique SiteId, a summarized area and geographical coordinates. The value from the mid point of the new EMEP grid cell was used for the cell.

Nitrogen effects on biological diversity

The Norwegian NFC has a long-term and well established cooperation with experts at Norwegian Institute for Nature Research (NINA) regarding impacts on terrestrial vegetation from nitrogen deposition. The submitted empirical critical loads for terrestrial vegetation have been discussed with and quality controlled by NINA scientists the several last submissions.

Regarding nitrogen effects on the biological diversity of ocean, coastal as well as inland waters the NFC has a long-term and well established cooperation with fellow scientists at NIVA.

References

Bobbink R, Hettelingh J-P (eds), 2011. Review and revision of empirical critical loads and dose-response relationships. Proceedings of an expert workshop, Noordwijkerhout, 23-25 June 2010, RIVM Report 680359002, Coordination Centre for Effects, Bilthoven, Netherlands, 244 pp www.rivm.nl/cce

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Critical loads data

Modelled critical loads

In response to the CCE Call for Data the Polish NFC submitted calculations for the following critical load function parameters: $CL_{max}(S)$, $CL_{min}(N)$, $CL_{max}(N)$ and $CL_{nut}(N)$ for six terrestrial habitats identified according to the EUNIS classification: broad-leaved, coniferous and mixed forests as well as natural grasslands, moors and heath land and mire, bog and fen habitats. The spatial resolution applied is determined by 1 km^2 grid cells, which contain 1 ha or more of the habitat. As requested, the 5×5 km^2 EMEP grid has been introduced.

Critical loads were calculated based on the Simple Mass Balance model. In general the input parameters were estimated in accordance with the Mapping Manual. In comparison to the 2008 CCE call for data the following changes or updates of input data have been introduced:

- the recent version of the Corine Land Cover 2006 map was applied to map the areas of the selected habitats and the considered protected areas;
- the average atmospheric deposition data for Ca, Mg, K, Na and Cl were supplemented with the monitoring data from 2009;
- the uptake data of base cations and nitrogen were updated by introducing the recently published by the Central Statistical Office data on stem and branch removal;

Table PL.1 General site information.

Plot No	LAT	LON	altitude (m)	FAO soil type	dominant tree species	forest age in 2009	C/N	N dep
207	53°58'35"	23°07'50"	140	Ferralic Arenosol	pine	75	low	low
305	53°18'50"	16°50'00"	105	Haplic Arenosol	pine	61	medium	medium
323	51°57'50"	17°12'20"	102	Haplic Arenosol	pine	69	high	high
410	53°11'00"	21°05'00"	125	Haplic Arenosol	pine	73	high	low
505	50°53'50"	17°38'40"	140	Gleyic Arenosol	pine	75	low	high

Table PL.2 General vegetation information for selected plots.

Plot No	Plant inventory year	Plant association (Braun-Balnquet)	Number of ground vegetation species
207	2008	Pinus-Oxalis / Corylo-Picetum	43
305	2008	Querco roboris - Pinetum	21
323	2008	Querco roboris - Pinetum	25
410	2008	Leucobryo-Pinetum typicum	17
505	2008	Calamagrostio-Quercetum petraea	23

- the chemical criterion used for acidity critical loads was changed from Al_{crit} = 0.02 eq/m³ to molar $[Bc/Al]_{crit}$ = 1 mol/mol.

The main source of soil data was the Level-II Forest Monitoring System operated by the Forest Research Institute within the National Monitoring of Environment funded by the Chief Inspectorate of Environment Protection. Data from 148 forest monitoring sites were regionalized to fit to a grid system determined by the 1 km² grid cell.

Empirical critical loads of nitrogen

Empirical critical loads for terrestrial ecosystems were computed as:

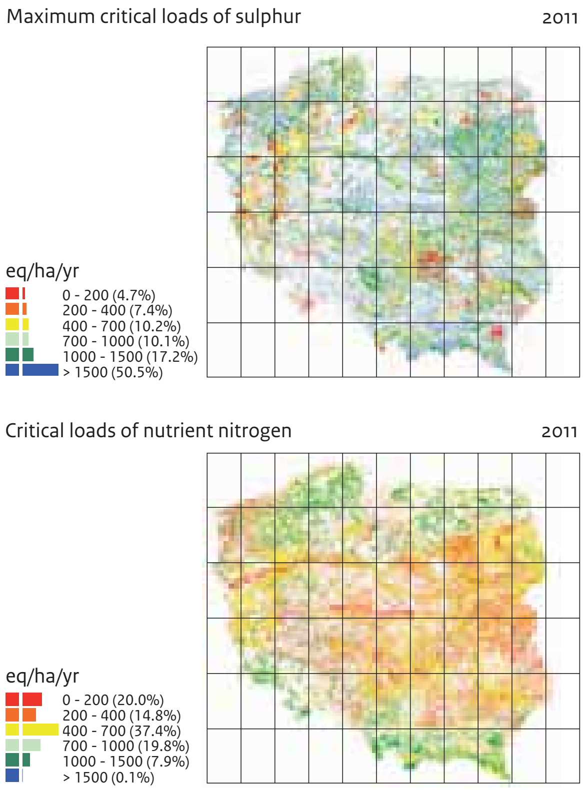
$$CL_{emp}(N) = CL_{lo} + f_{mod} \cdot (CL_{up} - CL_{lo})$$

where CL_{lo} and CL_{up} are the lower and upper end of the empirical N critical load interval under consideration and f_{mod} ($0 \le f_{mod} \le 1$) is a modifying factor. The lower and upper limits of $CL_{emp}(N)$ for each EUNIS class were taken from Bobbink and Hettelingh (2011). The modifying factors – precipitation, temperature and base cation availability – for all sites were derived from the cumulative distribution functions (CDFs) constructed for each relevant EUNIS class for all considered ecosystems, based on Polish CL input database.

Dynamic soil-vegetation modelling

The VSD+VEG model was applied to calculate soil response to S and N atmospheric depositions.
Five sites were chosen to run this model and to specify vegetation parameters. The sites were selected from the Level-II forest monitoring plots with different relations to high, medium and low C/N ratio values and high/low nitrogen deposition levels.

Figure PL.1 Maximum critical loads of sulphur and critical loads of nutrient nitrogen for Polish terrestrial ecosystems.

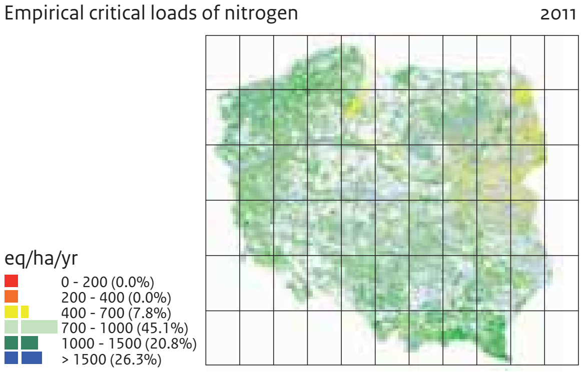


The plant species data form "grndveg363.txt" file provided by CCE, were used to prepare vegetation parameters lists for each selected plot.

Reporting nitrogen effects on biological diversity

Following the CCE request the Polish NFC has established a link and a foundation for future collaboration with Institute of Nature Conservation - Polish Academy of

Figure PL.2 Empirical critical loads of nitrogen for Polish terrestrial ecosystems.



Sciences which functions as the Polish national focal point responsible for reporting requirements under Article 17 of the Habitats EU Directive. Also habitat experts from the Chief Inspectorate of Environmental Protection and Chief Directorate of Environment Protection are invited to cooperate with the NFC teem in order to assess the nitrogen deposition effects to biodiversity. First results of this cooperation are expected to be available in June 2011.

Critical load maps

The critical load maps for $CL_{max}S$, $CL_{nut}N$ and $CL_{emp}N$ are shown in Figures PL.1 and PL.2.

References

Bobbink R, Hettelingh J-P (eds), 2011. Review and revision of empirical critical loads and dose-response relationships. Proceedings of an expert workshop, Noordwijkerhout, 23-25 June 2010, RIVM Report 680359002, Coordination Centre for Effects, Bilthoven, Netherlands, 244 pp www.rivm.nl/cce

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Modelled critical loads ($CL_{nut}N$) and exceedances

For this call only minor updates of previous country level data (Hettelingh et al. 2008, Report of Slovenia) were introduced. Due to EMEP grid refinement, the receptors were spatially redefined and most of previous data, including depositions, were ascribed to new receptors. The total number of receptors (forest sites) is 17,689 (before that: 12,691). In this report emphasis is placed on (the exceedance of) critical loads of nutrient nitrogen. Acidification is relatively less important for most part of Slovenia due to carbonate bedrock. However, some exceedances of critical loads of acidity still exist (data not shown) mostly in the vicinity of both main thermal power plants where bedrock is silicate. The smallest critical loads of nutrient nitrogen, calculated by the SMB model are found in the alpine region (*Pinus mugo* scrubland) and in some lowland sites (nutrient poor Scots pine forests). For the most of the country the $CL_{nut}N$ are in the range of 12–14 kg N ha^{-1} yr^{-1} (see Table SI.1).
Forest sites with the exceeded $CL_{nut}N$ are scattered across the country; higher density is observed in the central part, in some areas in the alpine region (*Pinus mugo* shrub) and in sites in the southern part of the country, where EMEP deposition estimates are high.

Table SI.1 CL_{emp}(N) and mean CL_{nut}(N) of different forest habitats of Slovenia and the percentage of forest type of the total forest area.

Forest habitat	% of forest area	$CL_{nut}N$ (kg/ha/yr)	$CL_{emp}N$ (kg/ha/yr)	Forest habitat	% of forest area	$CL_{nut}N$ (kg/ha/yr)	$CL_{emp}N$ (kg/ha/yr)
Adenostyles glabra subalpine spruce forests	0.68	12.6	10-15	Illyrian neutrophile spruce fir forests	3.82	11.2	10-15
Alpine grey alder galleries	0.00	11.3	10-15	Illyrian pedunculate oak-hornbeam forests	1.21	20.6	15-20
Alpine spring heath Scots pine forests	0.27	8.8	15-15	Illyrian ravine forests	0.06	13.1	10-20
Bazzania fir forests	1.98	11.2	10-15	Illyrian sessile oak-hornbeam forests	7.59	16.0	15-20
Calciphile montane inner Alpine spruce forests	0.07	12.5	15-15	Illyrian subalpine beech forests	0.00	11.4	10-15
Dinaric calcareous fir forests	0.26	11.0	10-15	Illyrian sub-Mediterranean *Pinus nigra* forests	0.04	7.8	15-15
Dinaric dolomite Scots pine forests	0.19	7.7	15-15	Illyrian woodrush-beech forests	17.54	13.2	10-20
Eastern Alpine acidophilous Scots pine woods	2.00	9.5	15-15	Illyrio-Alpine montane beech spruce forests	0.07	11.9	10-15
Eastern European poplar-willow forests	0.06	9.4	10-20	Illyro-Dinaric cold hollow spruce forests	0.13	12.2	10-15
Illyrian acidophile fir forests	0.08	11.7	10-15	Nemeral bog conifer woodland	0.00	12.7	5-10
Illyrian black pea sessile oak woods	0.19	12.5	10-20	Outer Alpine *Pinus mugo* scrub	1.48	8.4	5-10
Illyrian coastal beech forests	2.61	10.8	10-20	Pelago dinaride *Pinus mugo* scrub	0.02	8.0	5-10
Illyrian collinar neutrophile beech forests	21.83	12.8	10-20	Peri-Alpine *Bazzania* spruce forests	0.93	12.5	10-15
Illyrian high montane fir-beech forests	5.51	13.2	10-15	Pre-Alpine hop-hornbeam beech forests	5.88	11.3	10-20
Illyrian hop-hornbeam mixed oak woods	6.16	12.6	10-15	Sedge ash-alder woods	0.46	13.5	10-20
Illyrian hop-hornbeam woods	0.26	11.3	10-15	Southeastern Alpine bittercress beech forests	5.18	13.6	10-20
Illyrian montane fir-beech forests	13.40	12.5	10-20	Sub-Pannonic beech forests	0.01	12.1	10-20

Empirical critical loads ($CL_{emp}N$) and exceedances

We updated empirical critical loads of our forest sites in accordance to the recent European progress (WGE 2010). Similarly as modelled loads only forest and shrub sites are included. When intervals of critical loads are given in the report by the Working Group on Effects (WGE 2010), we took the mean and minimum values into consideration. The spatial pattern across the country is similar as for modeled CLs with the lowest values in lowland pine forests and alpine *Pinus mugo* shrub sites. The area of low CLs is small, but it is important for biodiversity protection – almost all of *Pinus mugo* shrub sites are located within Natura 2000 sites. The class of CLempN with highest frequency is in the range of 10–20 kg N ha^{-1} yr^{-1} (Table SI.2). Mean values of empirical critical loads are a bit higher than the ones calculated by the SMB (14.6 vs. 12.9 kg N ha^{-1} yr^{-1} when using the mean value of the empirical load range). When the mean value of the critical load range was used, the exceedances of $CL_{emp}N$ show a similar pattern as observed for $CL_{nut}N$, with higher density in the central part of the country. However, the total exceeded area is somewhat lower. When the minimum values of the empirical CL range were used (data not shown) the exceedances are considerable – in major parts of the

Table SI.2 Forest types with exceedances of $CL_{emp}N$ and the percentage of area exceeded.

Forest type	% of area
Dinaric dolomite Scots pine forests	20.8
Eastern Alpine acidophilous Scots pine woods	16.9
Nemeral bog conifer woodland	39.5
Outer Alpine *Pinus mugo* scrub	22.2
Pelago dinaride *Pinus mugo* scrub	100.0

Figure SI.1 Modelled ($CL_{nut}N$) and empirical ($CL_{emp}N$) critical loads of nutrient nitrogen and their exceedances.

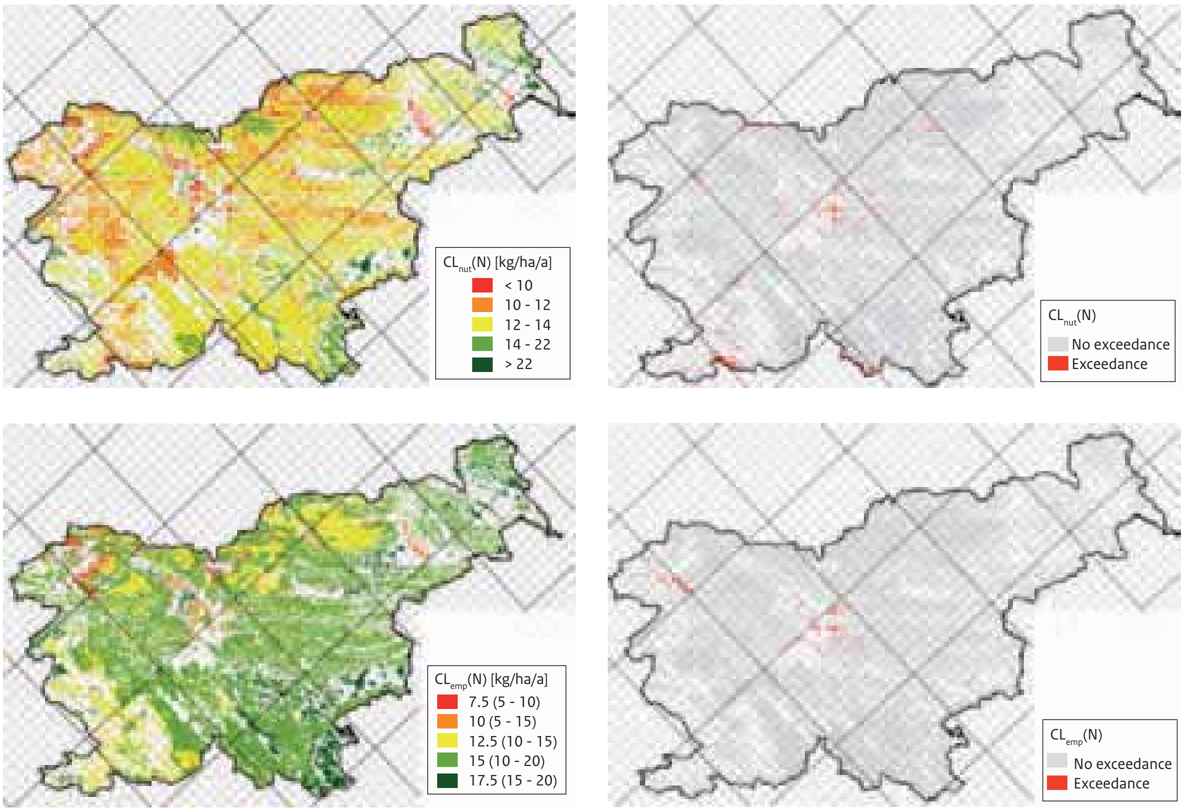


Table SI.3 Site information of two Level-II plots in Slovenia.

Site	Borovec	Brdo
Geogr. coordinates	45°32'12" N 14°48'16" E	46°17'14" N 14°24'17" E
Altitude	705 m	471 m
Biogeographic region	Dinaric	Pre-Alpine
Soil	Rendzic leptosol, (eutric cambisol)	Dystric cambisol
Mean pH of topsoil	6.6	4.1
Bedrock	Limestone	Fluvioglacial gravels and sands
Plant community	*Lamio orvalae-Fagetum*	*Vaccinio myrtilli-Pinetum*
Dominant tree species	*Fagus sylvatica*	*Pinus sylvestris*
Stand age	*80 yrs*	*100 yrs*

alpine and Dinaric karst forests the estimated N depositions exceed the critical loads (see Figure SI.1).

Soil-vegetation dynamic modelling of ICP Forest Level-II plots

Sites used for modelling

For this report two out of eight Slovenian ICP Forest Level-II plots were selected on the basis of data availability (longest time series to decrease interannual variability e.g. of wood increments, litterfall, depositions, water and temperature data). The sites are contrasting in soil conditions. Site «Brdo» is acidophilous species poor Scots pine forest and the «Borovec» site is beech forest lying on carbonate bedrock. Soil acidification due to N and S deposition can only be relevant for «Brdo» site where the soil is acidic. Carbon and nitrogen pool modeling is reasonable for both sites. Detailed information on sites is given in the Table SI.3.

Data sources

Dynamic modeling of acidification/eutrophication was performed using VSD+ (Bonten et al. 2011, Reinds 2009). The on-site measurements included in calculations were: pH, carbon and nitrogen contents, soil bulk density, base saturation, cation exchange capacity, soil temperature, C:N ratio of soil, humus and litter, wood increments and

Table SI.4 Input values for VSD+ for two Level-II plots of Slovenia. For details on parameters and units see the VSD+ manual (Bonten et al. 2011).

