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Critical Loads of Nitrogen and Dynamic Modelling

CCE Progress Report 2007

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Working Group on Effects
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ICP M&M Coordination Centre for Effects

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Abstract

Critical loads of nitrogen and dynamic modelling

This report summarizes the results of the 2006/2007 collaboration of the Coordination Centre for Effects (CCE) with its National Focal Centres (NFCs) concerning the call for data of nitrogen-related parameters. The voluntary nature of this call was intended to give scientific and technical leeway to the NFCs for testing new knowledge, prior to possible revisions of the 1999 Gothenburg Protocol and the Thematic Strategy for air pollution of the European Commission. New aspects of this call, in relation to earlier ones, are data concerning empirical critical loads of nitrogen, special attention for Natura 2000 areas, and the way that the dynamic modelling results can be applied in integrated assessment.

Nineteen NFCs responded to the call for voluntary data of which seventeen countries submitted modelled critical loads, 12 responded to the call for empirical critical loads and 11 submitted data for dynamic modelling. To complete a European map, a background database (including EECCA countries) of empirical critical loads has been compiled based on the newly available harmonised land cover map for the Convention.

Modelled critical loads of nitrogen are based on limits regarding nitrogen in the soil solution. Empirical critical loads, on the other hand, are based on findings regarding (vegetation) effects of (elevated) nitrogen deposition. Empirical critical loads are generally higher for the most sensitive ecosystems, compared to modelled critical loads. However, an ensemble assessment of the uncertainty of the exceedances of the two kinds of critical loads strengthens the robustness of the location of ecosystems at risk. For this a method similar to the treatment of uncertainties by the FCCC-IPCC has been tentatively applied.

In general, the computed sensitivity for eutrophication of ecosystems within Natura 2000 areas is similar as other protected areas designated by European countries.

Additional knowledge is required on the effects of exceedances of either critical load and related indicators and values for critical limits, for instance effects on biodiversity. For this, European wide application of dynamic vegetation models is the way forward.

NFC-results are described of the use in dynamic models of basic deposition scenarios that were compiled and provided by the CCE. Outcomes of this new approach (9 years, 7 variables) may assist the Task Force on Integrated Assessment Modelling in representing the temporal development of impacts caused by a wide range of emission reduction scenarios.

Key words: nitrogen, critical loads, air pollution, biodiversity, dynamic modelling

Rapport in het kort

Kritische drempels voor stikstof and dynamische modellering

In dit rapport staan de resultaten van de samenwerking in 2006/2007 tussen het Coordination Centre for Effects (CCE) en zijn National Focal Centres (NFC's) waarin de 'call for data' voor stikstofgerelateerde gegevens centraal staat. Het vrijwillige karakter dat de 'call' dit jaar had, maakt het mogelijk de laatste wetenschappelijke kennis te toetsen en de NFC's daarmee ervaring te laten opdoen. Dit als voorbereiding op een nieuwe 'call' ter ondersteuning van een mogelijke revisie van het Gothenburg Protocol uit 1999 en een mogelijke herziening van de thematische strategie luchtverontreiniging van de Europese Commissie. Nieuwe aspecten van deze 'call' zijn de aparte toepassing van empirische drempelwaarden van stikstofdeposities, speciale aandacht voor Natura 2000-gebieden, en het formaat van de resultaten van dynamische modellering, waardoor die direct toegepast kunnen worden bij het geïntegreerd doorrekenen van beleidsopties.

Negentien NFC's hebben gereageerd op de 'call', waarvan zeventien gemodelleerde kritische drempels hebben aangedragen, twaalf de empirische benadering hebben toegepast, en elf resultaten van dynamische modellering hebben opgestuurd. Ter aanvulling van de Europese kaart (inclusief EECCA landen) van kritische grenswaarden, is een achtergrond database met empirische drempelwaarden gemaakt, mede op basis van de voor de Conventie geharmoniseerde landgebruikkaart die nu beschikbaar is.

De gemodelleerde kritische drempels voor stikstof zijn gebaseerd op een grenswaarde voor de uitspoeling van stikstof. Met behulp van een massabalans is deze hoeveelheid om te rekenen in een drempelwaarde voor de depositie. Empirische kritische drempels zijn afgeleid van geconstateerde effecten op ecosystemen die optreden bij een (additionele) stikstofdepositie. In vergelijking met gemodelleerde kritische drempels voor stikstof zijn empirische kritisch waarden over het algemeen hoger voor de meest gevoelige ecosystemen. Maar de in kaart gebrachte overschrijdingen van empirische kritische drempels voor stikstof komen goed overeen met die van gemodelleerde drempels. Dit wordt bevestigd door toepassing van de methode waarop de FCCC-IPCC met onzekerheden omgaat.

Er lijkt geen systematische afwijking te zijn tussen Natura 2000-gebieden en overige natuurlijke gebieden. Het blijkt wel belangrijk om meer te weten over de effecten (op bijvoorbeeld biodiversiteit) van overschrijding en in het bijzonder over de indicatoren en kritische grenswaarden. Hiertoe is Europees brede toepassing van dynamische vegetatie modellen nodig.

De door de NFC's doorgerekende scenario's en opgestuurde resultaten (negen jaren, zeven variabelen) maken het mogelijk om alternatieve scenario's van het Task Force on Integrated Assessment Modelling (TFIAM) te evalueren. Hiertoe zullen het CCE en Centre for Integrated Assessment Modelling (CIAM) de database met kritische drempels, die in het RAINS model is opgenomen, uitbreiden met de resultaten van dynamische modellering, en toepassing hiervan uittesten.

Trefwoorden: stikstof, kritische drempelwaarden, luchtverontreiniging, biodiversiteit, dynamische modellering

Introduction

This report describes the results of the call for data on empirical critical loads of nitrogen and on results of European applications of dynamic models running predefined deposition scenarios. In its 25th session in September 2006, the Working Group on Effects (WGE), approved the proposal of the CCE workshop to issue a call for data for the nitrogen related parameters (EB.AIR/WG.1/2006/1 para.30 f).

The CCE issued the call in two parts, the first on empirical critical loads in relation to a surplus of nitrogen, sent on 8 November 2006, and the second on critical loads of N and S and dynamic modelling data, sent on 16 November 2006.

In addition to information provided in the Mapping Manual (www.icpmapping.org), detailed instruction documents for both parts were compiled by the CCE and distributed to the National Focal Centres.

Chapter 1 serves as an executive summary, including critical loads for nitrogen, both empirical and modelled, acidification, exceedance maps and dynamic modelling.

Chapter 2 analyses the data on critical loads and dynamic modelling submitted by National Focal Centres, including an inter-country comparisons of data statistics. Special attention is paid to the critical limits.

Chapter 3 demonstrates the potential use of the dynamic modelling results (for nutrient nitrogen) in integrated assessment.