Site: BOROVEC													
period	thick	bulkdens	Theta	pCO_2fac	CEC	bsat_0	Excmod	lgKAlBC	lgKHBC	expAl	lgKAlox	Cpool_0	CNrat_0
1960 - 2010	0.35	1.31	0.18	18.8	48.8	0.99	2	0.16	3.8	3	7.9	8000	18
RCOOmod	cRCOO	RCOOpars	TempC	percol	Ca_we	Mg_we	K_we	Na_we	SO_2_dep	NO_x_dep	NH_3_dep	Ca_dep	Mg_dep
0	0	0.96 0.9 0.039	7.1	0.71	0.8	0.4	0.25	0.25	EMEP	EMEP	EMEP	EMEP	EMEP
K_dep	Na_dep	Cl_dep	cCa_min	cMg_min	cK_min	kmin_fe	kmin_fs	kmin_mb	kmin_hu	frhu_fe	frhu_fs	frhu_mb	CN_fe
EMEP	EMEP	EMEP	0.01	0.01	0.001	8.7	0.07	1	0.002	0.0002	0.28	0.95	17
CN_fs	CN_mb	CN_hu	CN_rt	Nst	knit	kdenit	Nfix	ctCast	ctMgst	ctKst	rf_min	rf_nit	rf_denit
290	9.5	15.6	40	0.125	4	4	0.05	0	0	0	0.6395	0 .6395	0.0073
age_veg	veg_type	Nlfmin	Nlfmax	ncf	expNlfdep	growthfunc	bsatobs	Cpoolobs	Npoolobs	CNratobs			
30	4	1.52	2.9	0.5	8.2	1.5 0.72 0	0.935	10400	605	17.5			
Site: BRDO													
period	thick	bulkdens	Theta	pCO2fac	CEC	bsat_0	Excmod	lgKAlBC	lgKHBC	expAl	lgKAlox	Cpool_0	CNrat_0
1960 - 2010	0.4	1.31	0.12	21	9.75	0.15	2	0.16	3.8	3	7.9	7500	18
RCOOmod	cRCOO	RCOOpars	TempC	percol	Ca_we	Mg_we	K_we	Na_we	SO_2_dep	NO_x_dep	NH_3_dep	Ca_dep	Mg_dep
0	0.004379	0.96 0.9 0.039	8.1	0.65	0.025	0.02	0.025	0.025	EMEP	EMEP	EMEP	EMEP	EMEP
K_dep	Na_dep	Cl_dep	cCa_min	cMg_min	cK_min	kmin_fe	kmin_fs	kmin_mb	kmin_hu	frhu_fe	frhu_fs	frhu_mb	CN_fe
EMEP	EMEP	EMEP	0.0001	0.0001	0.0001	8.7	0.05	1	0.0005	0.0002	0.28	0.95	17
CN_fs	CN_mb	CN_hu	CN_rt	Nst	knit	kdenit	Nfix	ctCast	ctMgst	ctKst	rf_min	rf_nit	rf_denit
320	9.5	10.6	40	0.11	4	4	0.1	0	0	0	0.6395	0.6395	0.0073
age_veg	veg_type	Nlfmin	Nlfmax	ncf	expNlfdep	growthfunc	bsatobs	Cpoolobs	Npoolobs	CNratobs			
50	2	1.01	2	0.6	7.4	0.68 0.3 0	0.10	9700	430	22.5			

litterfall, rainfall, water content. Some data (detailed chemical parameters of equilibrium equations, weathering rates, mineralization rates, and transfer fractions of the litter-soil-microbes system, mineral content of stems) were not obtained during level II measurements and default values within VSD+ or literature data were used. For historic depositions of pollutants and base cations EMEP data were used. Model calibration was performed using the observed values of C and N pools, C:N ratio and base saturation for the year 2004.

The VSD+ model was used in conjunction with the Veg model developed by Sverdrup et al. (2007) to estimate deterioration/improvement of soil to host certain plant species. At each study site four 10×10 m^2 vegetation surveys were performed in 2004 and the species inventory of the site was used for the Veg model runs. Species missing in the database obtained from the CCE were not included in the model runs. There were 6 out of 31 and 28 out of 83 species missing in this database for the «Brdo» site and the «Borovec» site, respectively. The most dominant species of both sites were included in the model runs.

Results

Results of the VSD+ and Veg model runs are shown in Figures SI.2 and SI.3. The results of the Veg model are ecologically unrealistic, especially for the species-rich «Borovec» site. Such large cover and time variability of some moss and herbaceous species is not expected. Dominant forest management type (selective cutting) in Slovenia precludes large shifts in plant community composition during forest growth. For model to approach real community initial cover estimates of species should be used instead of assembling the community «from scratch».

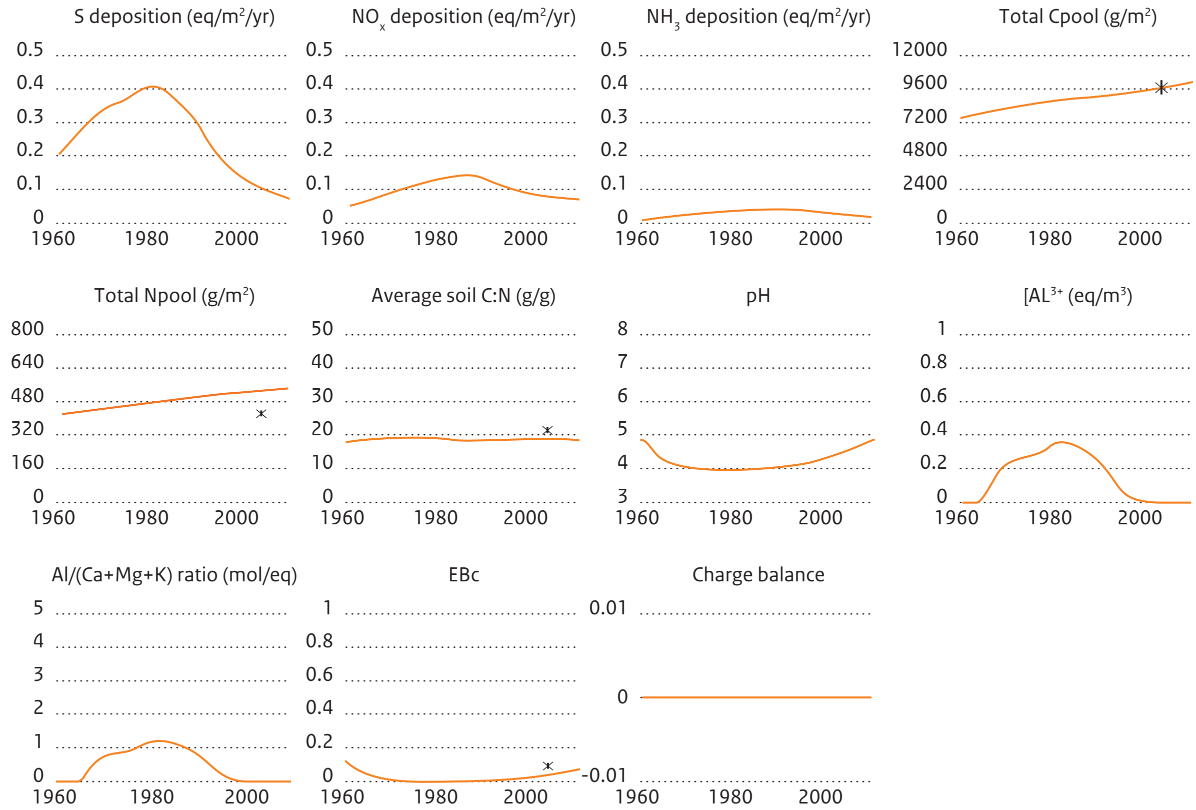
Collaboration with habitat experts

Since the implementation of Natura 2000 in Slovenia the country was obliged to produce only one report on Natura 2000 favorable conservation status (according to article 17 of the EU Habitats directive). The next report will follow in 2013. In previous report (2007) no particular emphasis was given by reporters on nitrogen deposition from the atmosphere as being an important pressure on habitats and species. Fertilization of grasslands however is frequently denoted as important driver of species loss and habitat deterioration.

For the work done so far no formalized collaboration with national reporters of Natura 2000 status has been established. Two authors of the Slovenian «NFC» are habitat (vegetation) experts (for forests and grasslands) and no additional support in this respect is needed. More effort, however, should be given in the future to inform the national reporters and Slovenian Environmental Agency about atmospheric depositions of nitrogen and exceedances as possible additional pressure on ecosystems and biodiversity.

Figure SI.2 Results of VSD+ dynamic model runs for the two forest sites for the period 1960–2010.

ICP-Forests Level-II Slovenia-BRDO



ICP-Forests Level-II Slovenia-BRDO

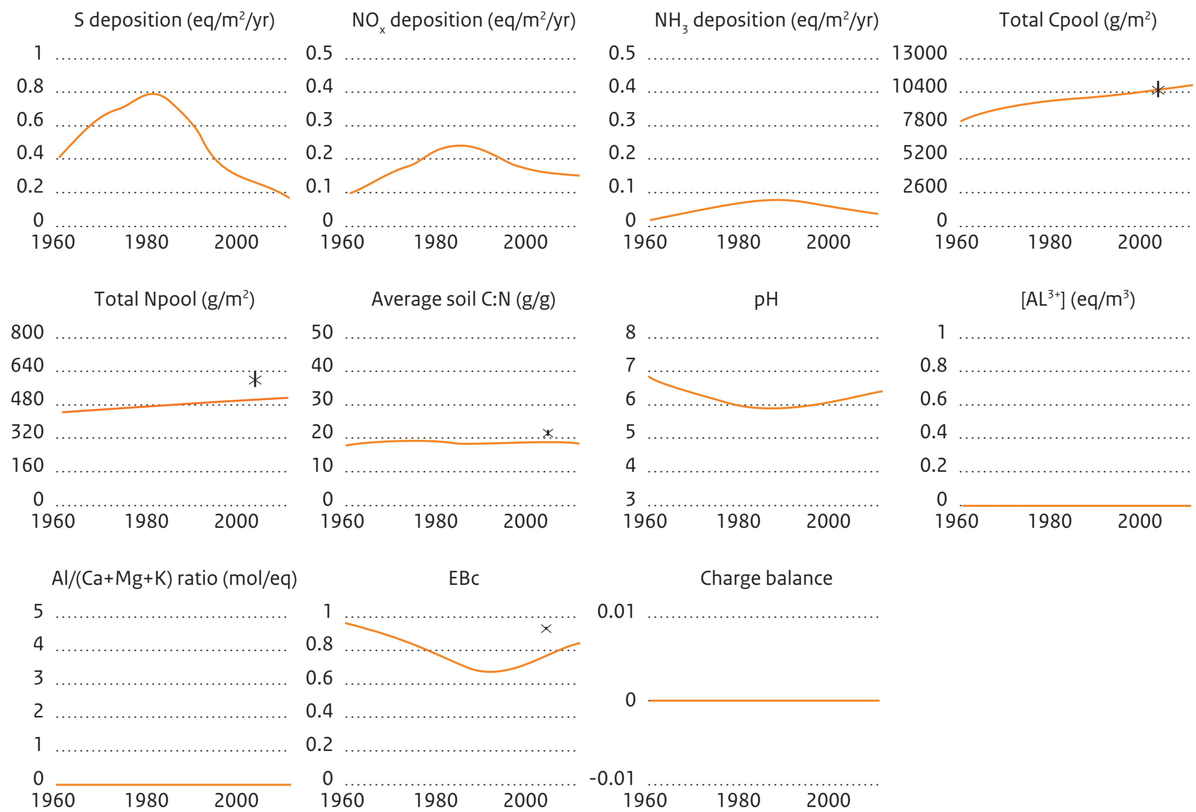
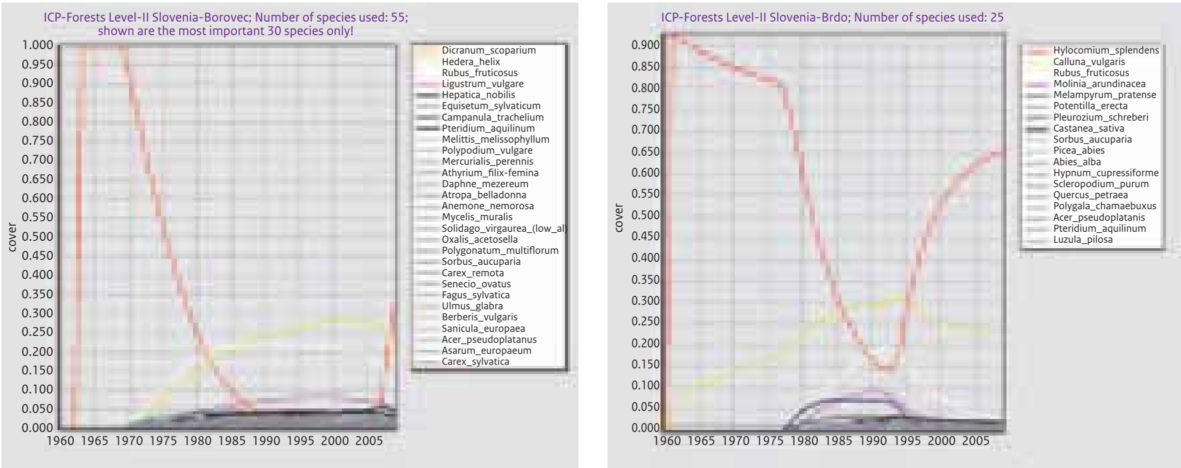


Figure SI.3 Veg module output for "Borovec" site (left) and "Brdo" site.



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Introduction

Sweden welcomed the Call for Data issued by the CCE in November 2010. From the Swedish perspective the ecosystem effects of air pollution are high at the scientific and political agenda together with several other major issues such as health effects of air pollution or effects of climate change. Despite the declining deposition of S and N through the two last decades, the impact on ecosystems is of major concern, both with respect to acidification and eutrophication of soils and waters, together with ground level ozone concentrations and biodiversity changes.

The call asks for the following four key outputs:

- Updated modelled critical loads on the 5×5 km^2 EMEP grid
- Updated empirical critical loads of nitrogen on the 5×5 km^2 grid
- Complete sets of input files to the soil-vegetation model runs
- Collaboration between NFCs and habitat experts on nitrogen effects on biological diversity

The Swedish NFC responded to the 4 points above. Critical loads were updated for both terrestrial ecosystems and for lakes, empirical critical loads were updated, VSD+Veg was tested and the NFC further developed the co-operation with national habitat experts. The database has been submitted to the CCE.

Lakes

Critical loads

The lakes with submitted critical loads are part of a Swedish national surveillance monitoring of lakes 2007, 2008 and 2009 (Grandin 2007). Lake water chemistry was measured at 2410 lakes with area > 1 ha selected by a stratified random selection. Lakes affected by liming (N=458) were corrected by using the average Ca:Mg ratio from non-limed reference lakes within 20 km distance and the Mg concentration of the liming agent (Fölster et al. 2011).

For freshwaters the critical loads were calculated using the first-order acidity balance (FAB) model as described in Henriksen and Posch (2001) and Rapp et al. (2002) with some modifications described below. The BC_{le} 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 calculations of nitrogen immobilisation were based on Gundersen et al. (1998). Nitrogen immobilisation was set to 100% for deposition up to 2 kg N/ha, 50% for the part of the deposition exceeding 2 kg/ha up to 10 kg/ha and 0% for the deposition exceeding 10 kg N/ha. In addition to this, leaching of organic nitrogen calculated from the lake concentration of Total Organic Nitrogen (TON), was regarded as non-acidifying. The chemical threshold, ANClimit, was calculated individually for each lake to a value corresponding to a change in pH of 0.4 units from reference conditions calculated by MAGIC (Moldan et al. 2004). This threshold is used as a definition of acidification in the Swedish Environmental Quality Criteria and for the fulfilment of Good Ecological Status within the EU Water Frame Directive (Fölster et al. 2007). When MAGIC was not run on the lake itself, the data used in the FAB model was taken from a similar lake within a database of MAGIC simulated lakes by a matching procedure (MAGIC library, www.ivl.se/magicbibliotek). Less than 5% of the lakes did not get any match, since no similar lakes were in the library. Those lakes were in most cases well buffered and unlikely to be acidified even at a very high deposition. CLmaxS, CLminN CLmaxN, nANCcrit, critvalue and nmBCo was then set to the same values as for the lake with the highest critical load (ID = 647139-138602) to ensure that the critical load for those lakes were not exceeded in further calculations and interpolations. The above described procedure of using MAGIC model and its extension MAGIC library was used in the same fashion as in the previous submission of CL data from Sweden. The library of lakes modelled with MAGIC was over the last two years expanded to present day 2400 lakes and the MAGIC model calculations.

Interpolation to the 5×5 km² EMEP grid

The total area of Sweden is regarded as 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. Sweden contains approximately 18,000 5×5 km^2 squares. Provided that there are close to 100 000 lakes in Sweden there are in average close to 5 lakes in each 5×5 square. The 2410 sampled lakes were distributed over 2106 of the 5×5 km squares. In most cases there was one modelled lake per 5×5 km square. The ecoarea was then set to 25 km^2.
For lakes within squares with more than one lakes, the ecoarea was set to 25 km^2 divided by the number of lakes within that square. For the approximately 16,000 squares with no modelled lakes inside the CL data were calculated by a linear interpolation between the lakes with calculated CLs. For each square the interpolated value for the centre of the square was selected. Squares along the coast distant from any measured lake were not interpolated.

Forest ecosystems

Modelled critical loads

Critical loads of acidity and nutrient N was calculated with the steady state soil chemistry model PROFILE (Sverdrup and Warfvinge 1993). The chemical criteria molar ratio Bc/Al in the soil solution was used, where Bc is molar concentration of base cations Ca^{2+}, Mg^{2+} and K^{+} and the Al is the sum of the molar concentrations of inorganic Al in the soil solution. The critical limit was set to Bc/Al=1, corresponding to a growth reduction of spruce by 20% (Warfvinge and Sverdrup 1995). The root weighted Bc/Al was used, since it is a more relevant measure than previously used Bc/Al in the soil layer with the lowest Bc/Al. The Bc/Al ratio was weighted over the soil horizons according to the root content of each layer. The soil layer specific root content was represented by an estimated fraction of Bc uptake from each layer. The root zone was assumed to be 0.5 m, except for a few sites with shallow soils, were it was assumed to be 0.15 m.

The CL for nutrient nitrogen, CLnutN, was based on the critical nitrogen concentration limit of 0.3 mg N/l in the water leaching from the root zone. This concentration represents the upper limit for Class 1 (low concentrations) according to the Swedish environmental quality standards for lakes (www.naturvardsverket.se). Calculations were performed on sites within the National Forest inventory (Hägglund 1985). Successful calculations were made on 17,141 forest sites in the acidity calculations and 17,333 sites in the nutrient N calculations.

S and N deposition data were derived from EMEP for 2010 on the 50×50 km^2 grid as provided by the CCE for the purpose of the Call. Wet deposition data for base cations were derived from the MATCH model (Robertson et al. 1999, www.smhi.se), in a 20×20 km^2 grid over Sweden. The deposition average for three years, 2006–2008 was used. Dry deposition was estimated based on the wet deposition in combination with the relation between wet and dry deposition of the different base cations in 1998, the last year for which modelled dry deposition of base cations is available. The calculated dry deposition of base cations was based on the assumption that the ratio between dry and wet deposition is the same now as in 1998. Mineralogy was based on soil data from the Swedish Geological Survey (Lax and Selenius 2005). Forestry data, e.g. uptake of base cations and nitrogen, originates in the National Forest Inventory (Hägglund 1985). More detailed information about the input data can be found in Akselsson et al. (2004).

The ecoarea for the forest sites were derived from the National Forest Inventory database. The sum of the ecoarea for all the sites corresponds to the total area of forest in Sweden.

Empirical critical loads of N

Empirical critical loads for five land use classes were applied according to Figure SE.2 and Table SE.1, based on Bobbink et al. (2010). A satellite based land use map for Sweden with the resolution 150×150 m^2 was used for the calculations (Mahlander et al. 2004).

Table SE.1 Land use classes and empirical critical loads applied.

Land use class	CL N interval kg ha^{-1} yr^{-1}	Suggested CL kg ha^{-1} yr^{-1}
Coniferous forest	5–10	5
Deciduous forest	10–20	10
Wetlands	5–10	5
Mountain areas	3–5	3

Mixed forest was given the interval of coniferous forest, with the lowest CL interval of the forest types, in order to protect the most sensitive species.

For wetlands and mountain regions there are different intervals for different ecosystem types. However the available land use maps do not distinguish between different wetland and mountain types. In Sweden the most common wetland type is poor fens and the second most common type is raised bogs. Rich fens also occur. Raised bogs are the wetland type with the lowest critical load interval, 5–10 kg ha^{-1} yr^{-1}. Thus raised bogs set the limit for wetlands, in order to protect all habitat types. For future assessment other information sources than satellite based maps should be explored to distinguish between different types of wetlands in Sweden.

The most common ecosystem type in the mountain regions in Sweden is arctic, alpine and subalpine shrub habitat (10–15 kg ha^{-1} yr^{-1}). There are, however, also areas with tundra (3–5 kg ha^{-1} yr^{-1}). The lower interval was chosen for the mountain areas. The interval 3–5 kg ha^{-1} yr^{-1} was also regarded as more realistic than the higher interval in these regions, where the current N deposition is less than 3 kg ha^{-1} yr^{-1}.