Chapter 4 explains how assemble assessment of impacts, using terminology of the FCCC-IPCC, show the robustness of exceedances of the critical loads of nutrient nitrogen.

Chapter 5 documents the compilation of the harmonized land cover map of Europe for use under the LRTAP Convention.

Chapter 6 shows applications of the harmonized land cover map, especially the creation of a European background database for empirical critical loads.

Chapter 7 describes the extension of the background database for modelling critical loads and dynamic modelling with the EECCA countries, Turkey and Cyprus.

Part II provides national reports justifying methods and data applied by National Focal Centres to enable the CCE compilation of European maps of critical loads.

Finally, three Appendices reprint the two instructions for the last call for data and the IPCC guidance note on treating uncertainties, respectively.

1. Status of European critical loads with focus on nitrogen

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1.1 Background

The Working Group on Effects (WGE), in its twenty-fifth session, approved the proposal of the ICP Modelling and Mapping to make a voluntary call for data with focus on nitrogen. It also recommended the use of the collaborative report commissioned by the CCE 'Development in deriving critical limits and modelling critical nitrogen loads for terrestrial ecosystems in Europe' (De Vries et al., 2007) as information for National Focal Centres (NFCs) for the call for data.

The CCE issued a call for voluntary data in the autumn of 2006. The voluntary nature of this call was intended to give scientific and technical leeway to the NFCs for testing new knowledge, prior to possible revisions of the 1999 Gothenburg Protocol and the Thematic Strategy for air pollution of the European Commission. The latter may require an update that will be formally adopted for use in integrated assessment modelling, i.e. based on a possible call for data in the autumn of 2007.

To support the call CCE had prepared, in collaboration with the Stockholm Environment Institute (SEI), a harmonized land cover database (see chapter 5) which covers the geographic domain of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants (EMEP). It is based on CORINE (Coordination and Information on the Environment) country-specific land cover information, where available, complemented with SEI data. It includes a translation from CORINE/SEI to EUNIS (EUropean Nature Information System) classes. This database could assist NFCs to verify ecosystem coverage, enable CCE to verify submitted data on empirical critical loads and provide information for Parties that have not submitted critical load data. The CCE used it to extend and update its background database, which now includes empirical critical loads (see Chapter 6), and enables the calculation of critical loads for acidification and eutrophication in countries in Eastern Europe, Caucasus and Central Asia (EECCA) (see chapter 7).

In response to the call for voluntary data the NFCs were requested to participate in:

1. a preliminary application of a broad range of critical limits in simple mass balance calculations to address biodiversity, as proposed in De Vries et al. (2007);
2. an application of empirical critical loads (Achermann and Bobbink, 2003) to (i) those EUNIS classes for which NFCs provided computed critical loads, and (ii) to Natura 2000 (N2K) sites. This work could improve the robustness of the European critical loads database, and could facilitate the interpretation of exceedances in a more biological context. Existing documentation on empirical critical loads is more explicit with respect to biological impacts then those related to exceedance of modelled critical loads;
3. an exploration of the possibility for dynamic modelling of eutrophication, taking into account available data (e.g. for the Very Simple Dynamic model (VSD), and more complex as described in De Vries et al., 2007)

The response to the call for data led to new information in comparison to earlier calls. Now, in addition to the traditional modelled critical loads, *CLnutN*, a number of NFCs extended their database to also include empirical critical loads, *CLempN*. This distinction will also be made in this chapter when describing the use of updated critical loads for the computation of average accumulated exceedances (AAE) and the percentages of area at risk.

The following sections provide a summary of the results of the call for voluntary data on critical loads for acidification and eutrophication and dynamic modelling variables, including exceedance maps. A more detailed overview and analysis of national data submissions regarding critical loads and dynamic modelling variables is presented in chapter 2, whereas country reports can be found in Part II of this report.

1.2 Response to the call for data

The CCE issued a call for voluntary contributions on empirical critical loads, modelled critical loads of acidification and eutrophication and dynamic modelling in November 2006. The deadlines for data submission were set as 28 February and 31 March 2007, respectively. The results are presented in Table 1-1. Nineteen parties responded to the call for voluntary data of which 17 countries submitted modelled critical loads, 12 responded to the first time call for empirical critical loads and 11 submitted data for dynamic modelling.

***Table 1-1**. The response of Parties to the Convention to the call for voluntary data*

Country code	Country	Modelled critical loads of sulphur and nitrogen	Empirical critical loads of nitrogen	Critical loads for N2K areas	Dynamic modelling
AT	Austria	X	X	X	X
BE	Belgium	X	-		X
BG	Bulgaria	X	X	X	-
BY	Belarus	X	-		-
CA	Canada	X	-		X
CH	Switzerland	X	X		X
CZ	Czech Republic	-	X	X	-
DE	Germany	X	X	X	X
FR	France	X	X	X	X
GB	United Kingdom	X	X	X	X
IE	Ireland	X	X		-
IT	Italy	X	-		-
LT	Lithuania	X	-		-
NL	Netherlands	X	X		X
NO	Norway	X	X		X
PL	Poland	X	X	X	X
SE	Sweden	X	-		X
SI	Slovenia	-	X	X	-
UA	Ukraine	X	-		-
Total	19	17	12	8	11
EU-27	14	12	10	8	8

Note that the results for Belgium are limited to Wallonia, and that Canada, Lithuania and Slovenia submitted data for the first time. Reports describing the country submissions can be found in PART II. Not all Parties submitted reports to substantiate their results.

The updated European critical load maps and data statistics were presented at the seventeenth CCE workshop (Sofia, 23–25 April 2007) and the twenty-third Task Force meeting (Sofia, 26–27 April 2007) of ICP Modelling and Mapping. Belarus, Canada, the Czech Republic and Ireland submitted data after the Task Force meeting within the agreed period for revisions.

The Task Force noted the current European dataset on empirical critical loads covered a large part of Central and Western Europe and that differences between empirical and modelled critical loads existed. It recommended to use both the computed critical load for eutrophication and appropriate ranges of empirical critical loads, provided by Achermann and Bobbink (2003), and results from the Workshop on effects of low-level nitrogen deposition (Stockholm, 28–30 March 2007) as measures of risk of nitrogen deposition to biodiversity. It also noted that values for critical concentration in the leachate could be obtained using Swedish and Dutch data, as provided in De Vries et al. (2007). The values should be used with caution, for instance in regions with extreme precipitation.

It recommended the WGE at its 26th session to request the CCE to issue a call for data on empirical and computed critical loads and dynamic modelling to Parties under the Convention at the end of 2007.

Results of the new call are proposed to become available to the TFIAM in 2008 for the support of the possible revision of the Gothenburg protocol under the LRTAP Convention and of the Thematic Strategy on Air Pollution under the European Commission.