Based on broad consensus between habitat experts, environmental researchers within the different fields, critical loads community and Swedish EPA we chose to use the precautionary principle and use the lowest value in all intervals. For wetlands there were guidelines about how to choose one value from the interval based on precipitation and P limitation. These guidelines were, however, not used since it was difficult to use with available national scale information for Swedish wetlands.

Comments and conclusions

Critical loads for lakes

For lakes, the median critical load of S deposition is 316 eq/ha/year, the N_{min} is 364 eq/ha/yr (i.e. the amount of N

Figure SE.1 Exceedance of the CL for lakes in Sweden (2006–08 deposition). For each square the 95th percentile is shown, i.e. 5% of the ecosystem area has this or higher exceedance.

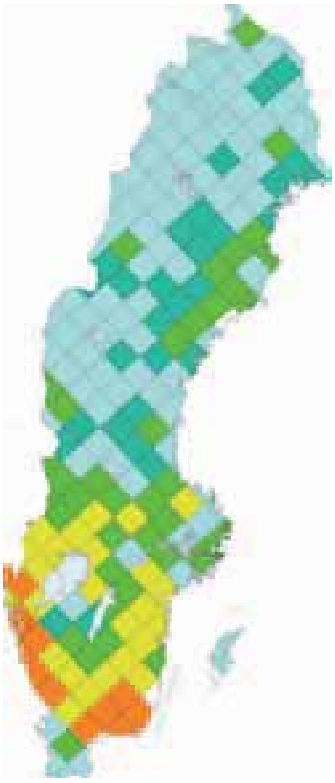
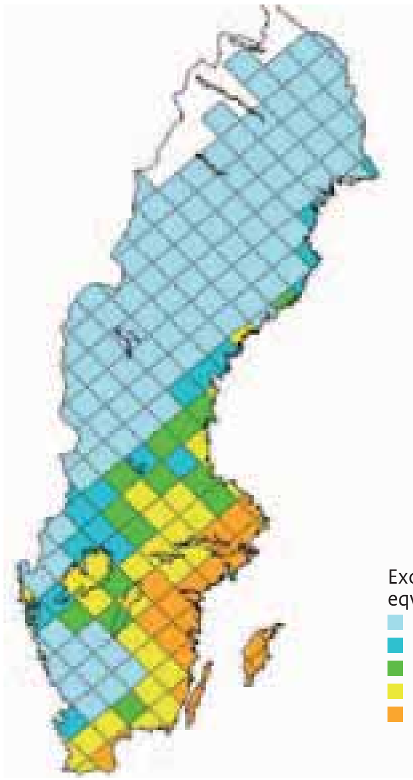


Figure SE.2 Exceedance of critical load of acidity, with the criteria molar BC/Al = 1 (root weighted), on 17,141 sites in Sweden. Exceedance based on EMEP deposition for 2010. For each square the 95th percentile is shown, i.e. 5% of the ecosystem area has this or higher exceedance.



deposition that is taken up by the ecosystem and does not cause any acidification) and the N_{max} is 1101 eq/ha/yr (i.e. the maximum amount of N deposition the ecosystem could take without inacceptable acidification, if the S deposition is zero). The differences between lakes are large. A number of lakes will not recover from acidification and many lakes that not become acidified under present day conditions. The area with exceedance of critical loads was 20% in 2006–2008 (Figure SE.1).

Critical loads for forest ecosystems

Modelled critical loads

The critical load of acidity was exceeded on 13% of the Swedish forest sites, based on the EMEP deposition for 2010 (Figure SE. 2). In the last call, when deposition from 2003–2005 was used for S, N and base cations, the critical load was also exceeded at 13% of the sites. However, the geographical distribution was somewhat different. In the new runs there was more exceedance in the southeast part of Sweden and less in parts of central Sweden. The differences can to a large extent be explained by lower base cation deposition from the MATCH model for 2006–2008 than for 2003–2005, but also by changes in deposition of S and N, e.g., by higher N deposition in parts of Sweden. The exceedance of the critical load of nutrient N, calculated with the PROFILE model and based on EMEP deposition from 2010, shows a clear gradient with decreasing exceedance from the southwest to the north, in accordance with the N deposition gradient. In the northern half of Sweden the critical load is not exceeded.

Empirical critical loads of N

The exceedances of the empirical critical loads are shown in Figure SE.4, with N deposition from EMEP for 2010. For illustration the implications of adopting the highest value in the CL intervals (Table SE.1) for the five considered ecosystems are in Figure SE.4.

The empirical critical loads of N using the lower values in the interval gave somewhat smaller exceedance than nutrient N (Figures SE.3 and SE.4), but the trends were very similar and the results were in the same order of magnitude. With the used lowest values in CL_{emp} intervals the empirical critical load of N was exceeded on the southernmost third of Sweden. For comparison the highest values in the intervals would result in only minor areas with exceedance, mainly in the southwest (Figure SE.4).

Soil-vegetation modelling: Testing VSD+Veg

For testing VSD+Veg in Sweden a set of 16 intensively monitored sites was used. The sites had previously been modelled with SAFE (Martinson et al. 2005) and ForSAFE models (Belyazid et al. 2006). The user interface of VSD+Veg is powerful, well-made and useful tool to apply and test the model on a site-specific level. It contains a number of useful features which make the work with the model efficient and convenient. During model tests on the 16 well documented sites, however, some serious difficulties were encountered. These include occasional model crashes and the failure of the calibration procedure, which we ultimately did not succeed to use. As a result the soil chemistry was modelled (VSD+) without calibration. Due to that the match between modelled and observed soil chemistry varied strongly among the 16 modelled sites, from acceptable at several sites to less than desirable on others.

The Veg-part of the model chain initially gave unrealistic results and poor match between observed and modelled vegetation cover. This improved some after correcting an error in generic vegetation table, but despite all efforts the modelled vegetation cover did not reflect reality well enough. The tests show that there is a need to revise the vegetation table as it shows some inconsistencies and is

Figure SE.3 Exceedance of critical load of nutrient N calculated with PROFILE with critical N concentration in soil solution = 0.3 mg l^{-1} on 17,333 sites in Sweden. Exceedance based on EMEP deposition for 2010.

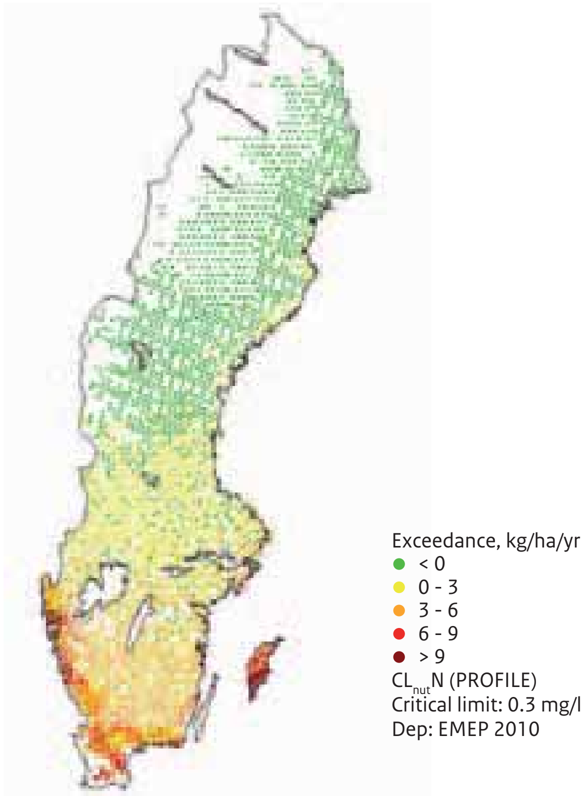
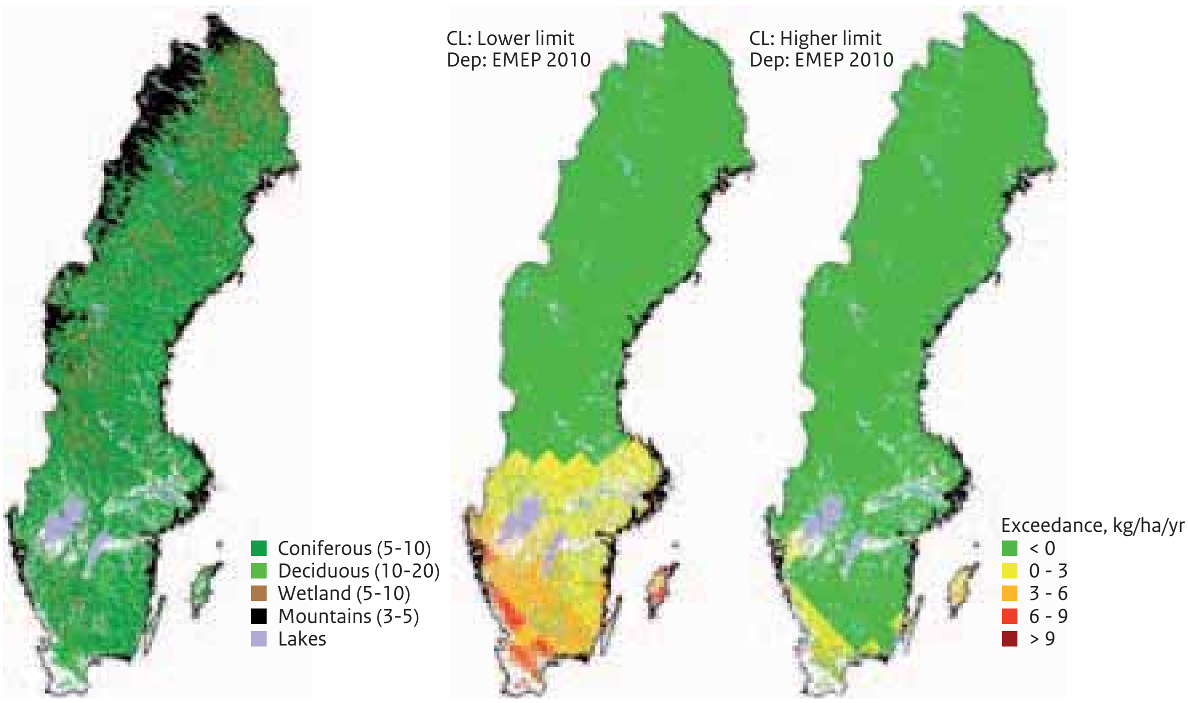


Figure SE.4 Exceedances of empirical critical load of N based on EMEP deposition for 2010.



not up to date with the latest revisions carried out. More testing of the table is also necessary when soil chemistry is properly modeled. More details of the model testing have been reported to the CCE.

During 2009 and 2010 the Critical Loads team at Lund University in Sweden developed a manual to support the use of VSD+Veg or ForSAFE-Veg for estimation of critical loads for nitrogen, based on biodiversity effects. This has resulted in a simple parameterization manual which can be found in Appendix B.

Collaboration between NFCs and habitat experts on nitrogen effects on biological diversity

As a response to the Call for Data issued in 2009, Swedish national biodiversity vegetation experts were contacted and a network was formed in spring 2010. Second national workshop on "Critical Loads based nitrogen deposition assessment for Habitats Directive Article 17 reporting" was organised in Stockholm, 24 February 2011. At this meeting, work focussed on nitrogen deposition as a threat to biodiversity in Swedish natural and semi-natural ecosystems in connection to the overall European critical loads for each ecosystem. Also, the stepwise approach (steps 1–5) described in Annex 2 of the Call for Data (see Appendix A) was discussed in connection to the possible use of the method of both habitat experts and the NFC to assess whether nitrogen deposition is a "pressure/threat" to habitats listed in Annex I of the Habitats Directive (92/43/EEC). The possibilities for evaluating large-scale vegetation changes in Sweden were discussed, and especially, the possibilities for relating the documented vegetation changes to nitrogen deposition as opposed to in response to land use and other drivers such change in atmospheric deposition (other than of N) or change of climate. Several large-scale long-term vegetation change assessments have been carried out at several places in Sweden (Falkengren-Grerup 1990, Tyler and Olsson 1997, Oredsson 1990 1999, 2008, Maad et al. 2009). These data have still not been analysed in detail in order to assess whether or not nitrogen deposition has been a prominent driver for the observed changes. Further efforts to synchronise the work on effects of N carried out under the LRTAP Convention with work carried out towards the Habitat directive were discussed.

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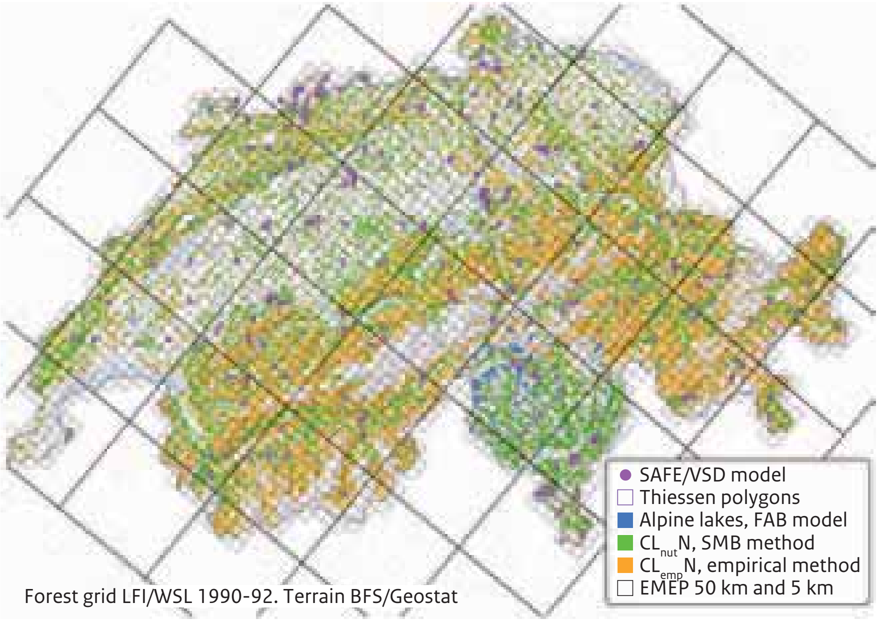
Overview

This document gives a summary of the data sources and the methods used to calculate Swiss sulphur and nitrogen critical loads, and highlights the changes since the data submission in 2008 (Achermann et al. 2008). In response to the current CCE call for data, there is also a chapter presenting the results of dynamic soil-vegetation modelling with VSD+, which was run on 32 Swiss test sites. Furthermore, an abstract presenting the results from several studies focussing on nitrogen effects related to biological diversity in Switzerland is included.

As in the previous data submission, the Swiss data set on critical loads of acidity and nutrient nitrogen is compiled from the output of four modelling and mapping approaches (see Figure CH.1):

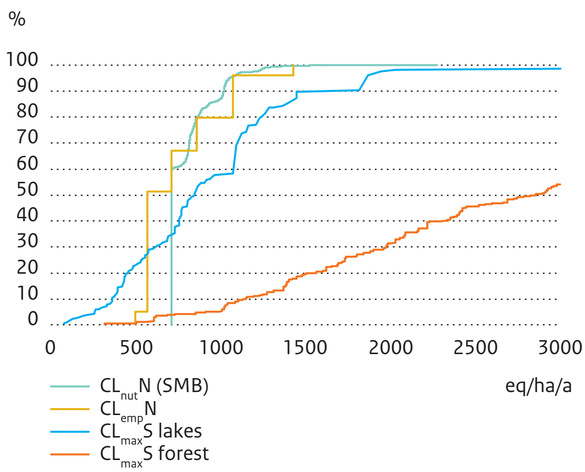
1. The dynamic models SAFE and VSD (very simple dynamic model) were used for assessing acidifying effects of air pollutants on forest soils. The multi-layer model SAFE was calibrated and applied on 260 sites, where full soil profiles were available. For calculating critical loads of acidity and deposition scenarios with VSD, the required flux input-data were calculated by the SAFE model.
2. The SMB method for calculating critical loads of nutrient nitrogen ($CL_{nut}N$) was applied on 10,608 forest sites. 10,348 of these sites originate from the National Forest Inventory (NFI, see LFI 1990/92), which is based on a 1×1 km² grid. They are complemented by the 260 sites with soil profiles (which are partly identical with the NFI-sites).

Figure CH.1 Overview of sensitive ecosystems and modelling approaches in Switzerland.



3. The empirical method for mapping critical loads of nutrient nitrogen *($CL_{emp}N$)* includes different natural and semi-natural ecosystems, such as raised bogs, fens, species-rich grassland, alpine heaths and poorly managed forest types with rich ground flora. The mapping was done on a 1x1 km grid combining several input maps of nature conservation areas and vegetation types. The total sensitive area amounts to 14,496 km^2.
4. Critical loads of acidity were calculated for 100 sensitive alpine lakes in Southern Switzerland applying a generalized version of the FAB model (first order acidity balance).

Figure CH.2 Cumulative frequency distributions of $CL_{nut}N$ (SMB and empirical method) and $CL_{max}S$ (forests and Alpine lakes).



Some essential results are shown in Figure CH.2 as cumulative frequency distributions: $CL_{nut}N$ for forests (SMB method), $CL_{emp}N$ for (semi-)natural ecosystems (empirical method) as well as the maximum critical load of sulfur ($CL_{max}S$) for forests (SAFE/VSD models) and Alpine lakes (FAB model).

Critical loads of acidity for forests

Deposition

Wet and dry deposition rates were modeled or interpolated on the basis of results from various monitoring sites. The deposition of N, S, Bc, Na and Cl was calculated with a generalised combined approach for the reference year 2000. Thimonier et al. (2004) describe the methods related to N and S deposition in forests. These site-specific modelled depositions for the reference year were used to scale the updated deposition trend data supplied by the CCE (Hettelingh et al. 2008; Appendix A).

Combined application of SAFE and VSD

The modelling of critical loads of acidity is based on 260 forest plots (see Figure CH.1) for which the layered soil input is available. The sources of all input data required for the SAFE model runs were listed in the CCE Status Report 2005 (Posch et al. 2005).
PRESAFE and SAFE are used to simulate input data for the VSD model, especially flux data such as weathering, nutrient uptake and deposition rates. N-processes other than uptake and leaching (immobilisation, denitrification) are yet only considered in VSD. For the current submission,

Table CH.1 Range of input parameters used for calculating CLnutN with the SMB method.

Parameter	Values	Comment
fde	0.2 – 0.7 depending on the wetness of the soil	For NFI-sites, information on wetness originates from soil map 1:200,000. For SAFE-sites it is a classification according to the depth of the saturated horizon.
Nle(acc)	4 kg N ha^{-1} yr^{-1} at 500m altitude 2 kg N ha^{-1} yr^{-1} at 2000m altitude	linear interpolation in-between. Acceptable leaching mainly occurs by management (after cutting), which is more intense at lower altitudes. Q and [N]acc are not used (for explanations see Slootweg et al. 2007).
Ni	1.5 kg N ha^{-1} yr^{-1} at 500m altitude 2.5 kg N ha^{-1} yr^{-1} at 1500m altitude	linear interpolation in-between. At high altitudes the decomposition of organic matter slows down due to lower temperatures and therefore the accumulation rates of N and C are naturally higher.
Nu	0.7 – 7.0 kg N ha^{-1} yr^{-1}	present uptakes calculated on the basis of estimated long-term harvesting rates and average element contents in stems.

the models were set up as follows:
- The SAFE model version V.2008 (S. Belyazid, pers. comm. 29 Feb 2008) was used for preparing the input to VSD.
- In former submissions, the multi-layer output of SAFE was aggregated to one layer in order to run the single-layer model VSD. Now, already the calculations in PreSAFE/SAFE are made in a one-layer mode.
- Fluxes for VSD are drawn from SAFE model runs at critical load deposition (instead of current legislation deposition), using the criterion $Bc/Al^{3+} = 1$.
- Due to the results of the data checks performed with the CCE-software (Access data base) in 2008, input data were improved for a small number of sites, e.g. carbon and nitrogen pools as well as C:N ratios.

Determining the ecosystem area

Critical loads of acidity are calculated for 260 SAFE-sites that are not regularly distributed within the country. The NFI-sites (National Forest Inventory), however, are systematic samples, representing a forest area of 1 km^2 each. Therefore, the area of forest represented by one SAFE-site was determined by those NFI-sites situated within the respective Thiessen-polygon constructed for the SAFE-sites (see Figure CH.1), and all acidity parameters were copied from a SAFE-site to the affiliated NFI-sites. In consequence, *EcoArea* was set to 1.0 km^2 for all resulting sites with critical loads for acidity.
If a NFI-site is situated on a 1x1 km grid cell containing also a site with empirical critical loads, *EcoArea* is set to 0.8 km^2 for the NFI-site and to 0.2 km^2 for the empirical site. Thus, double counts are avoided.

Critical loads of nutrient nitrogen (SMB method)

$CL_{nut}N$ are calculated by the SMB method for the 260 forest sites used in dynamic modelling and for 10,348 sites of the National Forest Inventory (NFI). Thereby, only NFI-sites with a defined mixing ratio of deciduous and coniferous trees are included (LFI 1990/92). This corresponds approximately to the managed forest area; for example brush forests and inaccessible forests are excluded.
The input for calculating the nitrogen process was presented in the CCE Report 2007 (Slootweg et al. 2007). Table CH.1 gives a summary of the input parameters values. In a second step, the lower limit of $CL_{nut}N$ calculated by the SMB was set to 10 kg N ha^{-1} a^{-1} (corresponding to the lower limit of $CL_{emp}N$ used for forests). This means, all values of $CL_{nut}N$ below 714 eq ha^{-1} a^{-1} were set to 714. This was done with respect to the fact that so far no empirically observed harmful effects in forest ecosystems were published for depositions lower than 10 kg N ha^{-1} a^{-1} and for latitudes and altitudes typical for Switzerland. Therefore, the critical loads calculated with the SMB method were adjusted to empirically confirmed values.

Empirical critical loads of nutrient nitrogen

The application of the empirical method is based on vegetation data compiled from various sources and aggregated to a 1×1 km^2 raster (see Figure CH.1, orange colour).
Overall, 43 sensitive vegetation types were identified and included in the critical load data set:
- 1 type of raised bog; source Federal Inventory of Raised and Transitional Bogs of National Importance (EDI 1991) (see Table CH.2);
- 3 types of fens; source Federal Inventory of Fenlands of National Importance (WSL 1993) (see Table CH.2);
- 21 types with various vegetation worthy of protection (Hegg et al. 1993), including rare and species-rich forest types, grasslands and alpine heaths (see Table CH.2);
- 18 types of dry grassland; source National Inventory of Dry Grasslands of National Importance (TWW, FOEN 2007) (see Table CH.3).

Table CH.2 The empirical method: selected ecosystems and critical load values applied in Switzerland (kg N $ha^{-1} a^{-1}$).

Ecosystem type	CLN range	Relevant vegetation types in Switzerland	$CL_{emp}N$	EUNIS code
Coniferous forests	5-15	Molinio-Pinetum (Pfeifengras-Föhrenwald)	12	G3.44
		Ononido-Pinion (Hauhechel-Föhrenwald)	12	G3.43
		Cytiso-Pinion (Geissklee-Föhrenwald)	12	G3.4
		Calluno-Pinetum (Heidekraut-Föhrenwald)	10	G3.3
		Erico-Pinion mugi (Ca) (Erika-Bergföhrenwald auf Kalk)	12	G3.44
		Erico-Pinion sylvestris (Erika-Föhrenwald)	12	G3.44
Deciduous forests	10-20	Quercion robori-petraeae *(Traubeneichenwald)*	15	G1.7
		Quercion pubescentis *(Flaumeichenwald)*	15	G1.71
		Fraxino orno-Ostryon *(Mannaeschen-Hopfenbuchwald)*	15	G1.73
Arctic and (sub)-alpine scrub habitats	5-15	Juniperion nanae (Zwergwacholderheiden)	10	F2.23
		Loiseleurio-Vaccinion (Alpenazaleenheiden)	10	F2.21
Sub-atlantic semi-dry calcareous grassland	15-25	Mesobromion (erecti) (Trespen-Halbtrockenrasen)	15	E1.26
Molinia caerulea meadows	15-25	Molinion (caeruleae) *(Pfeifengrasrieder)*	15	E3.51
Mountain hay meadows	10-20	Chrysopogonetum grylli *(Goldbart-Halbtrockenrasen)*	15	E1.2
		Seslerio-Bromion (Koelerio-Seslerion) *(Blaugras-Trespen-Halbtrockenrasen)*	12	E1.2
		Stipo-Poion molinerii *(Engadiner Steppenrasen)*, sub-alpine	10	E1.24
(sub)-alpine grassland	5-10	Festucetum paniculatae *(Goldschwingelrasen)*	8	E4.3
		Elynion *(Nacktriedrasen)*, alpine	8	E4.42
		Seslerion (variae) *(Blaugrashalden)*, alpine	8	E4.43
		Caricion ferrugineae *(Rostseggenhalden)*, alpine	8	E4.41
Poor fens	10-15	Scheuchzerietalia *(Scheuchzergras)*	10	D2.21
		Caricion fuscae *(Braunseggenried)*	12	D2.2
Rich fens	15-30	Caricion davallianae *(Davallsseggenried)*	15	D4.1
Raised bogs	5-10	Sphagnion fusci *(Hochmoor)*	7	D1.1

The TWW data set complements well the grassland types mapped by Hegg et al. (1993). It contains 18 vegetation groups, which partially also occur in the inventory of Hegg. The two inventories are used here in a complementary way, because they answer different purposes: the atlas of Hegg gives an overview of the occurrence of selected vegetation types, while TWW focuses on the precise description of objects with national importance.

The values for $CL_{emp}N$ have been based on Achermann and Bobbink (2003). They were revised considering the findings of the recent Workshop in Noordwijkerhout (UNECE 2010). In addition, the relative sensitivity of the ecosystems was reassessed by Burnand (2011). The revised critical loads for fens and for several grassland types are lower than in previous data submissions.

If more than one type occured within a 1×1 km^2 grid-cell the lowest value of $CL_{emp}N$ was selected for this cell.

Critical loads of acidity for alpine lakes

Critical loads of acidity for alpine lakes were calculated with a generalised FAB-model (Posch et al. 2007). The model was run for the catchments of 100 lakes in Southern Switzerland (see Figure CH.1) at altitudes between 1650 and 2700 m (average 2200 m). To a large extent the selected catchments consist of crystalline bedrock and are therefore quite sensitive to acidification.

The data are submitted since 2005. In the present CCE call for data, the mean lake depth was requested. At present, this parameter is unknown for most of the lakes.

Dynamic soil-vegetation modelling

The European dynamic soil chemistry model 'Very Simple Dynamic' (VSD) model was upgraded with relevant organic carbon and nitrogen dynamics (VSD+, Slootweg et al. 2010; Appendix B) and linked to the Swedish ground vegetation composition simulation tool Veg (Sverdrup et al. 2007).

VSD+ was tested in Switzerland by means of series of forest sites monitored by the Institute for Applied Plant Biology (IAP, Schönenbuch). The sites are also part of the national database used to derive critical sulphur and nitrogen loads and were used for earlier SAFE and ForSAFE model runs. Input for the VSD+ model was therefore

Table CH.3 Empirical critical loads for nitrogen assigned to 18 types of dry grasslands (TWW) of the national inventory of dry grasslands (FOEN 2007), in kg N $ha^{-1} a^{-1}$.

TWW-code		Vegetation type	EUNIS	Remarks	$CL_{emp}N$
1	CA	Caricion austro-alpinae	E4.4	alpine grassland	8
2	CB	Cirsio-Brachypodion	E1.23	similar to TWW 18 (E1.26), also used as hay meadow	15
3	FP	Festucion paniculatae	E4.3	similar to TWW 13	8
4	LL	(low diversity, low altitude)	E2.2	contains different types, promising diversity when mown, therefore lower range chosen	20
5	AI	Agropyrion intermedii	E1.2	transitional type	20
6	SP	Stipo-Poion	E1.24	pastures/fallows in large inner-alpine valleys; CLempN based on national expert-judgment (Hegg et al. 1993)	10
7	MBSP	Mesobromion / Stipo-Poion	E1.26	similar to TWW 18 (E1.26), pastures	15
8	XB	Xerobromion	E1.27	meadows/pastures/fallows in large inner-alpine valleys; CLempN based on national expert-judgment (Hegg et al. 1993)	12
9	MBXB	Mesobromion / Xerobromion	E1.26	similar to TWW 18	15
10	LH	(low diversity, high altitude)	E2.3	contains different types of dry grassland at high altitude	15
11	CF	Caricion ferrugineae	E4.41	similar to E4.4, alpine grassland	8
12	AE	Arrhenatherion elatioris	E2.2	often used as meadows, lower range chosen as it occurs at all altitude levels	20
13	FV	Festucion variae	E4.3	middle of the range chosen	8
14	SV	Seslerion variae	E4.43	alpine grassland	8
15	NS	Nardion strictae	E1.71	meadows, subalpine	12
16	OR	Origanietalia	E2.3	meadows/fallows	15
17	MBAE	Mesobromion / Arrhenatherion	E1.26	similar to TWW 18, slightly more nutrient-rich than Mesobromion	20
18	MB	Mesobromion	E1.26	genuine semi-dry grassland	15

generally extracted from input and output (e.g. weathering rates) of these multi-layer soil chemistry model runs. The basic data extraction procedure is described in the Swiss contribution to the 2010 CCE Status Report (Slootweg et al. 2010) and details of the data acquisition are compiled in the Swiss contribution to the 2005 CCE Status Report (Posch et al. 2005). Regarding the input of MetHyd (Slootweg et al. 2010; Appendix C), which is integral part of the VSD+ model, the site-specific climate data (monthly resolution) was updated with the relative sunshine duration, to allow the use of national meteorological data instead of the background database.

For each site we simultaneously calibrated the Gapon exchange coefficients (lgKAlBC, lgKHBC), the aluminium-(hydr)oxide dissolution constant and the exponent (lgKAlox, expAl) and the initial pools of carbon and nitrogen (Cpool_0, Npool_0) using present base saturation and C and N pools of the first 0.15 m of the soils as well as annual averages of measured hydrogen ion and, if necessary, aluminium concentrations in the soil solution. The simulations were limited to the time interval 1900 to 2100. Seven out of 32 sites were calibrated acceptably well. Yet, the sites cover varied tree populations, mixed deciduous/coniferous (3) and coniferous (4), and reside on varied height levels, Plateau (4), Pre-Alps (2) and Alps (1). Figure CH.3 compares modelled and observed soil solution chemistry. Soil solution was usually sampled bi-weekly by means of lysimeters from 3 different soil depths. The measurements for the soil depth closest to the respective limit of the soil compartment used for modelling were straight forwardly averaged for each of the measurement years, usually spanning from 1998 to 2008. The model accurately reproduced soil solution concentrations of chloride (Figure CH.3B) and sodium (Figure CH.3D), implying reasonable assumptions regarding hydrology and weathering as well as correct deposition input of these ions. Sulphate concentrations (Figure CH.3A) are only slightly underestimated by the model most likely due to an underestimation of the deposition input. A little more scatter is found with the base cation concentration (Figure CH.3C), the simulation of which is complicated by the consideration of additional processes such as cation exchange and nutrient cycling. So far the soil chemistry models (e.g. VSD, SAFE) tended to systematically overestimate nitrate concentrations in the soil solution, even if immobilization and denitrification of N were considered. The more complex and integrated N processes

Figure CH.3 Comparison of measured and modelled annual averages of ion concentrations in soil solution.

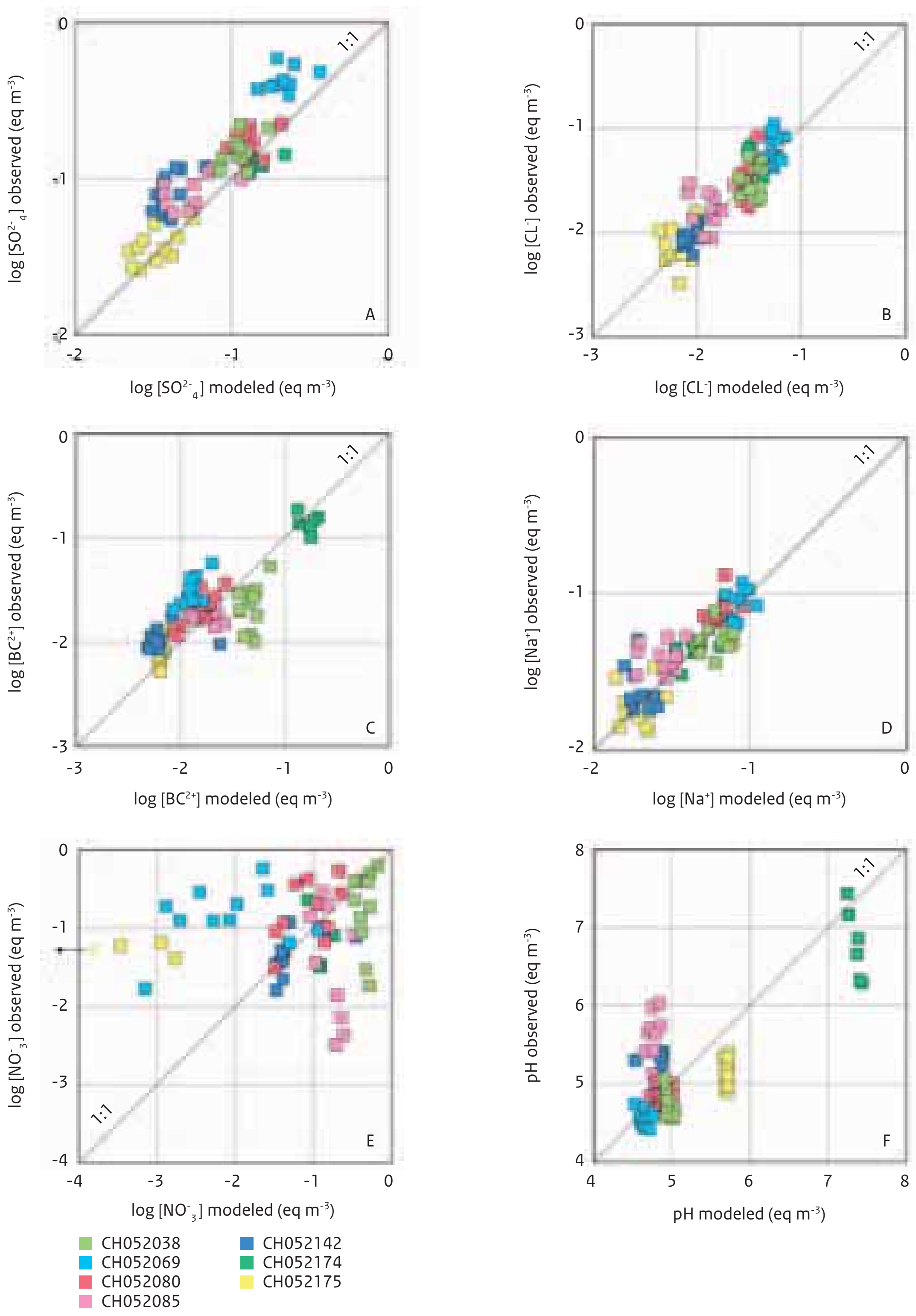


Figure CH.4 Comparison of observed and predicted plant species occurrence (A) for sites with observations. Comparability of the total modelled and observed ground vegetation composition (CzI) and predicted cover (cov) of the reference m² of the plots, if only observed species are considered (B).

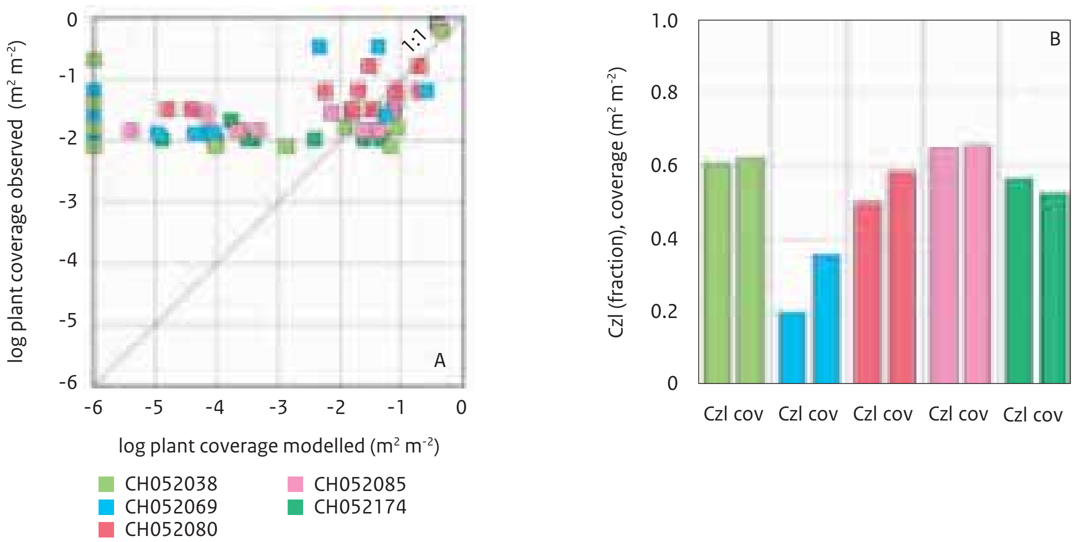


Table CH.4 Number of plant species observed on the plots and predicted by the Veg model.

Site ID	Forest type	Height a.s.l.	Number of plant species		
			observed	modelled	
			reference year	reference year	period
		(m)	(-)	(-)	(-)
CH052038	mixed deciduous/coniferous	740	16[1]	36	45
CH052069	coniferous	413	16[1]	22	170
CH052080	mixed coniferous/deciduous	505	17[1]	61	190
CH052085	mixed coniferous/deciduous	948	14[1]	80	83
CH052142	coniferous	957	n.a.	152[1]	184
CH052174	coniferous	519	18[2]	55	183
CH052175	coniferous	1550	n.a.	134[1]	210

Reference years are [1]2003 and [2]2004.

of VSD+ help to overcome this shortcoming. Although the general bias disappeared, the correlation of modelled and measured nitrate concentrations appears still insufficient (Figure CH.3E). Discrepancies in the prediction of relevant soil solution ion concentrations also affect the assessment of the soil solution pH, which exhibits substantial deviation from measurements (Figure CH.3F).

For the simulation of the ground vegetation composition with the recently linked Veg module, an updated generic ground vegetation parameter table (S. Belyazid, pers. comm. 9 Nov 2010) covering 374 plant species was used. All available climatic (soil moisture, light availability at ground level and temperature) and geochemical (nitrogen availability, base cation availability and soil acidity) drivers affecting the plant community composition were activated, and the simulation period was set, as with VSD+, to 1900 to 2100. Veg used 218 of the 374 plant species (coverage limit for consideration: 1 $cm^2\ cm^{-2}$) to simulate the ground vegetation composition of the 7 sites. The number of species used differs substantially from site to site for both an individual reference year and the total simulation period (Table CH. 4).

The model also predicts substantially higher numbers of species than currently observed on the plots and, consequently, if only observed species are being considered, the total modelled coverage of the plot spans from 0.36 to 0.66 $m^2\ m^{-2}$ (Figure CH.4B). Only 50% of the observed dominant species are also found as dominant species in the model predictions and the Czekanoswski index (CzI), here used as measure of the comparability of total modelled and observed vegetation covers, ranges from moderate 0.20 to acceptable 0.65. Figure CH.4A depicts the pattern behind the CzI numbers, showing species with modelled and observed surface coverage in the same order of magnitude but also a substantial tendency to model underestimations.

Figure CH.5 Percentage of cover by Rubus fruticosus agg. in relation to modelled N deposition in Swiss forest observation plots of the intercantonal forest survey programme (Flückiger and Braun 2004).