1.3 Maps of critical loads of nitrogen

Figure 1-1 shows modelled critical loads of nutrient nitrogen (left) and empirical critical loads (right) based on data provided by NFCs and on the CCE background database for countries that did not submit data. Comparison of both maps lead to a number of observations. First, *CLnutN* tends to be lower than *CLempN* in almost the whole of Europe. Empirical critical loads lower than 200 eq $ha^{-1}a^{-1}$ do not occur. Second, ecosystems in the north of Fennoscandia are more sensitive to eutrophication than those in the rest of Europe, irrespective of the kind of critical load. Third, the 5^{th} percentile *CLempN* of most ecosystems lies between 700 and 1000 eq $ha^{-1}a^{-1}$, while most of the 5^{th} percentile *CLnutN* fall in the ranges 200-400 and 400-700 eq $ha^{-1}a^{-1}$.

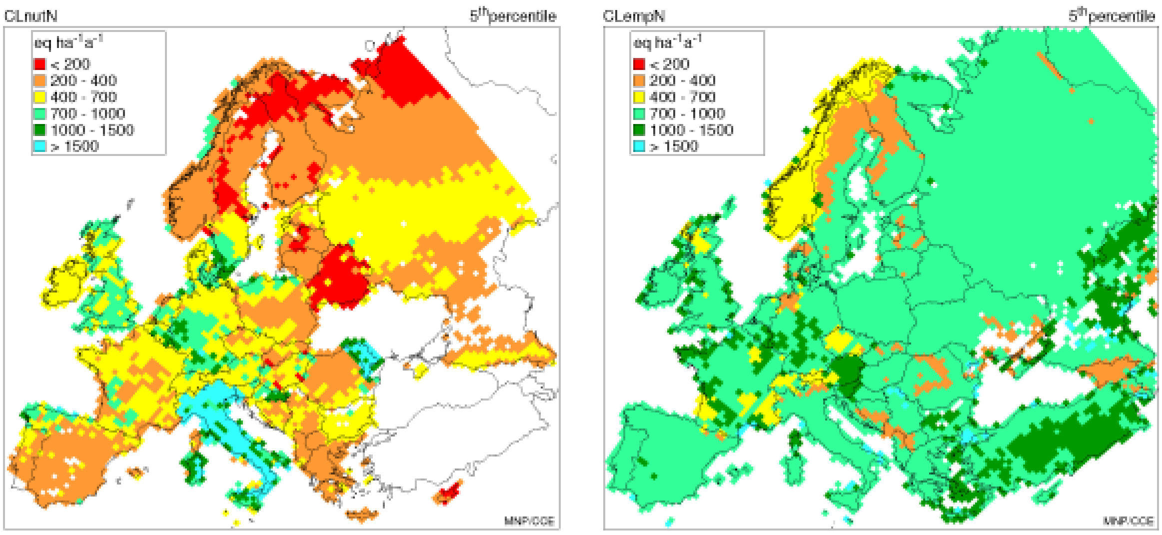

Figure 1-1. *The 5^{th} percentiles of the modelled critical loads of nutrient nitrogen for all ecosystems (left) and of the empirical critical loads (right) on the EMEP50 grid.*

The reasons for these differences are not straight-forward. Empirical critical loads are based on qualitative expert opinions that have been classified in ecosystem specific ranges. The expert opinions are based on biological (vegetation) impacts that have been reported at (elevated) nitrogen deposition levels (Achermann and Bobbink, 2003). Modelled critical loads of nitrogen are based on limits regarding nitrogen in the soil solution. Adverse N-effects occur, according to current applications of geo-chemical models, when the critical nitrogen concentration in the soil solution is violated. Depending on the value of the nitrogen concentration and subject to the variability caused by combinations of vegetation classes (uptake), soil types (denitrification) and meteorology (precipitation surplus), the Simple Mass Balance model can arrive at any positive number value for *CLnutN*. This explains the higher discriminatory power of European *CLnutN* compared to the qualitative *CLempN*. The fact that *CLempN* is generally higher than *CLnutN* seems to be related to the incomplete way by which values of critical limit parameters – relevant to *CLnutN* – can be associated to ranges of biological effects that have been assigned to *CLempN*. Current and near future work of the ICP M&M – with more focus on vegetation modelling – aims to remedy this discrepancy. Meanwhile, both the ranges of empirical critical loads and information on critical limit concentrations (See the instructions to NFCs in Appendix B) were provided to the National Focal Centres to assist them in responding to the call for voluntary contributions.

Finally, it is noted that NFC data can now be used to produce critical load maps for all ecosystems as illustrated in Figure 1-1, but also maps focussing on critical loads for distinctive EUNIS classes and for Natura 2000 areas. For countries that do not submit data, the CCE background database can be used. A compilation of a relevant background database for critical loads of Natura 2000 areas is currently in preparation.

1.4 Critical load exceedances

Table 1-2 summarizes exceedances of the critical loads for acidification. Table 1-3 gives an impression of preliminary exceedances of *CLnutN* and *CLempN*. Two statistical indicators are relevant for the interpretation of exceedances. The first one is the percentage of the ecosystem area that is protected ('Protected %') and the second is the average accumulated exceedance (AAE in eq ha^{-1} a^{-1}). Acidifying and eutrophying depositions were calculated by EMEP with emissions for the Current LEgislation scenario in 2010 and 2020 (CLE-2010 and CLE-2020, respectively) and the Maximum Feasible Reductions scenario in 2020 (MFR-2020). The deposition to European ecosystems in EMEP grid cells of national emissions and seashipping emissions[1] were computed using source-receptor relationships that the EMEP programme has computed, using a 5-year average meteorology.

Exceedance of *CLempN* has been documented to cover a wide range of risk of nitrogen deposition. The exceedance of *CLnutN* implies a risk that is caused by an excessive amount of nitrogen in the soil solution. The use of both critical loads separately may contribute to the robustness of exceedances and their geographical distribution (see chapter 4).

Table 1-2 shows that 91% and 94% of European ecosystem area in the EMEP domain (EMEP) is computed to be protected against acidification under CLE-2010 and CLE-2020, respectively. The related average accumulated exceedances are 38 and 22 eq $ha^{-1}a^{-1}$. The application of best available technology leads to a protection against acidification of 99%, and an AAE of 3 eq $ha^{-1}a^{-1}$.

The area protected and AAE can vary considerably between countries with the highest protection of 100% and the lowest of 21%.

[1] Seashipping emissions have been assigned to three shipping categories that have been distinguished under the EMEP programme.