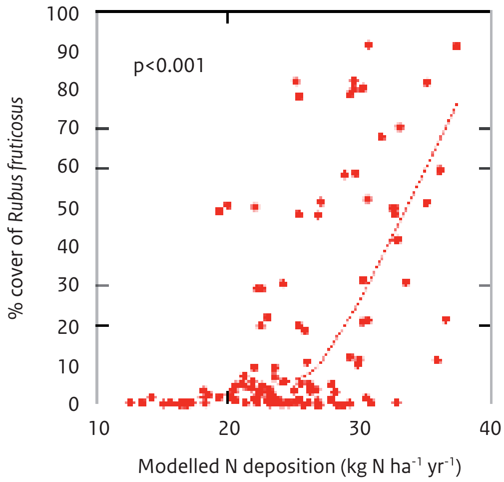
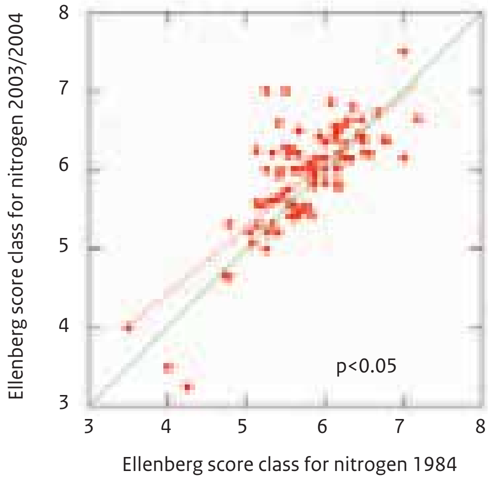


Figure CH.6 The change of the Ellenberg N values between 1984/85 and 2003/2004 at forest sites of the intercantonal forest survey programme in Switzerland (Flückiger and Braun 2004).



In summary, VSD+ ran only through a limited number of sites, if successful calibration of relevant measured soil parameters is taken as decision criterion. Reasons for the observed calibration failures are currently not well understood and could be due to:

- inadequate model conception or model implementation,
- handling errors in the model application,
- erroneous input derivation or insufficient quality of the input, and
- inconsistencies between input and reference data.

Regarding the aspired regional application of VSD+, this restraint needs to be resolved and a better understanding of the model's tolerance limits is needed, having in mind that regional input is prone to often considerable uncertainty. Upon successful calibration, VSD+ returned soil solution chemistry, which generally was acceptably comparable to measurements with the exception of nitrate concentrations, leaving room for improvements in the C and N dynamics.

The Veg model, run with input/output of VSD+, only partially reproduced the observed ground vegetation composition (maximum CzI=0.65). Veg generally considers substantially more species than being observed on the plot, leading to a frequently large number of species with only marginal coverage. This points to a conceptual incompatibility of potential and existing ground vegetation composition, which hampers the evaluation of the model's performance.

Evidence of nitrogen effects on biological diversity

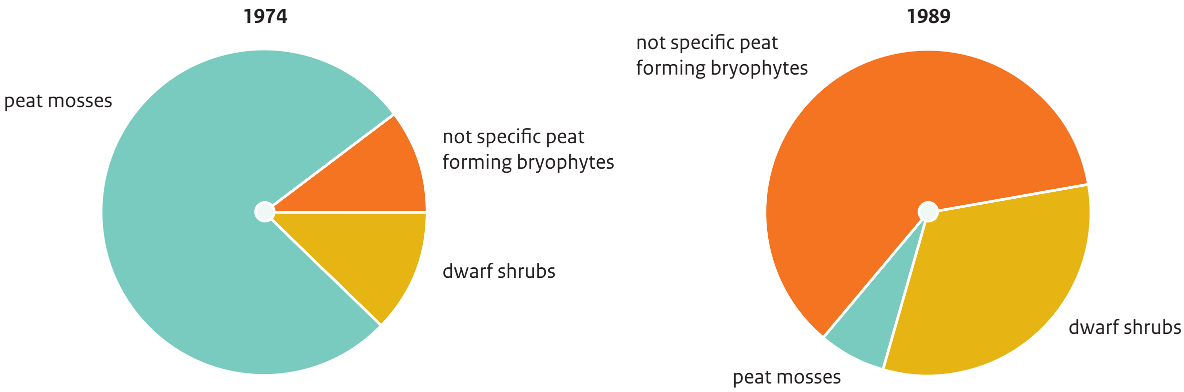
In Switzerland, a significantly increased abundance of nitrophilous species was observed at 17 of 18 forest sites in two regions (northern Switzerland, with modelled N deposition for 1995 of 20–30 kg N $ha^{-1} yr^{-1}$, and the Geneva region, with N deposition of 15–20 kg N $ha^{-1} yr^{-1}$) after comparing vegetation data from the period 1938–47 with those from the 1984–85 (Kuhn et al. 1987).

At 37 forest sites in the Central Plateau of Switzerland, the comparison between two surveys of ground vegetation between 1940/1965 and 1998 revealed a decreased frequency of 241 species and an increased frequency of 44 species, some of them typical nitrophilous species, such as *Rubus fruticosus, Rubus caesius, Dryopteris dilatata, Dryopteris filix mas, Sambucus nigra, Hedera helix* and *Urtica dioica*. The N deposition in this region was between 30 and more than 40 kg N $ha^{-1} yr^{-1}$ (Walther and Grundmann 2001).

The cover of *Rubus fruticosus species* increased strongly in Swiss forest plots with a modelled N-deposition rate of ≥ 25 kg N $ha^{-1} yr^{-1}$ (Flückiger and Braun 2004, Figure CH.5). According to its Ellenberg N value, *Rubus fruticosus* would not be classified as a nitrophilous plant, but its shoot development seems to be highly stimulated by N. The same holds true for *Deschampsia flexuosa*, which also shows a positive reaction to N.

A comparison of the soil vegetation from inventories at several sites of the inter-cantonal forest survey carried out in the years 1984/85 and repeated in 2003/2004 has shown an increase in the occurrence of nitrophilous species on

Figure CH.7 Change of species composition in the Swiss raised bog Rothenthurm between 1974 and 1989 (Held et al. 1992).



the basis of Ellenberg N values (Flückiger and Braun, 2004, Figure CH.6). Changes might have taken place already before 1984/85 since the emissions of nitrogen containing air pollutants in Switzerland showed a strong increase since 1950 and reached their peak around 1985.

An assessment of the changes of the species composition in the Swiss raised bog Rothenthurm was carried out between 1974 and 1989 (Held et al. 1992). Significant changes were observed, i.e. a decrease of peat mosses and an increase of not specific peat-forming bryophytes and dwarf shrubs (Figure CH.7). The changes were interpreted to be a result of drainage and increases of N inputs.

The quality status and development of raised bogs and fens of national importance in Switzerland was assessed for the period 1997-2001 and again between 2002 and 2006 (BAFU, 2007; summary in English by FOEN, 2008). The results show a decrease of the quality of the ecosystems. More than 25% of the raised bogs and fens became drier, in about 25% of the ecosystems an increase of the eutrophication status and in about one third an increase of the occurrence of woody plants can be observed, about 20% show a decrease of the humus content in the soil. The typical bog character decreased in 15% of the raised bogs and fens.

A specific N-deposition related study as part of the gridded Swiss Biodiversity Monitoring was carried out (Kohli et al. 2011) aiming at evaluating possible relationships between spatial differences of N-deposition and the nutrient supply in soils as well as its influence on species diversity and the occurrence of nitrophilous species. Thus the study does not analyze changes over time, but evaluates spatial differences at the point in time of a gridded inventory. The results show a significant increase of the nutrient supply in soils of mountains, forests and grassland with increasing N-deposition. The diversity of vascular plants decreases significantly with increasing N-deposition in grasslands. When grasslands and alpine pastures are stratified according to different altitudinal zones , then the diversity of vascular plants, mosses and molluscs decreases with increasing N-deposition in the colline and montane zone, whereas an increase of the diversity of mosses can be observed for alpine pastures with increasing N-deposition. The diversity of molluscs decreases also in mountains with increasing N-deposition. The fraction of nutrient indicating species of vascular plants increases in grasslands, forests and mountains (Figure CH.8). The statistical correlations are sometimes weak and indicate that other site-specific factors including management practices play a more important role.

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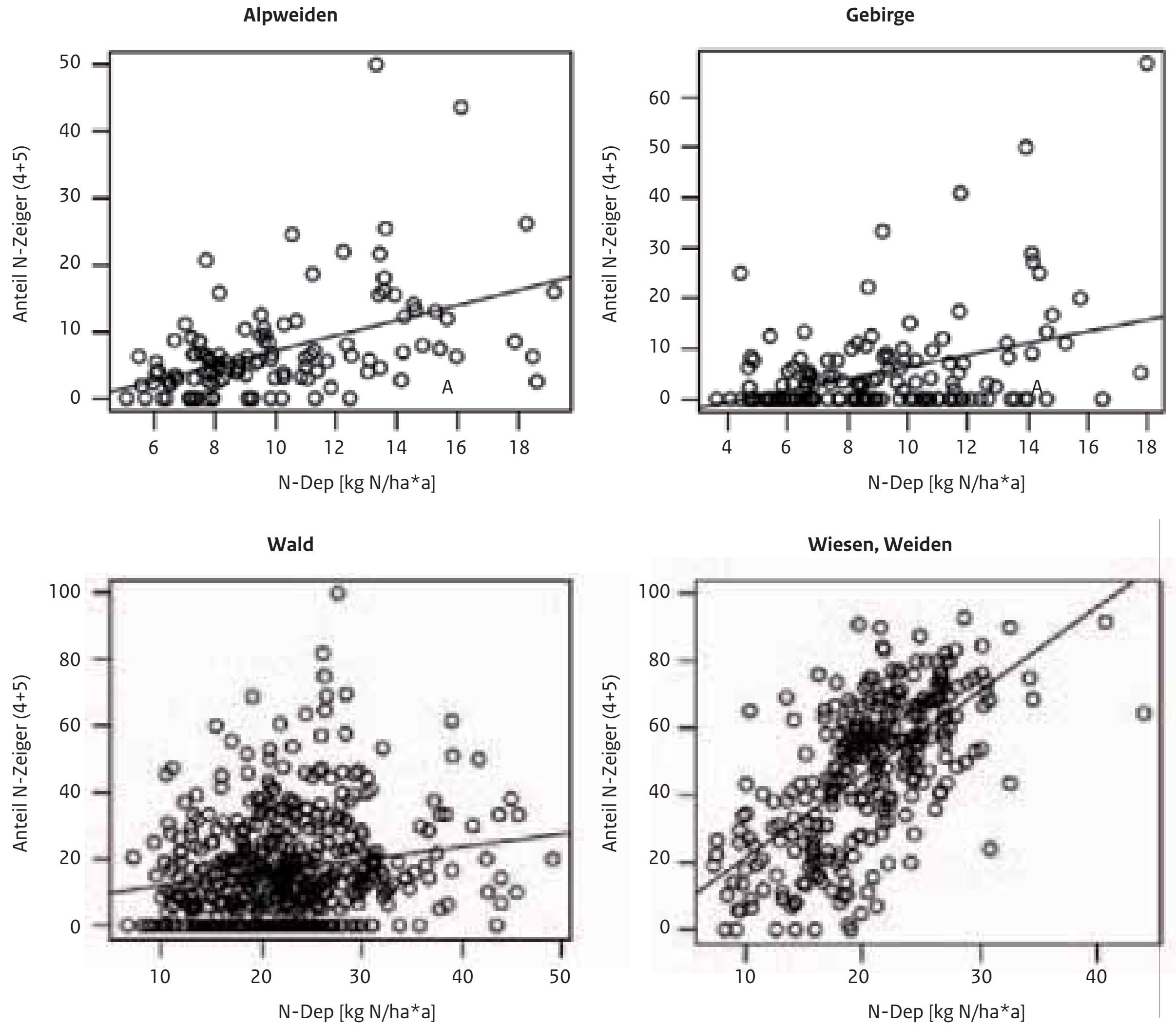
Figure CH.8 Correlations between N-deposition and the fraction of nutrient indicating vascular plants for alpine pastures (Alpweiden), mountain areas (Gebirge), forests (Wald) and grasslands (Wiesen/Weiden) resulting from a specific N-deposition related study as part of the gridded Swiss Biodiversity Monitoring (Kohli et al. 2011).



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United States of America

National Focal Center Pilot Study (FOCUS)

Beginning in 2006, the primary forum for critical loads research and development coordination in the United States has been the Critical Loads of Atmospheric Deposition Science Committee (CLAD) of the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/clad/). In 2010/2011 in the "FOCUS Pilot Study" project, CLAD gathered and synthesized empirical and calculated critical loads data from dozens of regional and national-scale projects. CLAD members provided that data as an informal, unofficial submission to the Coordination Centre for Effects (CCE) in the interests of international cooperation and exchange of information on the effects of atmospheric deposition on ecosystems. CLAD hopes to join a productive and meaningful dialogue with the international scientific community on methods for estimating, calculating, mapping, interpreting, and refining critical loads.

Richard Haeuber, CLAD Co-Chair (2010–2011)
U.S. Environmental Protection Agency

Richard Pouyat, CLAD Co-Chair (2010–2011)
U.S. Forest Service

Tamara Blett, CLAD Chair (2009)
National Park Service

Collaborating institutions

U.S. Environmental Protection Agency
USDA Forest Service
National Park Service
Western Governors' Association
U.S. Geological Survey
Syracuse University
Northern Carolina State University
University of Virginia
E&S Environmental & Ecosystems Research Group

Introduction

This document contains information and documentation useful for understanding the CLAD critical load of N and S Access database submitted in response to the CCE call for critical load data. This document supports the Access database entitled "CLAD_Critical_Load_data_08-04-11.mdb". It briefly describes the database variables, how critical load values were determined, and the databases that were used in compiling the critical loads data included in the Access database.

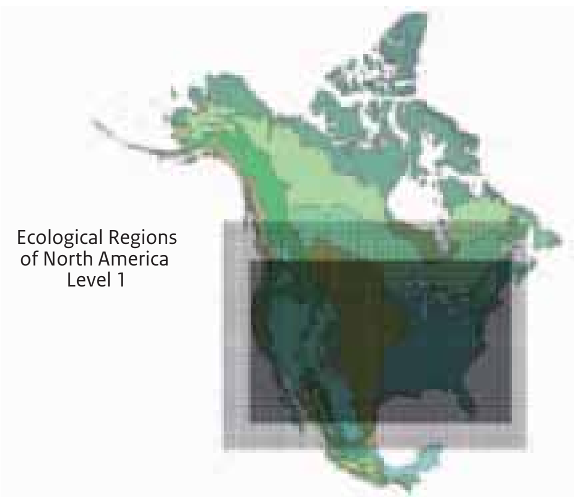
Table US.1 Structure of the database-table 'ecords'.

Variable	Explanation	Note
SiteID	Unique(!) identifier of the site	1
Lon	Longitude (decimal degrees)	2
Lat	Latitude (decimal degrees)	2
I36	Horizontal coordinate of the CMAQ 36 km grid	3
J36	Vertical coordinate of the CMAQ 36 km grid	3
I12	Horizontal coordinate of the CMAQ 12 km grid	3
J12	Vertical coordinate of the CMAQ 12 km grid	3
EcoArea	Area of the ecosystem within the CMAQ grid cell (km^2)	4
Protection	0: No specific nature protection applies 1: Special Protection Area (Wilderness) 2: Special Protection Area (Federal Lands) 3: Special Protection Area (State) 4: Special Protection Area (Private) –1: protection status unknown	5
ECORcode1	EcoRegion code Level 1	6

1. Identifier for each critical load: 1–499,999 Empirical; 500,000–1,000,000 Surface water; >1,000,000 Soil.
2. The geographical coordinates of the site or a reference point of the polygon (sub-grid) of the receptor under consideration in decimal degrees. The following projection was used:

Projection: Lambert_Conformal_Conic		Geographic Coordinate System:	
False_Easting:	0.00000000	GCS_Sphere_ARC_INFO	
False_Northing:	0.00000000	Datum:	D_Sphere_ARC_INFO
Central_Meridian:	-97.00000000	Prime Meridian:	Greenwich
Standard_Parallel_1:	33.00000000	Angular Unit:	Degree
Standard_Parallel_2:	45.00000000		
Latitude_Of_Origin:	40.00000000		
Linear Unit:	Meter		

Figure US.1 Map showing CEC ecoregion I and 12×12 km^2 and 36×36 km^2 CMAQ grids.



3. The column and row coordinate value of the 12×12 km^2 and 36×36 km^2 CMAQ-grid cell in which the receptor is located. Community Multiscale Air Quality (CMAQ) is the indices used by the US EPA air quality and deposition model. The model is run at both 12 km and 36 km scales (http://www.epa.gov/AMD/CMAQ/) (see Figure US.1).
4. Area of the ecosystem within the 12×12km^2 CMAQ grid cell (km^2) that the critical load represents. For empirical critical loads, urban and agriculture areas were excluded from the EcoArea estimate, using NLCD 2001 (National Land Cover Database) (www.epa.gov/mrlc/nlcd-2001.html). EcoAreas for empirical critical load values range from 0.01 to 144 km^2. EcoAreas for soil critical load values represent forest areas only and range from 4 to16 km^2. EcoAreas of surface water critical load values were set to the drainage area of the site and ranged from 0.01 to 144 km^2.
5. Protection classifications were not determined for the US data.
6. The EUNIScode was replace with the CEC (Commission for Environmental Cooperation) EcoRegion level 1 code, which represents the Omernik (1987) ecoregion classification for North America (Figure US.1). Level I ecological regions are: Arctic Cordillera, Tundra, Taiga, Hudson Plains, Northern Forests, Northwestern Forested Mountains, Marine West Coast Forests, Eastern Temperate Forests, Great Plains, North American Deserts, Mediterranean California, Southern Semi-Arid Highlands, Temperate Sierras, Tropical Dry Forests and Tropical Wet Forests (www.epa.gov/wed/pages/ecoregions/na_eco.htm).
7. Steady-state soil and surface water critical loads for acidity are included. Soil critical loads were calculated based by simple mass balance (SMB) models that calculate base cation weathering using clay correlation-substrate methods (Sverdrup et al. 1990). See McNulty

Table US.2 Attributes of the table 'CLdata'.

SiteID	Identifier of the site (same as in Table US.1)	1
$CL_{max}S$	Maximum critical load of sulphur (eq ha^{-1} a^{-1})	7
$CL_{min}N$	Minimum critical load of nitrogen (eq ha^{-1} a^{-1})	7
$CL_{max}N$	Maximum critical load of nitrogen (eq ha^{-1} a^{-1})	7
$CL_{nut}N$	Critical load of nutrient nitrogen (eq ha^{-1} a^{-1})	7
nANCcrit	The quantity –ANCle(crit) (eq ha^{-1} a^{-1})	8

Table US.3 Attributes of the table 'inputs' for soils.

SiteID	Identifier of the site	1
crittype	Chemical criterion used for acidity CL calculations: = 0 – Other = 1 – molar[Al]: [Bc] = 2 – [Al] (eq m^{-3}) = 3 – base sat (%) or change in base sat or no change in base sat = 4 – pH = 5 – [ANC] (eq m^{-3}) = 6 – molar[Bc]:[H] = 7 – molar [Bc]:[Al] = 8 – molar [Ca]:[Al] = 9 – molar [Al]:[Bc] AND [Al] > 0.1meq/L	
critvalue	Critical value for the chemical criterion given in 'crittype'	
BC_{dep}	Total deposition of base cations (BC = Ca+Mg+K+Na) (eq ha^{-1} a^{-1})	9
CL_{dep}	Total deposition of chloride (eq ha^{-1} a^{-1})	9
BC_{we}	Weathering of base cations (BC = Ca+Mg+K+Na) (eq ha^{-1} a^{-1})	10
BC_{upt}	Net removal of base cations (BC = Ca+Mg+K+Na) (eq ha^{-1} a^{-1})	11
Q_{le}	Amount of water percolating through the root zone (mm a^{-1})	12
lgKAlox	Equilibrium constant for the Al-H relationship (log10)	
Nimacc	Acceptable nitrogen immobilised in the soil (eq ha^{-1} a^{-1})	7
N_{upt}	Net removal of nitrogen (eq ha^{-1} a^{-1})	11
f_{de}	Denitrification fraction (0≤fde<1) (-)	
N_{de}	Amount of nitrogen denitrified (eq ha^{-1} a^{-1})	7

et al. (2007) for more details on the methods and databases used to calculate the soil critical loads. $CL_{nut}N$ was also determined by the SMB model.
Steady-state surface water critical loads were determined by multiple approaches. For all surface water critical loads, CLmin for nitrogen was set at 114.4 eq ha^{-1} a^{-1}; denitrification was set to 71.4 eq ha^{-1} a^{-1}; long-term net nitrogen immobilization was set to 43 eq ha^{-1} a^{-1}. Base cation weathering was determined by three different methods: modified F-factor, regional regression model and MAGIC model (Sullivan et al. 2010).

8. Soil critical loads were based on molar [Bc]:[Al] ratio of 1 for deciduous forest and 10 for conifer forest. The single value of 1 was entered in the database.
9. Base cation deposition was included as the sum of wet Ca, Mg, K, Na deposition. Data source for most sites was the average annual wet base cation deposition for the conterminous US for years from 1994–2000 based on measurements collected by National Atmospheric Deposition Program/National Trends Network. See McNulty et al. (2007) for more details.
10. Base cation weathering rates were calculated using the correlation-substrate methods for critical loads for soils (Sverdrup et al. 1990).
11. Base cation and nitrogen uptake/removal were included in soil critical load calculations, but are not all represented in the US database. See McNulty et al. (2007) and Pardo et al. (2007) for more details on how base cation and nitrogen uptake/removal w ere calculated.
12. Average annual runoff was based on the line coverage representing average annual runoff in inches per year for the US from 1951 to 1980 produced by Gebert et al. (1987).
13. Empirical critical loads of nitrogen (eq ha^{-1} a^{-1}) were set for 5 receptors (Recep). Each receptor has its own SiteID. The approach for setting empirical critical loads for receptors 1–4 was based on Pardo et al. (2011; see Table US.5); the low end of the ranges was reported for these critical loads.

Table US.4 Attributes of the table 'EmpNload'.

SiteID	Identifier for the site	1
$CL_{emp}N$	Empirical critical load of N (eq ha^{-1} a^{-1})	13
Recep	Receptor: = 0 – Other = 1 – Fungi = 2 – Henceforth lichens = 3 – Herbaceous = 4 – Forests = 5 – Lichen	13

Table US.5 Attributes of the table 'h2oinputs'.

SiteID	Identifier for the site	1
Crittype	Criterion used: = 5 – [ANC] (ueq/L)	14
Critvalue	Value of the criterion used	14
BC_{dep}	Wet deposition of base cations (BC = Ca+Mg+K+Na) (eq ha^{-1} a^{-1})	15
CL_{dep}	Wet deposition of chloride (eq ha^{-1} a^{-1})	15
BC_{we}	Weathering of base cations (BC = Ca+Mg+K+Na) (eq ha^{-1} a^{-1})	7
BC_{upt}	Net growth uptake of base cations (BC = Ca+Mg+K+Na) (eq ha^{-1} a^{-1})	16
Qs	Annual runoff flux (m a^{-1})	12
Nimacc	Acceptable nitrogen immobilised in the soil (eq ha^{-1} a^{-1})	7
N_{upt}	Net growth uptake of nitrogen (eq ha^{-1} a^{-1})	11
Nitrif	Nitrification in the catchment (meq m^{-2} a^{-1})	7
Denitrf	Denitrification rate in catchment (meq m^{-2} a^{-1})	7
WSH	Size of watershed (ha)	
Measured	On-site measurements for surface water calculations: 0 – No measurements, 1 – Eastern Lake Survey (ELS) 2 – National Stream Survey (NSS) 3 – Western Lake Survey (WLS) 4 – EMAP Northeast Lakes & TIME Lakes 5 – MAHA or MAIA & Time Lakes 6 – LTM 7 – REMAP 8 – USGS 9 – USFS 10 – State 11 – NLS 2010 12 – WSA 2007 13 – Other	

Lichen-based critical loads for atmospheric nitrogen deposition (receptor 5) were determined by the approach described in Geiser et al. (2010), which used airscores (Table US.7) and average annual precipitation by ecoregion classification to estimate lichen based critical loads for nitrogen. Average annual precipitation amounts were determined by 1961–1990 climatic normals at 4 km resolution (prism.oregonstate.edu/products/matrix.phtml?vartype=tmax&view=data). See Geiser et al. (2010) for more details.

14. Acid neutralizing capacity (ANC) is used as the surface water critical load criterion for all values. The value of the ANC criterion is set equal to 50 µeq/L.
15. Base cation deposition is the sum of wet Ca, Mg, K, Na deposition (eq ha^{-1} a^{-1}).
16. Base cation and nitrogen uptake/removal are included only in some of the surface water critical loads calculations. See mcnulty et al. (2007) for more details on how base cation uptake/removal was calculated.

Table US.6 Empirical critical load of nitrogen (eq ha^{-1} a^{-1}) from Pardo et al. (2011).

EcoRegion Level I		Empirical critical loads of N			
		Henceforth lichens	Lichens	Herbaceous	Forests
2	Tundra		1	1	
3	Taiga	5	1	6	
5	Northern Forests	5	2	>7	>3
6	NW Forested Mtns	5	2.5	4	4
7	Marine West Coast	5	2.7		5
8	Eastern Temperate Forests	5	4	<17.5	>3
9	Great Plains	12		5	
10	NA Deserts		3	3	
11	Mediterranean California	7.8	3	6	17
13	Temperate Sierras		4		
15	Tropical Wet Forests			<5	

Table US.7 Empirical critical load of nitrogen (eq ha^{-1} a^{-1}) from Pardo et al. (2011).

EcoName	EcoCode1	AirMin	AirMax
Northern Forests (US)	5	0.21	0.21
Marine West Coast Forests	7	0.21	0.21
NW Forested Mtns	6	0.21	0.49
Eastern Temperate Forest	8	0.33	0.33
Mediterranean CA	11	0.33	0.49
Temperate Sierras	13	0.49	0.49

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Part 4

Appendices

Appendix A
Instructions for submitting Critical Loads of N and S and site-specific soil-vegetation model runs

This appendix is a reprint of the last version of the instructions sent to the National Focal Centres with the Call for Data. It also includes the 'Annex 2' of that Call on 'Critical loads based nitrogen deposition assessment for Habitats Directive Article 17 reporting'.

1. Introduction

This document contains the instructions for the submission of data to the CCE on empirical and modelled critical loads of nitrogen and sulphur, as well as inputs of soil-vegetation model runs on sites.

Your submission should contain the following key outputs:

1. **Updated modelled critical loads on the 5 km × 5 km EMEP grid**, together with input variables to allow consistency checks and inter-country comparisons.
2. **Updated empirical critical loads on the 5 × 5 grid**, based on the revised Table of empirical critical loads established at the "Workshop on the review and revision of empirical critical loads and dose-response relationships" (Noordwijkerhout, 23-25 June 2010) and adopted at the 29th session of the Working Group on Effects. (http://www.unece.org/env/documents/2010/eb/wge/ece.eb.air.wg.1.2010.14.e.pdf)
3. **Complete sets of input files to the soil-vegetation model runs.**
4. **Your NFC report for inclusion in the CCE Status Report 2011, including a short description of the collaboration between NFCs and habitat experts.**

2. What's new and/or important to know?

2.1 Deadline and other general information:

- **Deadline** for submissions is **7 March 2011**
- **The email addresses of the CCE has changed!** Due to the transfer of the CCE to RIVM the email addresses has changed since 1 January 2011. The email address of the contact person regarding this call is jaap.slootweg@rivm.nl and the URL of our ftp-site is ftp://ftp.rivm.nl/cce/
- Please email your **submission** to jaap.slootweg@rivm.nl. The data can be attached to the email, but large data files can also be uploaded to ftp://ftp.rivm.nl/cce/incoming/ using ftp. After you have used ftp to submit your data, please inform Jaap Slootweg by an email.
- All information is also available on our website www.rivm.nl/cce/ under ***News***. It is suggested to look occasionally for updates.
- Updated versions of chapters of the Mapping Manual are available at www.icpmapping.org
- Instruction videos on the use of VSDplus-Studio, which includes VEG, and the MetHyd model are available under 'News' of www.rivm.nl/cce.

2.2 Critical loads data

Since 2008, changes to the data structure we would like to highlight are:

- In comparison to the data structure of the 2008 critical loads database, the 'inputs' table now contains the indices i and j, referring to the new EMEP grid.
- **None of the data submitted before this call will be used.** It is not feasible for the CCE to convert historic national data on a 50×50 EMEP grid to the 5×5 EMEP grid.
- **The ranges for the empirical critical loads and the use of modifying factors have changed!** Empirical critical loads have been reviewed and revised at the "Workshop on the review and revision of empirical critical loads and dose-response relationships" (Noordwijkerhout, 23-25 June 2010). You can find the final drafts of the chapters of this document at www.rivm.nl/cce under *News*[1]
- **The structure of the tables for submitting CL data has been slightly changed compared to the 2008 call for data.** Most important is the reference to the new 5 × 5 EMEP grid. A description of this grid and a GIS data file (an ARCGIS shape file) are available on ftp://ftp.rivm.nl/cce/outgoing/. Also the *h2oinputs* has been simplified, see **3.3**. **Data structure for inputs of aquatic ecosystems.**
- The preferred **file format** is an Access database file (mdb), but Excel files or comma-separated ASCII files are also accepted. The easiest way is to use the template Access database made available by the CCE.
- 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 critical load database. You are kindly urged to apply them.

2.3 Dynamic soil-vegetation modelling

- In comparison to the call for dynamic modelling data in 2008, no regional dynamic modelling results are included in this call, and all related variables are absent. Dynamic modelling is focussing on testing at individual sites.
- **Testing of soil-vegetation modelling;** NFCs are encouraged to:
  Complete the generic (relevant for any part of Europe) Table[2] of the **European vegetation species list** including VEG parameters that is made available under www.rivm.nl/cce with site-specific information, for the sites on which you intend to run VSDplus-VEG. A crucial part of the vegetation models are the list of modelled species. A combined list of species (available under news of www.rivm.nl/cce), relevant for any part of Europe, should be completed to facilitate the support of scenario analysis of the change of species diversity on a European scale.
- Apply VSDplus-VEG over a simulation period towards a target year for which you have site specific information, in order to compare simulated to monitored species diversity.
- Validation of model combinations (VSDplus-VEG Studio as provided with this call or your own model for simulating soil-vegetation dynamics) could include the comparison between current and historic species Ecological explanations for the differences and updates/ extension of the **European vegetation species list** are valuable contributions.
- Historic depositions and the **deposition scenarios** for nitrogen and sulphur are from the 'Review of the 1999 Gothenburg Protocol', Executive Body for the Convention (2007), ECE/EB.AIR/WG.5/2007/7, made available from the CCE upon request.
- **ICP forests plots** are potential datasets to verify soil-vegetation models!

2.4 Reporting "nitrogen effects on biological diversity" in your NFC documentation

- In your NFC reporting, please include an account of effects of nitrogen, as established in (semi-) natural areas in your country, in collaboration with habitat experts. Encouragements of NFCs to contact habitat experts and other national networks in the field of nitrogen sources and effects have been discussed and documented in the meetings of the Task Forces M&M in 2007 (para 36g), 2008 (para 40c), and 2009 (para 31c). During its 26th meeting (Paris, 22-23 April 2010) the Task Force M&M "encourage NFCs to relate to national habitat experts in Parties to the Convention, including national focal points in EU Member States who are responsible for reporting requirements under Article 17 of the Habitats Directive." Therefore, for this call for data the CCE proposes to make a structured start (see Annex 2) with the collaboration between National Focal Centres and national habitat experts (the list is included in Annex 2) involved in the reporting on "Favourable Conservation Status".

1 Bobbink RS, Hettelingh J-P (eds) (2010) Review and revision of empirical critical loads and dose-response relationships, Proceedings of an international workshop, Noordwijkerhout 23-25 June 2010, PBL-CCE/B-Ware Report, Bilthoven, *in press*.

2 Generated by H. Sverdrup, and S. Belyazid in collaboration with the Swedish Environmental Protection Agency, the Swiss Federal Office for the Environment and the CCE, including French, Swedish and Swiss data [and some more].

Table 1 Structure of the database-table *'ecords'*.

Variable	Explanation	Note
SiteID	Unique(!) identifier of the site	1
Lon	Longitude (decimal degrees)	2
Lat	Latitude (decimal degrees)	2
I	EMEP5 horizontal coordinate	3
J	EMEP5 vertical coordinate	3
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	4
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	5

3. Data structure

The easiest way to assemble and submit data is to use the **Access** database, which is available from the CCE website www.rivm.nl/cce/ under *News*.

In the data structure the table 'ecords' holds the geographic attributes of the ecosystems, listed in Table 1. A submission for a country may contain multiple datasets, but only a single 'ecords' table.

Notes on Table 1 (see last column):

1. Use integer values only (4-bytes)!
2. The geographical coordinates of the site or a reference point of the polygon (sub-grid) of the receptor under consideration (in decimal degrees, i.e. 48.5 for 48°30', etc.)
3. Indices (2-byte integers) of the 5km×5km EMEP-grid cell in which the receptor is located. See Appendix D of the CCE Status Report 2010 (a preprint can also be found on www.rivm.nl/cce).
4. Please remove (spurious) records with an ecosystem area smaller than 1 ha. Furthermore, make sure that the ecosystem area does not exceed the size of the land area of your country in the respective grid cell
5. You can find information on EUNIS (updated 2005) at http://eunis.eea.eu.int/

The other parts of the data structure are summarized in Tables 2 to 5 below. The database you submit should contain at least 2 tables of which one should be *'ecords'*. It may also include tables with the structure of *'EmpNload'*, *'CLdata'* in combination with *'inputs'* and/or *'h2oinputs'*.

Routines in the software provided by the CCE allow you to perform consistency checks on your data. It is strongly recommended to carry out these checks! They (may) generate screen messages, which should be followed up. Some of the checks verify the values to be in a normal 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.

3.1. Data structure for modelled critical loads and input data

Table 2 Attributes of the table *'CLdata'*.

Variable	Explanation
SiteID	Identifier of the site
$CL_{max}S$	Maximum critical load of sulphur (eq $ha^{-1} a^{-1}$)
$CL_{min}N$	Minimum critical load of nitrogen (eq $ha^{-1} a^{-1}$)
$CL_{max}N$	Maximum critical load of nitrogen (eq $ha^{-1} a^{-1}$)
$CL_{nut}N$	Critical load of nutrient nitrogen (eq $ha^{-1} a^{-1}$)
nANCcrit	The quantity –ANCle(crit) (eq $ha^{-1} a^{-1}$)

Table 3 Attributes of the table *'inputs'*.

Variable	Explanation
SiteID	Identifier of the site
cNacc	Acceptable (critical) N concentration for CLnutN calculation (meq m^{-3})
crittype	Chemical criterion used for acidity CL calculations: = 1: molar [Al]:[Bc]; = 2: [Al] (eq m^{-3}); = 3: base sat.(-); = 4: pH; = 5: [ANC] (eq m^{-3}); = 6: molar[Bc]:[H]; = 7: molar [Bc]:[Al]; = 8 molar [Ca]:[Al]; = 11: molar [Al]:[Bc] AND [Al] > 0.1meq/L; = –1: other
critvalue	Critical value for the chemical criterion given in 'crittype'
thick	Thickness (root zone!) of the soil (m)
bulkdens	Average bulk density of the soil (g cm^{-3})
Cadep	Total deposition of calcium (eq ha^{-1} a^{-1})
Mgdep	Total deposition of magnesium (eq ha^{-1} a^{-1})
Kdep	Total deposition of potassium (eq ha^{-1} a^{-1})
Nadep	Total deposition of sodium (eq ha^{-1} a^{-1})
Cldep	Total deposition of chloride (eq ha^{-1} a^{-1})
Cawe	Weathering of calcium (eq ha^{-1} a^{-1})
Mgwe	Weathering of magnesium (eq ha^{-1} a^{-1})
Kwe	Weathering of potassium (eq ha^{-1} a^{-1})
Nawe	Weathering of sodium (eq ha^{-1} a^{-1})
Caupt	Net growth uptake of calcium (eq ha^{-1} a^{-1})
Mgupt	Net growth uptake of magnesium (eq ha^{-1} a^{-1})
Kupt	Net growth uptake of potassium (eq ha^{-1} a^{-1})
Qle	Amount of water percolating through the root zone (mm a^{-1})
lgKAlox	Equilibrium constant for the Al-H relationship (log_{10}) (The variable formerly known as Kgibb)
expAl	Exponent for the Al-H relationship (=3 for gibbsite equilibrium)
pCO_2fac	Partial CO_2-pressure in soil solution as multiple of the atmospheric CO_2 pressure (-)
cOrgacids	Total concentration of organic acids (m*DOC) (eq m^{-3})
Nimacc	Acceptable nitrogen immobilised in the soil (eq ha^{-1} a^{-1})
Nupt	Net growth uptake of nitrogen (eq ha^{-1} a^{-1})
fde	Denitrification fraction (0≤fde<1) (-)
Nde	Amount of nitrogen denitrified (eq ha^{-1} a^{-1})
Measured	On-site measurements included in the data for CL calculations: 0 – No measurements, 1 ICP – Forest, 2 – ICP Waters, 4 – ICP Integrated Monitoring, 8 – ICP Vegetation, 16 – Other Measurement Program. (If more than one of the listed possibilities applies, the code numbers should be added!)

3.2 Data structure for empirical critical loads

Table 4 Attributes of the table *'EmpNload'*.

Variable	Explanation
SiteID	Identifier for the site
CLempN	Empirical critical load of nitrogen (eq ha^{-1} a^{-1})

3.3. Data structure for inputs of aquatic ecosystems

Table 5 'h2oinputs' has been simplified and brought in line with the current Call for Data. As mentioned above, the results of the critical load calculation is no longer part of the '*h2oinputs*' table, but resides in the 'CLdata' table (see Table 2).

Table 5 Attributes of the table '*h2oinputs*'.

Variable	Explanation
SiteID	Identifier for the site
crittype	Criterion used: = 5: [ANC] (eq/m^3); see Table 3 for other criteria
critvalue	Value of the criterion used
areaL	Lake area (ha) (set to zero for a stream)
areaC	Catchment area (ha) (incl. lake area)
depth	Mean lake depth (m)
Qs	Annual runoff (m a^{-1})
nmBC0	Non-marine pre-acidification base cation flux (eq ha^{-1} a^{-1})[a]
Nimacc	Acceptable amount of nitrogen immobilised in the soil (eq ha^{-1} a^{-1})
N_{upt}	Average net growth uptake of nitrogen (eq ha^{-1} a^{-1})
fde	Denitrification fraction (0≤fde<1) (-)
Nde	Average amount of nitrogen denitrified (eq ha^{-1} a^{-1})
sN	Net mass transfer coefficient for N in the lake (m a^{-1})
sS	Net mass transfer coefficient for S in the lake (m a^{-1})
cOrgacids	Total concentration of organic acids (m*DOC) (eq m^{-3})
Measured	On-site measurements included in the data for CL calculations: 0 – No measurements, 1 – ICP Waters, 2 – ICP Integrated Monitoring, 4 – Other measurement programme (if more than one applies, their numbers should be added)

[a] Either computed from a mass balance of BC deposition, weathering and uptake (analogously to the SMB model) or as Qs·$[BC]_0^*$ (as in the SSWC model).

4. Documentation

Please provide the CCE with documentation to substantiate and justify sources and methods applied in response to the call for data. It is strongly recommended to apply agreed methods as described in Chapter 5 of the Mapping Manual (www.icpmapping.org) and only list the sources and describe the deviations from the Manual.

The CCE reporting requirements are currently best served by sending a WORD document with a plain single-column WORD layout. Please avoid complicated formatting of your text and tables and figures: E.g., no special fonts; also, figure captions should be plain text and not part of the figure!
The final layout will be done by the CCE.

You are encouraged to structure your contribution including 3 sections, i.e. "Methods and Data", "Evaluation of modelled vegetation changes" and "Nitrogen effects on biological diversity". The latter section should include preliminary results of your collaboration with national habitat experts.