Table 1-2. *The area protected from the risk of acidification based on emission data according to Current LEgislation in 2010 (CLE-2010), 2020 (CLE-2020) and Maximum Feasible Reductions in 2020 (MFR-2020) using a recent RAINS -emission database for land-based and marine sources, the source receptor relationship obtained from the EMEP programme based on a 5 year average meteorology and critical loads for acidification updated in 2007 in response to the call for voluntary data. Critical loads are obtained from NFCs (in bold) and based on the CCE background database otherwise (also published in ECE/EB.AIR/WG.1/2007/11/Corr.1).*

Country code	CLE-2010		CLE-2020		MFR-2020	
	Protected area %	AAE eq ha^{-1} a^{-1}	Protected area %	AAE eq ha^{-1} a^{-1}	Protected area %	AAE eq ha^{-1} a^{-1}
AL	100	0	100	0	100	0
AT	**100**	**0**	**100**	**0**	**100**	**0**
BA	55	242	73	162	100	0
BE	**86**	**97**	**90**	**66**	**99**	**7**
BG	**100**	**0**	**100**	**0**	**100**	**0**
BY	**52**	**190**	**64**	**121**	**96**	**3**
CH	**93**	**29**	**94**	**20**	**99**	**1**
CY	**100**	**0**	**100**	**0**	**100**	**0**
CZ	**52**	**193**	**76**	**67**	**98**	**3**
DE	**41**	**364**	**53**	**227**	**83**	**44**
DK	**89**	**18**	**92**	**15**	**100**	**1**
EE	**100**	**0**	**100**	**0**	**100**	**0**
ES	**100**	**0**	**100**	**0**	**100**	**0**
FI	**99**	**2**	**99**	**2**	**100**	**0**
FR	**92**	**24**	**95**	**16**	**100**	**0**
GB	**86**	**46**	**91**	**28**	**98**	**3**
GR	94	28	97	13	100	0
HR	**100**	**0**	**100**	**0**	**100**	**0**
HU	**100**	**0**	**100**	**0**	**100**	**0**
IE	**90**	**23**	**94**	**13**	**99**	**0**
IT	**100**	**0**	**100**	**0**	**100**	**0**
LT	**39**	**290**	**44**	**197**	**86**	**13**
LU	78	200	79	143	82	12
LV	**100**	**0**	**100**	**0**	**100**	**0**
MD	**97**	**10**	**97**	**5**	**100**	**0**
MK	85	18	96	2	100	0
NL	**21**	**1594**	**22**	**1433**	**33**	**606**
NO	**88**	**27**	**89**	**22**	**96**	**5**
PL	**36**	**364**	**55**	**155**	**100**	**1**
PT	95	25	95	17	100	0
RO	94	19	98	3	100	0
RU	**99**	**2**	**99**	**1**	**100**	**0**
SE	**87**	**16**	**90**	**12**	**99**	**0**
SI	100	0	100	0	100	0
SK	**86**	**67**	**91**	**26**	**100**	**0**
UA	**100**	**0**	**100**	**0**	**100**	**0**
YU	73	47	94	5	100	0
EU25	84	84	88	48	98	7
EU27	85	79	89	45	98	6
EMEP	91	38	94	22	99	3

***Table 1-3**. Country specific areas protected from the risk of eutrophication and country specific Average Accumulated Exceedances (AAE) of critical loads for eutrophication based on modelled (left) and empirical critical loads (right) obtained from NFCs (in bold) and based on the CCE background database otherwise. Emissions and depositions from RAINS and the EMEP programme as in Table 1-2. (also published in ECE/EB.AIR/WG.1/2007/11/Corr.1).*

Country code	Empirical						Modelled					
	CLE-2010		CLE-2020		MFR-2020		CLE 2010		CLE 2020		MFR 2020	
	Protected area %	AAE eq $ha^{-1} a^{-1}$	Protected area %	AAE eq $ha^{-1} a^{-1}$	Protected area %	AAE eq $ha^{-1} a^{-1}$	Protected area %	AAE eq $ha^{-1} a^{-1}$	Protected area %	AAE eq $ha^{-1} a^{-1}$	Protected area %	AAE eq $ha^{-1} a^{-1}$
AL	27	152	27	156	100	0	0	482	0	491	51	38
AT	**65**	**49**	**87**	**20**	**99**	**1**	**4**	**272**	**20**	**158**	**95**	**8**
BA	43	75	52	49	100	0	0	289	1	235	94	3
BE	49	481	49	408	51	126	**35**	**371**	**54**	**289**	**80**	**97**
BG	**56**	**108**	**65**	**89**	**100**	**0**	**2**	**391**	**4**	**340**	**83**	**12**
BY	10	179	11	148	100	0	**38**	**262**	**41**	**241**	**78**	**49**
CH	**32**	**157**	**49**	**100**	**97**	**1**	**1**	**608**	**3**	**488**	**47**	**72**
CY	96	3	79	16	100	0	**39**	**88**	**24**	**139**	**80**	**9**
CZ	**7**	**262**	**33**	**126**	**93**	**6**	**1**	**553**	**4**	**390**	**55**	**63**
DE	**5**	**483**	**17**	**338**	**73**	**71**	**24**	**455**	**33**	**341**	**63**	**99**
DK	32	501	32	473	41	88	**13**	**618**	**14**	**576**	**42**	**120**
EE	98	1	97	1	100	0	**54**	**58**	**57**	**60**	**98**	**3**
ES	64	68	72	43	99	2	**19**	**259**	**27**	**207**	**65**	**28**
FI	100	0	100	0	100	0	**56**	**42**	**59**	**37**	**97**	**1**
FR	**37**	**180**	**48**	**122**	**93**	**5**	**3**	**453**	**5**	**363**	**58**	**63**
GB	**91**	**32**	**92**	**25**	**97**	**2**	**21**	**334**	**28**	**261**	**75**	**36**
GR	71	40	71	40	100	0	0	438	0	436	26	75
HR	33	197	34	149	100	0	**59**	**161**	**61**	**125**	**93**	**8**
HU	35	208	35	141	100	0	**9**	**262**	**25**	**178**	**90**	**10**
IE	**65**	**124**	**70**	**89**	**97**	**2**	**16**	**528**	**19**	**444**	**33**	**167**
IT	19	452	19	369	68	73	**99**	**2**	**99**	**2**	**100**	**0**
LT	22	174	22	148	100	0	**0**	**521**	**0**	**487**	**27**	**93**
LU	31	572	31	457	31	122	0	1007	0	840	2	354
LV	82	12	86	9	100	0	**5**	**317**	**5**	**298**	**59**	**38**
MD	39	274	39	252	100	0	**100**	**0**	**100**	**0**	**100**	**0**
MK	46	99	48	85	100	0	0	396	0	364	90	4
NL	**8**	**1217**	**10**	**1095**	**25**	**488**	**11**	**1170**	**12**	**1049**	**28**	**460**
NO	**99**	**1**	**99**	**1**	**100**	**0**	**98**	**2**	**98**	**1**	**100**	**0**
PL	**1**	**255**	**3**	**149**	**100**	**0**	**12**	**504**	**17**	**410**	**55**	**73**
PT	85	16	93	7	100	0	6	215	8	153	93	3
RO	22	270	22	216	96	1	0	645	0	572	20	74
RU	97	4	96	4	100	0	**65**	**51**	**65**	**54**	**99**	**2**
SE	92	9	94	8	100	0	**88**	**14**	**89**	**12**	**96**	**2**
SI	**71**	**42**	**88**	**17**	**100**	**0**	0	572	0	458	42	36
SK	12	218	19	114	97	0	**1**	**380**	**6**	**257**	**85**	**15**
TR	98	2	96	6	100	0						
UA	1	373	1	328	100	0	**0**	**385**	**0**	**416**	**100**	**0**
YU	60	40	74	26	100	0	1	316	2	271	99	1
EU25	59	139	64	99	94	14	42	232	45	186	79	33
EU27	57	147	61	107	94	12	38	256	42	208	76	34
EMEP	77	69	79	52	98	5	56	133	58	115	90	15