Annex 2 to the CCE Call for Data 2010-2011

Critical loads based nitrogen deposition assessment for Habitats Directive Article 17 reporting – Cover Note for ICP M&M National Focal Centres

This document provides information on using critical loads for nutrient nitrogen to assess the threat from nitrogen deposition to achieving favourable "conservation status" for species and habitats listed in the Annexes of the EC Habitats Directive (92/43/EEC). It is relevant only to EU27 countries.
The objective of the Habitats Directive is to achieve favourable conservation status for the species and habitats listed in the Annexes. Article 17 of the Directive requires Member States to report the conservation status of habitat and species listed in the Directive every six years. The next reporting round is due in 2013. The Commission and Member States are currently drafting guidance for undertaking conservation status assessments. Nitrogen deposition is recognised as a threat to biodiversity in Europe. It is listed as a potential 'pressure and threat' to conservation status in the Commission guidance.

The document sets out the background to the reporting obligations under the Directive and recommends a methodology for assessing nitrogen as a pressure/threat to Annex I habitats based on (empirical) critical loads of nutrient nitrogen. It has been produced following agreement at the 2010 Task Force meeting of the ICP on Modelling and Mapping. The document is aimed at both NFCs and authors of Article 17 reports. It aims to promote the use of established assessment methods developed under the CLRTAP to assess the threat to conservation status.

The document is currently draft and will be finalised following agreement of the format for and guidelines for reporting under Article 17 of the Habitats Directive, which should be available in spring-summer 2011. However, this draft document is provided to NFCs now, in order to raise awareness of the reporting obligations under the Habitats Directive and to encourage an early dialogue between NFCs and their country's lead on Habitats Directive reporting.

Appendix B
Manual for Setting Flora Parameters for the Veg model

Salim Belyazid[1], Harald Sverdrup[2], Bengt Nihlgård[3]

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Introduction

Recent developments in dynamic modelling have made it possible to complement the existing chemical indicators of atmospheric deposition effects on ecosystems with biological ones (Belyazid et al. 2011, De Vries et al. 200). One of these developments is based on the Veg model, a dynamic model of plant community composition (Sverdrup et al. 2007, Belyazid 2006). See also Chapter 3 of this Report for the changes introduced to the original Veg formulations.

The Veg model simulates changes in plant communities based on variations in abiotic drivers and completion between plants. On one hand, the model requires a geochemical platform providing information about soil chemistry and hydrology, ground level light intensity, and air temperature. On the other hand, the model is built upon response functions specific for given plants or plant groups. These response functions describe the window of a given driver within which a plant or plant group can occur. The purpose of the present manual is to provide a guideline to the parameterization of the response functions that form the basis of the Veg model.

Use of the Veg model and this Manual

The Veg model is available from the CCE as a sub-model of the VSD+ model, and comes with a generic European plant parameterization table. At present, the table contains response parameters for 372 plants or plant groups. The European table can be used as a catalogue of plants to be directly selected for modelling at specific sites, or as anchors for estimating response parameters for new plants identified by the user.

Table B.1 (next page) shows an example of how a plant group (*Dicranum* spp) is represented and parameterized in the vegetation table used by Veg. Each variable is described in more detail in later sections:

1. The first variable σ is the delay time (years) it takes a given plant or plant group to occupy a potential fraction of space or yield its current ground in case it is declining.
2. The nitrogen (mgN L^{-1}soil solution) response window is described by three variables: k_+ denotes the threshold when is promoting, k_- denotes the threshold of decline due to N, and w describes the speed/shape of response.

Table B.1 An example of the parameterization of a plant group for use with Veg.

Latin name	Time[1]	Nitrogen[2]			Ca[3]	pH_4	Soil moisture[5]			Temperature[6]			Light[7]		H[8]	R[9]	G[10]
	σ	k_+	k_-	w	k_{Ca}	pH_{half}	W_{min}	W_{top}	W_{max}	T_{min}	T_{top}	T_{max}	L_{min}	L_{max}	h	rd	k_G
Dicranum spp	20	0.67	1	3	0	3.45	0	0.1	0.45	−4	7	15	83	416	0.02	0	0

3. Calcifuge retardation k_{Ca} denotes the negative effect some plants experience under elevated calcium concentrations in the soil solution (mgCa L^{-1}).
4. pH_{half} is the value of soil solution pH at which a plant is at half its strength.
5. Plant response to moisture (fraction of soil saturation) is defined with three variables, being the minimum moisture below which the plant is excluded (W_{min}), an optimal window (between W_{top} and W_{max}), and decline above W_{max} until it reaches 0 at saturation (=1) (unless W_{max} = 1).
6. The temperature (°C) response is given by a minimum value below which the plant is excluded (T_{min}), an optimal value at which the plant has full strength (T_{top}), and a maximum temperature value above which a plant is excluded (T_{max}).
7. The light response (μmol_{photon} m^{-2} sec_{-1}) is given by a minimum light intensity requirement (L_{min}) below which a plant is excluded, and an optimal value at which a plant reaches full strength in response to light (L_{max}).
8. Plants are also characterized by a height (m) value *h*, which represents the elevation of the part of a plant that is able to shade out other plants.
9. Plants access different soil depths based on their root depths (*rd*) class as described below.
10. Finally, each plant is characterized by a grazing palatability factor (k_G), which describes how readily grazed upon the plant can be in presence of grazers.

The plant names listed in the European table and used by the model can either represent a single plant species, or a group of plants with common associations. When parameterizing new plants or plant groups, it is up to the user to make this distinction. If a single plant species is of interest, we recommend parameterizing this plant independently. If a group of plants is more representative of a certain trait of interest to the user, this group can be aggregated under a same name. With this in mind, this manual gives guidance into how to parameterize new plants that are not listed in the European table at its current state (November 2011). We also encourage any new additions to the table to be communicated to the CCE so as it can be included in the general European table.

Setting plant parameters

A user should start by identifying plants or plant groups of interest for the ecosystem studied. We recommend the used to start by looking for the selected plant name in the European table. If the plant name exists, it can be used directly or modified in case the user has ground to revise specific responses (for example, a user may have data supporting a wider temperature envelop than that stated in the table). Such changes should be communicated to the CCE.

If the plant or plant group does not exist in the European table, the user can follow the steps listed below to set the plant parameters one by one:

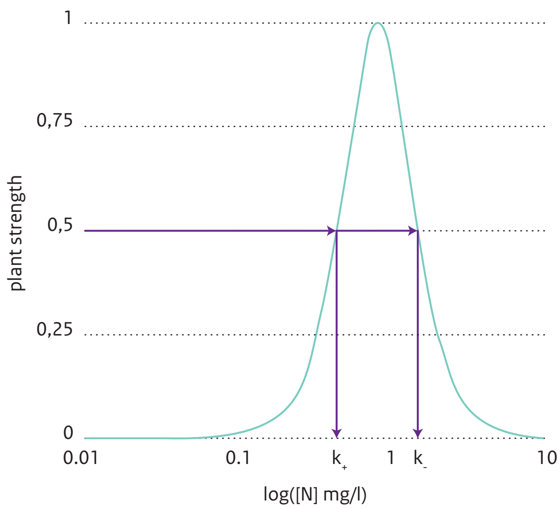
1. The delay time parameter:
The delay time (years) is the time a competitor must wait to reach the full strength allowed by the combined drivers and constraints and until the incumbent plant will leave the place wanted. The delay time usually lies between the average generation time and the average population age. Average population age is between 1/3 and 1/2 of the plant's lifespan. As a default, the delay time will be taken as 1/3 of the maximum age possible, when such estimates are available. Minimum delay time is 1 year, and it is assumed to be constant.

2. The nitrogen response:
The N response parameters describe the relationship between plant strength and soil solution nitrogen concentration (mg L^{-1}) shown in Figure B.1.

To simplify the parameterization, the user only needs to determine a class index for the promoting effect of N and one for the retarding effect. The classes for the promoting effect of N are shown in Table B.2. And retardation due to N is done according to the classes shown in Table B.3.

3. The calcifuge effect:
Only certain plants are negatively affected by elevated concentration of calcium in the soil solution. Ca^{2+} ions hinder the uptake of other nutrients and may disrupt the ion balance of certain sensitive plants. The parameter of the calcifuge retardation is given as the average yearly soil solution Ca^{2+} concentration (mg L^{-1}) in the rooting zone at which a given plant strength is reduced to half its optimal. A value of 0 means the plant experiences no adverse effect due to elevated soil alkalinity.

Figure B.1 Percentage of cover by *Rubus fruticosus* agg. in relation to modelled N deposition in Swiss forest observation plots of the intercantonal forest survey programme (Flückiger and Braun 2004).



4. Plant response to soil solution pH:

We assume the pH response to be limited to a promoting effect, while assigning any possible negative effect of alkalinity to the calcifuge response. In this way, plant response to pH is parameterized by defining the pH value at which the plant is at half its optimal potential (what we call the half-strength pH value). The half-strength pH value corresponds to 2 pH units below optimal pH.

5. Plant response to water availability:

A given plant is assumed to exist within a certain window of soil moisture availability. Different plants access water at different soil depths depending on their rooting depth (see below). For plants without roots, we assume that they respond to soil moisture in the upper most soil layer. The user should identify a category for water need according to the following classification:

0 = plants tolerate prolonged periods of droughts;
1 = plants tolerates dry conditions (soil moisture between wilting point and field capacity);
2 = plants thrive under well drained but not dry conditions (soil moisture around field capacity);
3 = plants thrive under moist conditions (soil moisture between field capacity and field saturation);
4 = plants tolerate prolonged periods of soil water saturation.

The soil moisture response scale is given as fraction of the soil moisture saturation (0 = wilting point, 1 = water saturation). Within the response classes listed above, the minimum water response variable (W_{min}) denotes the level below which a plant cannot survive. The window between W_{top} and W_{max} represents the optimal soil moisture conditions for a plant. Beyond W_{max}, a plant is negatively affected until it disappears at saturation. If a plant can survive at water saturation, it W_{max} = 1 should be specified.

6. Light requirements:

We assume that plants can only be negatively affected by lack of light, and that no adverse response can follow from and excess of light intensity. Light is measured in (μmol_{photon} $m^{-2} sec^{-1}$). Plant responses to light can be classified as follows:

0 = very shade tolerant plants (can exist under dense closed canopies);
1 = shade tolerant plants (can exist under closed but not dense canopies);
2 = plants occurring permeable, open canopies;
3 = light demanding plants, occurring in open fields;
4 = plants requiring unimpeded straight light.

7. Plant response to temperature:

The temperature (°C) response window can usually be derived from overlapping plant distribution maps with temperature maps. The temperature values refer to

Table B.2 Classes for the promoting effect of N.

Class	k_ (mg N L^{-1})	Description
0	0	N fixing plants, need no external N input
1	0.1	Plants requiring very little N (<1 kg N ha^{-1} yr^{-1})
2	0.4	Requiring small amount of N (2 kg N ha^{-1} yr^{-1})
3	0.8	Intermediate requirement of N (4 kg N $^{ha-1}$ yr^{-1})
4	1.5	Substantial requirement of N (8 kg N ha^{-1} yr^{-1})
5	2.0	Very high requirement of N (>12 kg N ha^{-1} yr^{-1})

Table B.3 Classes for the retardation due to N.

Class	k_ (mg N L^{-1})	Description
1	1	Retarded by little N (4–8 kg N ha^{-1} yr^{-1})
2	3	Intermediate N retardation (8–16 kg N ha^{-1} yr^{-1})
3	10	Retarded by high amounts N (16–32 kg N ha^{-1} yr^{-1})
4	1000	Not retarded by N

annual averages. If only one of the values for T_{min}, T_{top} and T_{max} is known, the user can use the following assumption to derive the other two variables: $T_{max} = T_{min} + 8$ °C and $T_{opt} = T_{min} + 5$ °C.

8. Plant shading height:
Effective shading height (m) is the elevation of the plant part that is able to shade neighbouring plants. It is not necessarily the same as the plant total height. Trees form a separate level above the ground vegetation. We assume that understory vegetation has a maximum height of 1.2 meters, after which the plants are assumed to enter the tree level. The shading height of a given plant is assumed to be constant, independent of age and establishment stage.

9. Plant rooting depth:
This is the effective rooting depth (m) of plants, by which they are able to access water and nutrients at different soil depth. For consistency, the user should enter a root class according to the following:
0 = plants with no roots (e.g., mosses);
1 = shallow roots (< 0.1 m);
2 = intermediate rooting depths (between 0.1 m and 0.4 m);
3 = deep roots (> 0.4 m).

10. Palatability:
The effect of grazers can be one of the strongest factors determining the composition of a plant community. Yet, knowledge about the density of type of grazers is not always available. In case this information is present, the user can chose to categorize plants into the following palatability classes:
0 = toxic or inedible, never eaten;
1 = avoided, but eaten in times of shortage;
2 = acceptable, eaten when better food is scarce;
3 = good, generally browsed on;
4 = very sought for, heavily grazed on.

References

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Belyazid S, Sverdrup H, Kurz D, Braun S, 2011. Exploring ground vegetation change for different deposition scenarios and methods for estimating critical loads for biodiversity using the ForSAFE-VEG model in Switzerland and Sweden. *Water, Air and Soil Pollution* 216: 289-317

De Vries W, Wamelink GWW, Van Dobben H, Kros J, Reinds GJ, Mol-Dijkstra JP, Smart SM, Evans CD, Rowe EC, Belyazid S, Sverdrup HU, Van Hinsberg A, Posch M, Hettelingh J-P, Spranger T, Bobbink R, 2010. Use of dynamic soil-vegetation models to assess impacts of nitrogen deposition on plant species composition: an overview. *Ecological Applications* 20(1): 60-79

Sverdrup H, Belyazid S, Nihlgård B, Ericson L, 2007. Modelling change in ground vegetation response to acid and nitrogen pollution, climate change and forest management at in Sweden 1500–2100 A.D. *Water, Air and Soil Pollution: Focus* 7: 163-179

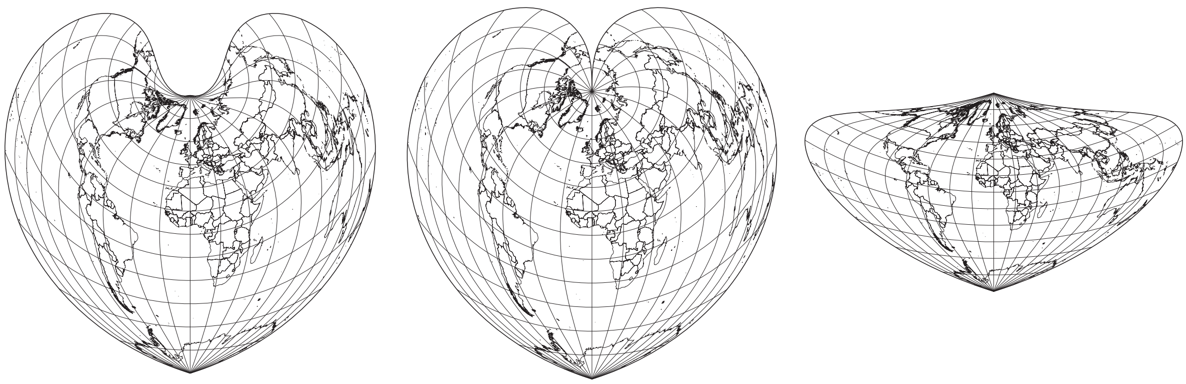
Appendix C
The Stabius-Werner map projection

Maximilian Posch

The heart-shaped ('cordiform') map on the cover of this report is drawn in the so-called Stabius-Werner projection. This projection was created around 1500 by Johannes Stabius (1450–1522) of Vienna, who belonged to a circle of humanists associated with the court of the Holy Roman Emperor Maximilian I. It was popularized in treatises by the Nuremberg parish priest and mathematician Johannes Werner (1468–1522), and the projection was commonly used – *inter alia* by Abraham Ortelius (1527–1598; the inventor of the atlas) and Gerardus Mercator (1512–1594; the first to call a book of maps an 'atlas') – for world maps and some continental maps well into the 17th century.

The Stabius-Werner projection is a special case of the so-called Bonne projection, introduced by Rigobert Bonne (1727–1795), royal cartographer to France. It is an equal-area projection that has been widely used during the late 19th and early 20th century for maps of continents in atlases.

Figure C.1 Maps of the World in the Bonne projection with central meridian at 0°. Left: central parallel at 50°N; Centre: 'central parallel' at the North Pole (the Werner-Stabius projection); Right: central parallel at 10°N.



For a spherical Earth with radius *R*, the equations for converting longitude λ and latitude φ into coordinates *x* and *y* in the plane are (Snyder 1987):

(C-1) $x = R \cdot \rho \cdot \sin E,\ y = R \cdot (\cot \varphi_1 - \rho \cos E)$

with

(C-2) $\rho = \cot \varphi_1 + \varphi_1 - \varphi$ and $E = (\lambda - \lambda_0) \cdot \cos \varphi / \rho$

where λ_0 and φ_0 are the central meridian and parallel, resp., i.e. the lines along which there is no distortion. More details on this – and almost any other – projection can be found in Snyder (1987). In Figure C.1 maps of the World are shown in the Bonne projection, all centered at the Greenwich meridian, but with different central parallels.

References

Snyder JP, 1987. *Map Projections – A Working Manual*. U.S. Geological Survey Professional Paper 1395, United States Government Printing Office, Washington DC, 383 pp

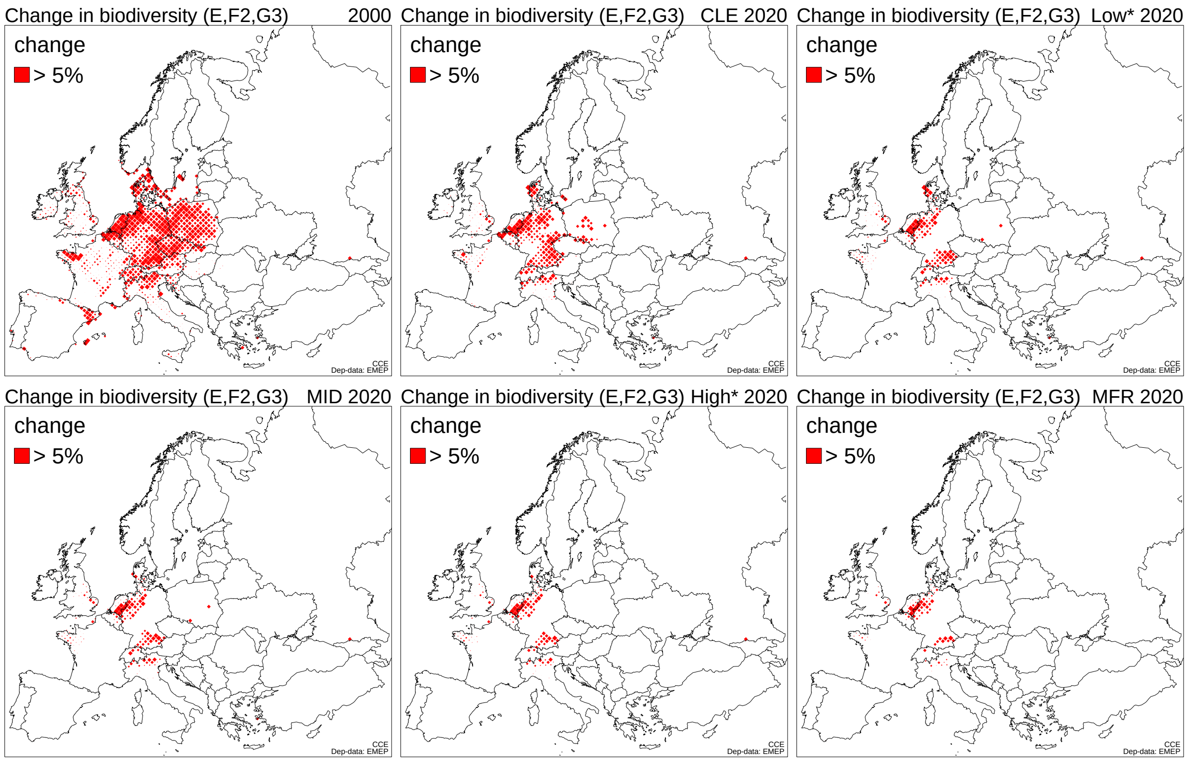
Wikipedia: http://en.wikipedia.rog/wiki/Johannes_Werner

Wikipedia: http://en.wikipedia.rog/wiki/Johannes_Stabius

Errata
CCE Status Report 2011

Page 20:
In Figure 1.4 wrong maps have been placed; the correct Figure is shown below.
Note: The figure captions, as well as the percentages in Table 1.5 are correct!

Figure 1.4 The location of natural areas (covering about half, i.e. about 2 million km^2 of the European natural area characterised by the EUNIS classification) where the computed change of biodiversity is higher than 5% (red shading) in 2000 (top-left) and in 2020 under the CLE (top-centre), Low* (top-right), MID (bottom-left), High* (bottom-centre) and MFR (bottom-right) scenarios.



Part 3: NFC Reports

Due to a technical oversight the report by the NFC of the United Kingdom has not appeared in the printed copy of the 2011 CCE Status Report. It has been layouted in the same style as all other NFC reports and can be found below and on the webpage of the CCE in conjunction with the other national reports.

Approved by,
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Introduction

In response to this call for data the UK are re-submitting (a) critical loads of acidity; and (b) critical loads of nutrient nitrogen (based on the mass balance equation) for managed woodlands. No changes have been made to these data sets. In addition, the UK are submitting updated and revised empirical critical loads of nutrient nitrogen for (a) broad habitat types; (b) Special Areas of Conservation (SACs) and Specially Protected Areas (SPAs), which form the Natura 2000 network of sites in the UK. It should be noted that the critical loads data for the broad habitats remain the official UK data for use in the generation of European-scale maps, databases and integrated assessment modelling activities under the LRTAP Convention. The data for designated sites are intended only for comparison with similar data for designated areas of other countries. The data for broad habitats and designated sites should not be used simultaneously as this will lead to a duplication of the areas for some habitats.

Update to Nitrogen Critical Loads for UK broad Habitats

Empirical critical loads of nutrient nitrogen have been reviewed and revised for the UK in light of the results of the CLRTAP workshop held in Noordwijkerhout in June 2010 (ECE/EB.AIR/WG.1/2010/14). A group of UK experts met in November 2010 to discuss where to set the UK 'mapping values' for each habitat from within the critical load ranges agreed at Noordwijkerhout. In January 2011 two reports became available (Stevens et al. 2011, Emmett et al. 2011) which reviewed nitrogen impacts on four UK habitats: calcareous grassland, acid grassland, dwarf shrub heath and bog. Emmett et al. (2011) collated the evidence of nitrogen impacts in relation to nitrogen deposition loads and evaluated the consequences for species prevalence and indices of habitat structure and function at different nitrogen deposition loads. This report provided UK evidence to support changes to the mapping values for calcareous grassland, dry acid grassland and heathland habitats; changes were only made where several strands of evidence were available, for example, a change in a single species plus functional indices, or changes in several species. However if no new UK evidence was available (for any habitat), either from these reports or elsewhere, the 2003 mapping value was retained. The only exception to this was the mapping value for bog. In 2003 the mapping value for UK bogs was set at the top of the range (10 kg N $ha^{-1}yr^{-1}$) on the basis that lower values were inappropriate for habitats in areas of high rainfall (Hall et al, 2003). Prior to this update we examined long-term (1961–90) average annual rainfall data across the geographic range of UK bogs which showed that although 85% of the area of bogs receive on average 1000–2000 mm rainfall per annum, and a further 7% receive more than 2000mm per annum, the remaining 8% of bog areas receive only 500–1000 mm of rainfall per annum. It was therefore decided, that for this habitat only, a rainfall modifier should be applied. A method proposed by the CCE (Slootweg et al. 2008, modified & extended) was considered. This gave considerable spatial variability in critical load values, from 6.9 kg N $ha^{-1}yr^{-1}$ for bogs in drier parts of the country to 10 kg N $ha^{-1}yr^{-1}$ in wetter regions. This approach was considered to infer a greater level of spatial knowledge of the impacts of nitrogen on habitats than currently exists. Instead a simpler approach was adopted, but using the cumulative distribution function (CDF) supplied by the CCE of bog habitat area vs rainfall across the entire European region, and a similar CDF based on UK data. From these data sets the rainfall ranges calculated to give median critical loads of 8 and 9 kg N $ha^{-1}yr^{-1}$ were derived, and mapping values assigned accordingly. The mapping value for all other areas of bog with higher annual average rainfall was set to 10 kg N $ha^{-1}yr^{-1}$. It should be noted that UK scientific evidence is being sought to also underpin this decision. Modifying factors were not applied in setting the national critical loads for any other habitat; although it was acknowledged that the use of modifying factors could be very important in site-specific applications where local knowledge was available.

A detailed report (Hall et al. 2011) on (a) changes to the UK habitat distribution maps; (b) application of a precipitation modifier in setting nitrogen mapping values to UK bog habitats; (c) changes to mapping values for broad habitats; will be made available from the UK NFC web site (http://cldm.defra.gov.uk). In summary the following revisions have been made:

- Nitrogen critical loads have been mapped for saltmarsh for the first time in the UK.
- The mapped distribution for dune grasslands (B1.4) has been improved and refined, resulting in a smaller total area for this habitat.
- The 2003 unmanaged mixed woodland class (G4) has been sub-divided into four new woodland habitat categories:
  - G1.6 Beech (*Fagus*) woodland
  - G1.8 Acidophilous oak (*Quercus*) dominated woodland
  - G3.4 Scots pine (*Pinus sylvestris*) woodland
  - G4 unmanaged mixed woodland not included in the above three classes; it is not possible to separately map these areas into coniferous and broadleaved woodland categories.
- A precipitation modifier has been used to set the mapping values for bogs to take account of potential differences in sensitivity to nitrogen in areas of low and high rainfall.

UK mapping values have been altered for a number of habitats (Table UK.1).

Update to Nitrogen Critical Loads for UK Natura 2000 Sites

Critical loads of nutrient nitrogen for UK SAC features have previously been submitted (Hall et al. 2007). For this update, the UK conservation agencies in collaboration with the UK NFC, have reviewed and revised the critical loads for SAC features, and applied the same methodology to SPA features. Individual features (Annex I habitats or Annex II features) were assessed in terms of their sensitivity to eutrophication and the corresponding EUNIS habitat classes for the features identified using the Habitats Dictionary of the National Biodiversity Network (http://habitats.nbn.org.uk/). Where a sensitive feature was a species, it was related to the EUNIS habitat in which it occurs. For SPAs the designated 'features' are bird species; these were related to the breeding, wintering or passage habitat(s). If nutrient nitrogen critical loads were available for the EUNIS class, they were applied. Where this was not the case, the critical loads for a similar EUNIS class were applied. However, there are some habitats identified as being sensitive to eutrophication for which there currently no appropriate critical loads available. A summary of the features is given in Table UK.2.

Table UK.1 Critical loads of nitrogen for broad habitats mapped nationally in the UK; values in bold type represent changes from 2003 values

Ecosystem	Critical load ranges and mapping values in kg N $ha^{-1}yr^{-1}$			
	2003 range[a]	2003 UK[b] mapping value	2010 range[c]	2010 UK mapping value[d]
Marine habitats:				
A2.5 Saltmarshes	30-40 (#)	Not mapped	**20-30 (#)**	**25**
Coastal habitats:				
B1.3 Shifting coastal dunes	10-20 (#)	15	10-20 (#)	Not mapped
B1.4 Coastal stable dune grassland	10-20 #	15	**8-15 #**	**9 acid dunes 12 non-acid dunes**
Bog habitats:				
D1 Raised and blanket bog	5-10 ##	10	5-10 ##	**8, 9, 10 depending on rainfall**
Grasslands and tall forb habitats:				
E1.26 Calcareous grassland	15-25 ##	20	15-25 ##	**15**
E1.7 Dry acid grassland	10-20 #	15	**10-15 ##**	**10**
E3.52 Wet acid grassland (*Juncus* meadows & humid *Nardus stricta* swards)	10-20 #	15	10-20 #	15
E4.2 Moss & lichen dominated mountain summits	5-10 #	7	5-10 #	7
Heathland habitats:				
F4.11U *Calluna* dominated wet upland heath	10-20 (#)	15	10-20 #	**10**
F4.11L *Erica tetralix* dominated lowland heath	10-25 (#)	15	**10-20 (#)**	**10**
F4.2 Dry heath	10-20 ##	12	10-20 ##	**10**
Forest habitats:				
G1 Broadleaved woodland	-		10-20 ##	See G4
G3 Coniferous woodland	-		5-15 ##	See G4
G4 Conifer/broadleaf woodland (ground flora)[e]	10-15 #[e]	12	-	12
G1.6 *Fagus* woodland	-	-	**10-20 (#)**	**15**
G1.8 Acidophilous *Quercus* dominated wood	Part of G4[f]	10[f]	**10-15 (#)**	10
G3.4 *Pinus sylvestris* woodland	-	-	**5-15 #**	**12**

[a] Achermann and Bobbink, (2003); b Hall et al. (2003); c ECE/EB.AIR/WG.1/2010/14 (2010); d Hall et al. (2011);
[e] Achermann & Bobbink (2003) for the protection of ground flora in all woodland types;
[f] For the protection of epiphytic lichens and algae in Atlantic oak woodland.

Table UK.2 Summary of the numbers of UK SACs and SPAs, feature type, and sensitivity to eutrophication

	Total number	Number sensitive to eutrophication	Number with CLnutN	Number without CLnutN
SAC sites	621			
SAC features (all)	126	113	88	25
SAC feature habitats	80	72	63	9
SAC feature species	46	41	25	16
SPA sites	257			
SPA feature species[a]	204	163	137	26

[a] All SPA features are species

For consistency with the broad habitat critical loads data submitted, the agreed UK mapping values (Table UK.3) have been used; where no national mapping value has been defined the mid-range value has been applied.

Table UK.3 EUNIS habitat critical loads assigned to Annex I habitats and Annex II species of SACs

Annex I habitats Annex II species	Interest Name	EUNIS class (same or most similar to Annex I habitat)	CLnutN (kg N ha^{-1} yr^{-1})	UK mapping value (kg N ha^{-1} yr^{-1})
H1130	Estuaries	A2.53/A2.54/A2.55 Pioneer, low-mid, mid-upper saltmarshes	20-30	25
H1150	Lagoons	A2.53/A2.54/A2.55 Pioneer, low-mid, mid-upper saltmarshes	20-30	25
H1220	Coastal shingle vegetation outside the reach of waves	B1.4 Coastal stable dune grasslands	8-15	11.5*
H1310	Glasswort and other annuals colonising mud and sand	A2.53/A2.54/A2.55 Pioneer, low-mid, mid-upper saltmarshes	20-30	25
H1320	Cord-grass swards	A2.53/A2.54/A2.55 Pioneer, low-mid, mid-upper saltmarshes	20-30	25
H1330	Atlantic salt meadows	A2.53/A2.54/A2.55 Pioneer, low-mid, mid-upper saltmarshes	20-30	25
H1420	Mediterranean saltmarsh scrub	A2.53/A2.54/A2.55 Pioneer, low-mid, mid-upper saltmarshes	20-30	25
H2110	Shifting dunes	B1.3 Shifting coastal dunes	10-20	15*
H2120	Shifting dunes with marram	B1.3 Shifting coastal dunes	10-20	15*
H2130	Dune grassland	B1.4 Coastal stable dune grasslands (calcareous)	10-15	12
H2130	Dune grassland	B1.4 Coastal stable dune grasslands (acid)	8-10	9
H2140	Lime-deficient dune heathland with crowberry	B1.5 Coastal dune heaths	10-20	15*
H2150	Coastal dune heathland	B1.5 Coastal dune heaths	10-20	15*
H2170	Dunes with creeping willow	B1.8 Moist to wet dune slacks	10-20	15*
H2190	Humid dune slacks	B1.8 Moist to wet dune slacks (low base availability)	10-20	12.5*
H2190	Humid dune slacks	B1.8 Moist to wet dune slacks (high base availability)	10-20	17.5*
H21A0	Machair	B1.4 Coastal stable dune grasslands	10-15	12
H2250	Dunes with juniper thickets	B1.5 Coastal dune heaths	10-20	15*
H2330	Open grassland with grey-hair grass and common bent grass of inland dunes	E1.94 Inland dune pioneer grassland	8-15	11.5*
H3110	Nutrient-poor shallow waters with aquatic vegetation on sandy plains	C1.1 Permanent oligotrophic lakes, ponds, pools	5-10	7.5*
H3130	Clear-water lakes or lochs with aquatic vegetation and poor to moderate nutrient levels	C1.1 Permanent oligotrophic lakes, ponds, pools	5-10	7.5*
H3160	Acid peat-stained lakes and ponds	C1.4 Permanent dystrophic lakes, ponds, pools	5-10	7.5*
H4010	Wet heathland with cross-leaved heath	F4.11 Northern wet heaths	10-20	10
H4020	Wet heathland with Dorset heath and cross-leaved heath	F4.11 Northern wet heaths	10-20	10
H4030	Dry heaths	F4.2 Dry heaths	10-20	10
H4040	Dry coastal heaths with Cornish heath	F4.2 Dry heaths	10-20	10
H4060	Alpine and subalpine heaths	F2 Arctic, alpine & subalpine scrub habitats	5-15	10*
H4080	Mountain willow scrub	F2 Arctic, alpine & subalpine scrub habitats	5-15	10*

H5110	Natural box scrub	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	15
H5130	Juniper on heaths or calcareous grasslands	F4.2 Dry heaths	10-20	10
H6130	Grasslands on soils rich in heavy metals	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	15
H6150	Montane acid grasslands	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
H6170	Alpine and subalpine calcareous grasslands	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
H6210	Dry grasslands and scrublands on chalk or limestone	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	15
H6211	Dry grasslands and scrublands on chalk or limestone, including important orchid sites	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	15
H6230	Species-rich grassland with mat-grass in upland areas	E1.7 Non-Mediterranean dry acid and neutral closed grassland	10-15	10
H6410	Purple moor-grass meadows	E3.51 Molinia caerulea meadows & related communities	15-25	20*
H6430	Tall herb communities	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
H6510	Lowland hay meadows	E2.2 Low and medium altitude hay meadows	20-30	25*
H6510	Lowland hay meadows	E2.2 Low and medium altitude hay meadows	20-30	25*
H6520	Mountain hay meadows	E2.3 Mountain hay meadows	10-20	15*
H6520	Mountain hay meadows	E2.3 Mountain hay meadows	10-20	15*
H7110	Active raised bogs	D1 Raised & blanket bogs	5-10	9**
H7120	Degraded raised bog	D1 Raised & blanket bogs	5-10	9**
H7130	Blanket bog	D1 Raised & blanket bogs	5-10	9**
H7140	Very wet mires often identified by an unstable `quaking` surface	D2 Valley mires, poor fens, transition mires	10-15	12.5*
H7150	Depressions on peat substrates	D2 Valley mires, poor fens, transition mires	10-15	12.5*
H7210	Calcium-rich fen dominated by great fen sedge (saw sedge)	D4.1 Rich fens, including eutrophic tall-herb fens, calcareous flushes, soaks	15-30	22.5*
H7220	Hard-water springs depositing lime	D4.2 Basic mountain flushes & streamsides with rich arctic-montane flora	15-25	20*
H7230	Calcium-rich springwater-fed fens	D4.1 Rich fens, including eutrophic tall-herb fens, calcareous flushes, soaks	15-30	22.5*
H7240	High-altitude plant communities associated with areas of water seepage	D4.2 Basic mountain flushes & streamsides with rich arctic-montane flora	15-25	20*
H8110	Acidic scree	F2 Arctic, alpine & subalpine scrub habitats	5-15	10*
H8120	Base-rich scree	F2 Arctic, alpine & subalpine scrub habitats	5-15	10*
H8210	Plants in crevices in base-rich rocks	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
H8220	Plants in crevices on acid rocks	F2 Arctic, alpine & subalpine scrub habitats	5-15	10*
H8240	Limestone pavements	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
H9120	Beech forests on acid soils	G1.6 Fagus woodland	10-20	15
H9130	Beech forests on neutral to rich soils	G1.6 Fagus woodland	10-20	15
H9160	Oak-hornbeam forests	G1.A Meso- & eutrophic Quercus woodland	15-20	17.5*

H9180	Mixed woodland on base-rich soils associated with rocky slopes	G1.A Meso- & eutrophic Quercus woodland	15-20	17.5*
H9190	Dry oak-dominated woodland	G1.8 Acidophilous Quercus-dominated woodland	10-15	10
H91A0	Western acidic oak woodland	G1.8 Acidophilous Quercus-dominated woodland	10-15	10
H91C0	Caledonian forest	G3.4 Pinus sylvestris woodland	5-15	12
H91D0	Bog woodland	D1 Raised & blanket bogs	5-10	9**
H91J0	Yew-dominated woodland	G3 Coniferous woodland	5-15	12
S1013	Geyer`s whorl snail	D4.1 Rich fens, including eutrophic tall-herb fens, calcareous flushes, soaks	15-30	22.5*
S1014	Narrow-mouthed whorl snail	E2.2 Low and medium altitude hay meadows	20-30	25*
S1014	Narrow-mouthed whorl snail	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
S1015	Round-mouthed whorl snail	D4.2 Basic mountain flushes & streamsides with rich arctic-montane flora	15-25	20*
S1044	Southern damselfly	F4.11 Northern wet heaths	10-25	10
S1065	Marsh fritillary butterfly	E1.7 Non-Mediterranean dry acid and neutral closed grassland	10-15	10
S1065	Marsh fritillary butterfly	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	15
S1065	Marsh fritillary butterfly	E3.51 Molinia caerulea meadows & related communities	15-25	20*
S1065	Marsh fritillary butterfly	E3.51 Molinia caerulea meadows & related communities	15-25	20*
S1079	Violet click beetle	G1 Broadleaved deciduous woodland	10-20	12
S1083	Stag beetle	G1 Broadleaved deciduous woodland	10-20	12
S1303	Lesser horseshoe bat	G1 Broadleaved deciduous woodland	10-20	12
S1304	Greater horseshoe bat	G1 Broadleaved deciduous woodland	10-20	12
S1308	Barbastelle	G1 Broadleaved deciduous woodland	10-20	12
S1323	Bechstein`s bat	G1 Broadleaved deciduous woodland	10-20	12
S1386	Green shield-moss	G3 Coniferous woodland	5-15	12
S1393	Slender green feather-moss	D2 Valley mires, poor fens, transition mires	10-15	12.5*
S1395	Petalwort	B1.8 Moist to wet dune slacks	10-20	15*
S1421	Killarney fern	G1 Broadleaved deciduous woodland	10-20	12
S1441	Shore dock	B1.8 Moist to wet dune slacks	10-20	15*
S1528	Marsh saxifrage	E4.3/E4.4 Alpine & subalpine acid & calcareous grassland	5-10	7.5*
S1614	Creeping marshwort	E2.2 Low and medium altitude hay meadows	20-30	25*
S1654	Early gentian	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	15
S1831	Floating water-plantain	C1.1 Permanent oligotrophic lakes, ponds, pools	5-10	7.5*
S1902	Lady`s-slipper orchid	G1 Broadleaved deciduous woodland	10-20	12
S1903	Fen orchid	B1.8 Moist to wet dune slacks	10-20	15*

* No UK Mapping Value set for this EUNIS class, so mid-range value applied; ** UK Mapping Value for SAC bogs set to 9 kg N $ha^{-1}yr^{-1}$; UK Mapping Value on national bog broad habitat maps set to values of 8, 9 or 10 kg N $ha^{-1}yr^{-1}$ depending on rainfall.

Spatial data on the location and area occupied by each feature within the SACs and SPAs are not readily available. Therefore, for this data submission, the "EcoArea" associated with each data record is based on the site area divided by the number of features for which critical loads have been set. Further, for some sites more than one feature is associated with the same EUNIS class; where this is the case the feature areas have been aggregated to enable the data to be submitted as a single record per EUNIS class per site.

This exercise has demonstrated an approach for assigning nitrogen critical loads to features of SACs and SPAs. It resulted in data being submitted for the features (habitats, species) of 532 SACs and 223 SPAs. However, there are still a number of features sensitive to eutrophication for which no appropriate critical loads are currently available.

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Report 680359003

Five scenarios have been used to assess the effects of nitrogen and sulphur on ecosystems in Europe. Although the measures proposed in these scenarios solve part of the problems with eutrophication and acidification, further emission reductions are needed in many areas of Europe. Nitrogen effects on plant species diversity are also addressed in this report.

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