Table 1-3 shows that the area within the EMEP domain that is protected against the risk of eutrophication effects (non-exceedance of *CLnutN* is 56% for CLE-2010 and 58% for CLE-2020 (90% under MFR2020). The protection based on empirical critical loads (non-exceedance of *CLempN*) is computed to increase from 77 % to 79% under emissions from CLE-2010 and CLE-2020 respectively (98% under MFR-2020). The Average Accumulated Exceedance using empirical critical loads is reduced from 69 to 52 eq $ha^{-1}a^{-1}$ in CLE-2010 and CLE-2020, respectively in the EMEP domain.

Figures 1-2 to 1-4 show trends between 1990 and CLE-2020 as well as MFR-2020 in the average accumulated exceedances of critical loads for acidity, empirical critical loads and critical loads for nutrient nitrogen. The size of the coloured squares reflects the area exceeded. It is clear from these figures that the risk is significantly reduced in 2020 compared to 1990 if maximum feasible reductions are applied. Areas with high exceedances (shaded red) are significantly reduced. However, in each of the maps it is also illustrated that areas with low exceedances (light-blue shaded) become larger and more areas are shown where exceedances do not occur any longer.

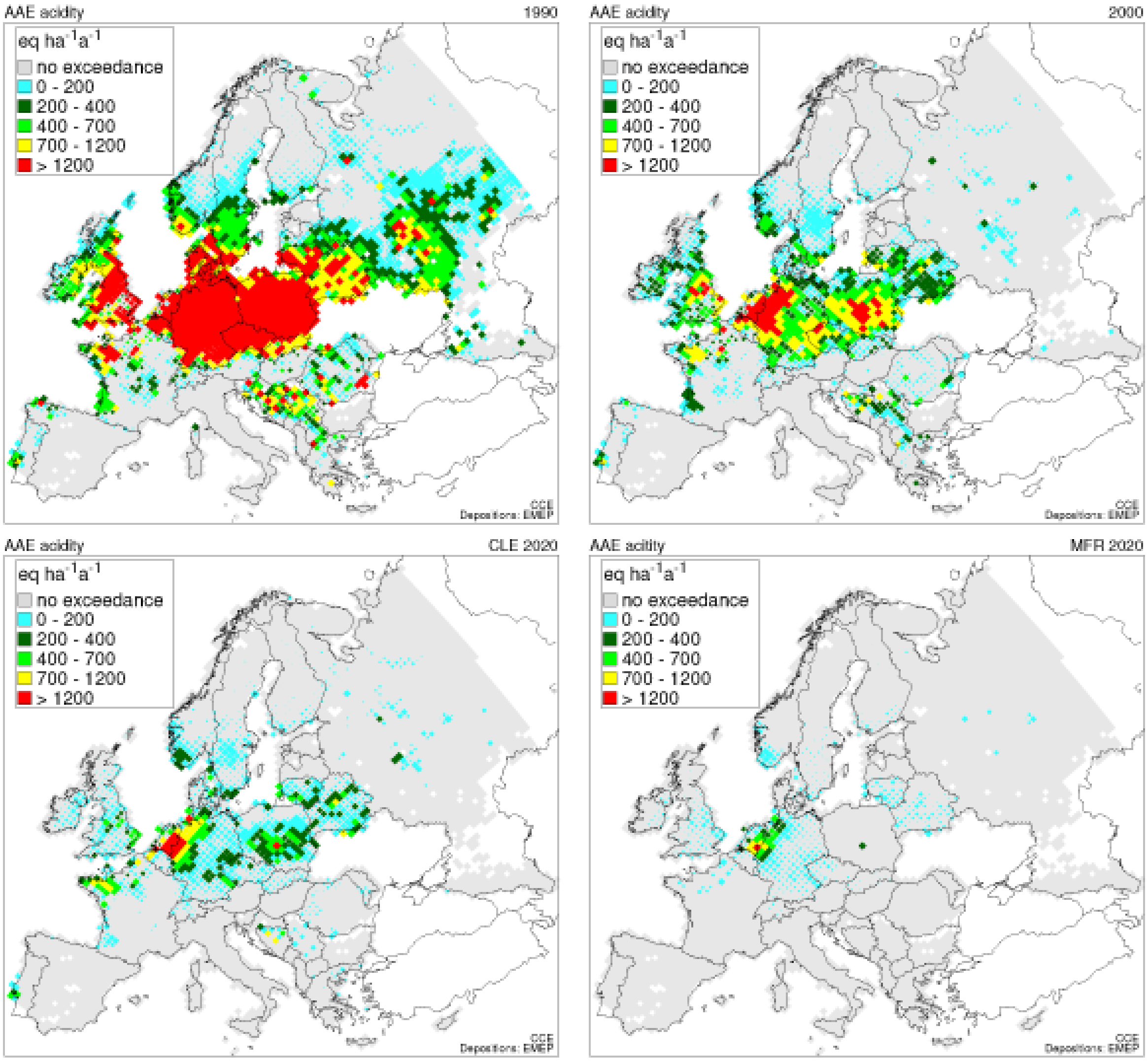

***Figure 1-2**. Average accumulated exceedance (AAE) of critical loads for acidity in 1990 (top left), 2000 (top right), in 2020 according to current legislation (bottom left) and in 2020 according to maximum feasible reduction. The size of the coloured squares reflects the area exceeded. Red shaded areas indicate highest exceedances.*

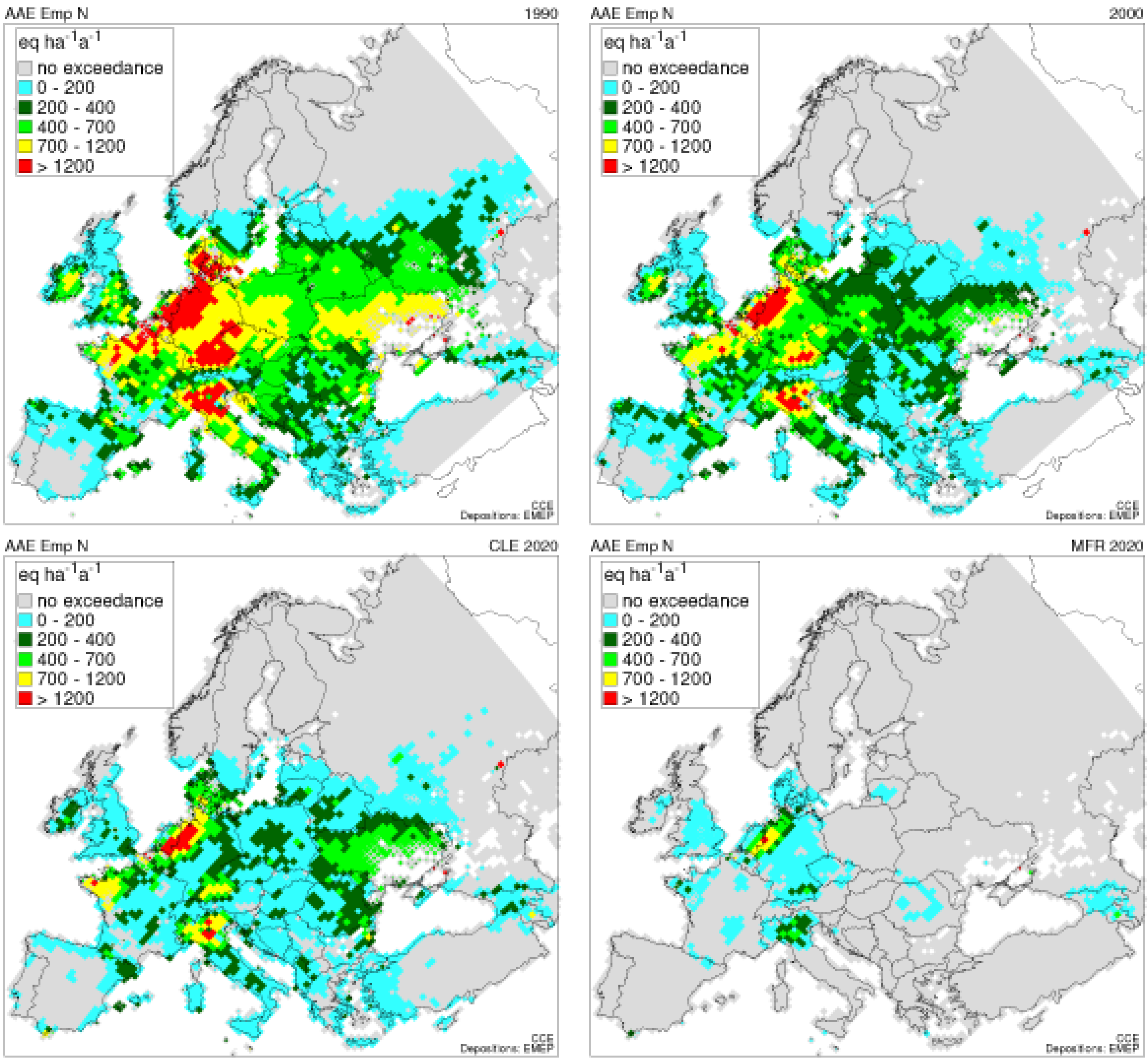

***Figure 1-3**. Average Accumulated Exceedance (AAE) of empirical critical loads, CLempN, in 1990 (top left), 2000 (top right), in 2020 according to current legislation (bottom left) and in 2020 according to maximum feasible reduction. The size of the coloured squares reflects the area exceeded. Red shaded areas indicate highest exceedances.*

Figure 1-3 illustrates that ecosystem areas of which the empirical critical loads are exceeded under MFR-2020 (bottom-right map) are mostly in EMEP grid cells located in Belgium, Denmark, Germany and the Netherlands. Areas with a high exceedance remain in the border area between the Netherlands and Germany also in MFR-2020.

Figure 1-4 shows that the magnitude of the average accumulated exceedances of *CLnutN* diminishes significantly from 1990 to MFR-2020. However, in comparison to Figure 1-3 a larger area remains at risk in MFR-2020. On the other hand the magnitude of AAE in the border area between The Netherlands and Germany lies in the range between 700 and 1000 eq $ha^{-1}a^{-1}$ compared to values higher than 1000 $ha^{-1}a^{-1}$ in Figure 1-3.

Figure 1-5 shows the AAEs using modelled (left) and empirical (right) critical loads that NFCs submitted for all ecosystems (top) and Natura 2000 areas (bottom). The geographic pattern of exceedances of critical loads for all ecosystems turns out not to differ significantly from exceedances for Natura 2000 areas only. This indicates that Natura 2000 areas are representative of all sensitive ecosystems in countries that submitted critical loads for both ecosystem categories. A general conclusion regarding the extent to which Natura 2000 areas are representative in the critical loads database for EU27 countries necessitates a common response of a larger number of EU countries.

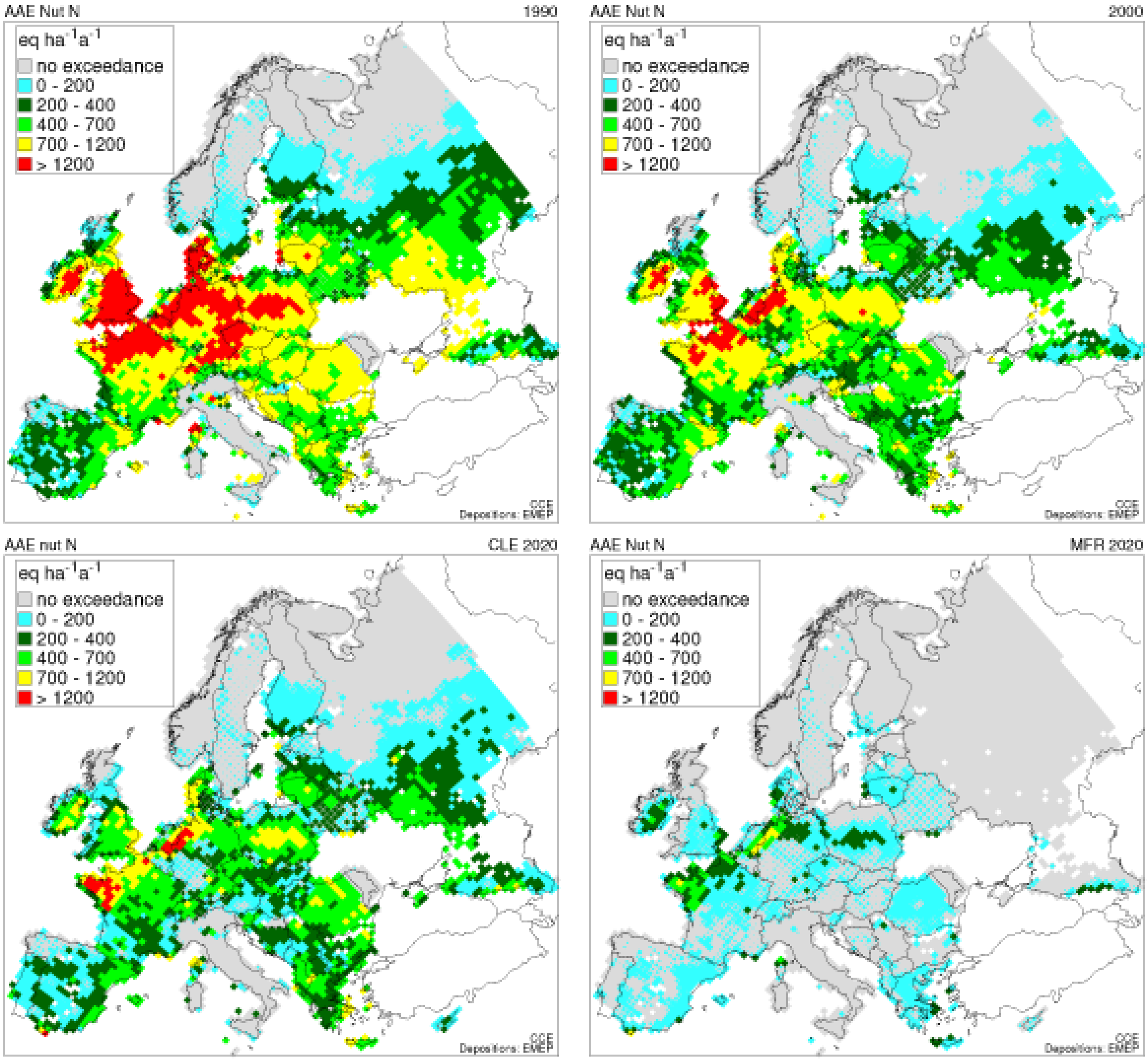

***Figure 1-4**. Average accumulated exceedance (AAE) of modelled critical loads, CLnutN, in 1990 (top left), 2000 (top right), in 2020 according to current legislation (bottom left) and in 2020 according to maximum feasible reductions. The size of the coloured squares reflects the area exceeded. Red shaded areas indicate highest exceedances.*

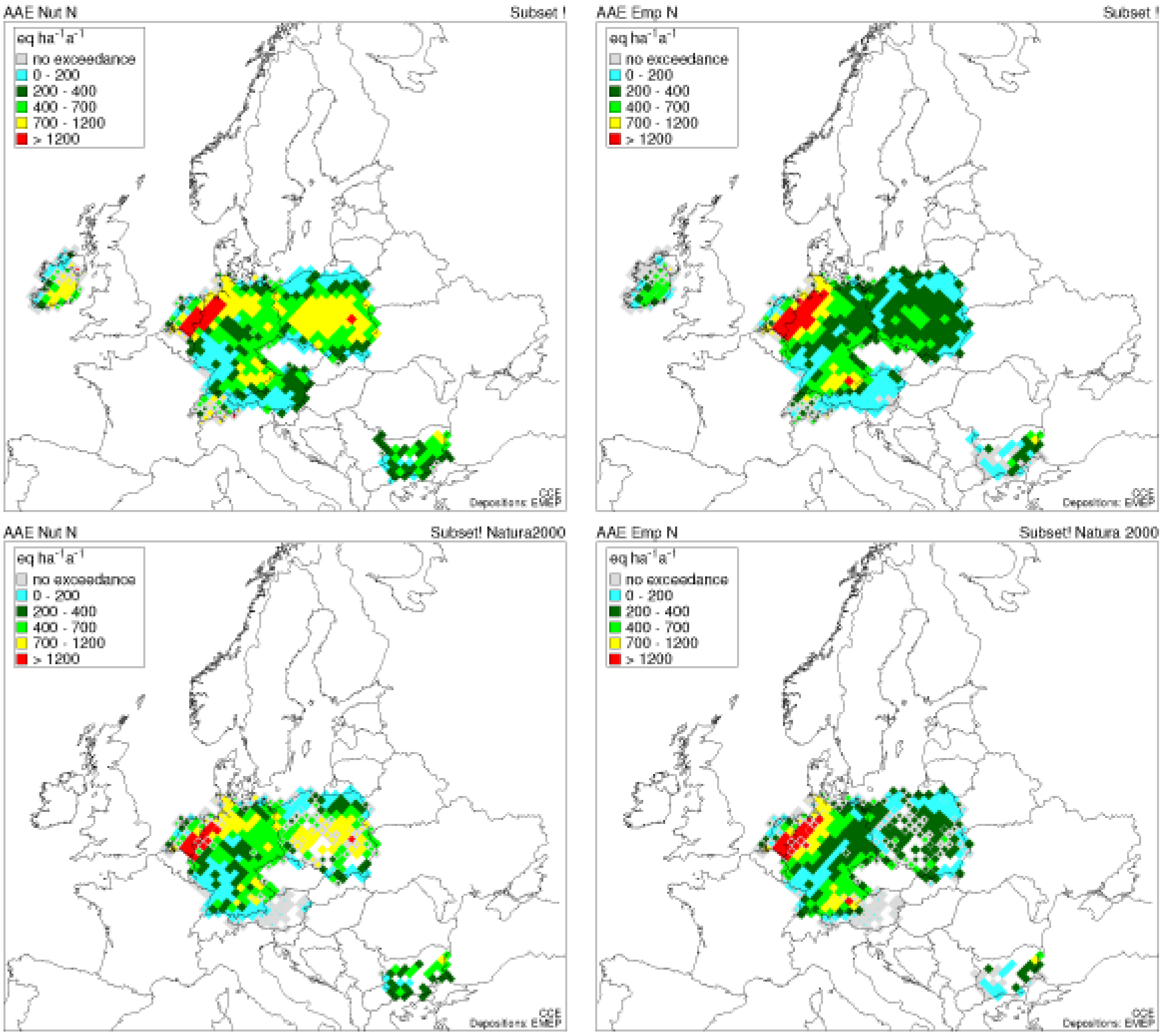

***Figure 1-5**. Average accumulated exceedance (AAE) using NFC data for CLnutN for all ecosystems (top left), CLempN (top right), CLnutN for Natura 2000 areas (bottom left) and CLempN for Natura 2000 (N2K) areas. The shaded area covers AAE computations by NFCs that submitted computed critical loads, empirical as well as critical loads for N2K areas.*

1.5 Dynamic modelling results

Dynamic modelling is an important part of the effects-based work. It can improve the understanding of the delayed response of natural systems to changes in exceedances. It is the key to understanding the effects on biodiversity caused by dynamic interactions between climate change and air pollution.

The call for voluntary contributions on dynamic modelling focussed on the application of the VSD model to acidification and eutrophication. It also explored national input data requirements for dynamic soil-vegetation models (De Vries et al., 2007).

Eleven NFCs provided results using selected deposition scenarios provided CCE. These included ecosystem-specific deposition (forest, (semi-)natural vegetation and grid average) for the period 1880–2010 for each grid cell. Deposition with CLE, MFR and natural background from 2020 onwards were made available.

Output was requested for the three deposition scenarios and sufficient scenarios in-between. It comprised the temporal development of critical indicators for acidification (e.g. base cation to aluminium ratio) and eutrophication (e.g. N concentration).

The temporal development of nitrogen concentration in soil solution with deposition scenarios was analyzed. Nitrogen dynamics are complex and slow. It was possible to compute damage delay times due to the exceedance of the critical load of nitrogen. However, it was more difficult, with simple biogeochemical models, to model the mechanisms behind recovery delay times, which bear relevance to air pollution policies.

The CCE and the Centre for Integrated Assessment Modelling (CIAM) will collaborate in testing to extend the current critical loads database in the RAINS model with dynamic modelling data. The results of the NFC response on dynamic modelling form the basis, e.g. by interpolation, for dynamic modelling of alternative deposition scenarios by the TFIAM.

1.6 Conclusions and recommendations

The call for voluntary data reached its objectives. This call was new compared to earlier calls in its request to NFCs to also submit empirical critical loads and critical loads for Natura 2000 areas and to apply new information for dynamic modelling. In addition, NFCs could use a novel land cover database that was harmonized in collaboration with the Stockholm Environment Institute.

Nineteen NFCs submitted data. Seventeen NFCs submitted data on modelled critical loads, twelve on empirical critical loads, eight on critical loads in Natura 2000 areas and eleven on dynamic modelling.

Maps of critical loads and exceedances relative to empirical and modelled critical loads and critical loads for Natura 2000 areas were summarized in this chapter.

Computations with the data yielded results that can be summarized as follows regarding nitrogen. For the 25 European Union member states (EU25) the area protection using empirical and modelled critical loads with CLE-2010 deposition is 59% and 42%, respectively. For the EU27 these percentages are 57% and 38% respectively and for the EMEP-domain 77% and 56% respectively. The AAE under CLE-2010 is 139 (based on empirical critical loads) and 232 eq ha^{-1} a^{-1} (based on modelled critical loads) for the EU25, 147 and 256 eq ha^{-1} a^{-1} for the EU27 respectively, and 69 and 133 eq ha^{-1} a^{-1} for the EMEP domain, respectively.

Regarding acidification, the protected area in the geographical domain of EMEP is 91%, 94% and 99% with CLE-2010, CLE-2020 and MFR-2020, respectively.

Results documented in this chapter have been presented to the twenty-third Task Force meeting (Sofia, 26–27 April 2007) and reported to the 25th session of the Working Group on Effects (WGE, Geneva, 29-31 August 2007; report nr. ECE/EB.AIR/WG.1/2007/11/Corr.1).

On the basis of this report the WGE approved the proposal of ICP Modelling and Mapping and CCE to make a new call for data related to critical loads and dynamic modelling in the end of 2007, and that the results would be made available to integrated assessment modelling in 2008.

References

Achermann and Bobbink (2003) Empirical critical loads for Nitrogen, Proceedings of an Expert Workshop, Berne, 11-13 November 2002, SAEFL, Env. Doc.164

De Vries W, Kros H, Reinds GJ, Wamelink W, Mol J, Van Dobben H, Bobbink R, Emmett B, Smart S, Evans C, Schlutow A, Kraft P, Belyazid S, Sverdrup H, Van Hinsberg A, Posch M, Hettelingh J-P (2007) Development in deriving critical limits and modelling critical loads of nitrogen for terrestrial ecosystems in Europe, Alterra-MNP/CCE report, Alterra report 1382 (available from the CCE)

2. Summary of national data

Jaap Slootweg, Maximilian Posch

2.1 Introduction

In 2006 The CCE, on invitation of the Working Group on Effects (WGE), issued a call for data in two parts.

The first part aimed at initiating a European database of empirical critical loads of nitrogen. Empirical critical loads are based on effects of (elevated) nitrogen deposition on ecosystems. A compilation of all relevant studies led to well established ranges (UBA, 2004). The value for the empirical critical load can be picked from this range, depending on other local factors, such as temperature, soil wetness, base cation availability. Some NFCs applied empirical critical loads in earlier submissions, mixed with loads calculated using the Simple Mass Balance (SMB) model. In this call, a clear distinction has been made and a database for empirical critical loads has been established, next to a database based on SMB or other models. These 'classic' critical loads are referred to as *modelled* critical loads to make a clear distinction between the two approaches. Another novelty of this call is the focus on Natura 2000 areas. These areas, for which the Habitats directive (92/43/EEC) and/or the Birds directive (79/409/EEC) apply, are of special interest for the conservation of natural habitats and bird species, and the maintenance of biodiversity. Therefore it is also important to know the sensitivity to nitrogen deposition of these areas.

The second part of the call aimed at updating national data on critical loads of sulphur and nitrogen and dynamic modelling. With this call it was stressed that the recommended critical concentrations for the calculation of *CLnutN* had been updated and extended with effects on other ecosystem types. The dynamic modelling part of the call focused on the changes in soil parameters as a result of different deposition scenarios.

These two calls are related to each other and the results of both will be described in this chapter. The critical loads are mapped and presented together with the distributions of some of the more important variables. The relation between the empirical and modelled critical load of nutrient nitrogen is explored in relation to the exceedance of each, and cross sections for Natura 2000 and national protection areas are shown. Special attention has been paid to the critical limits that are applied.

Changes in soil parameters over time for different deposition scenarios are presented in the paragraph on dynamic modelling.

2.2 Requested variables

There is obviously no list of 'input data' for empirical critical loads. Next to the load itself only data related to the geographical location and the status concerning the nature protection were asked. The call for data of critical loads of N and S and dynamic modelling data contained some important changes compared to earlier calls. The first change allowed relating the datasets of both calls. Another important change is the request of the critical nitrogen concentration, rather then the leaching flux. The resulting soil parameters relevant for dynamic modelling remained unchanged, but the much increased number of scenarios forced a technical adjustment. A full description with all the technicalities can be found in Appendices A and B.

One of the variables is the EUNIS code. This indicates the class according to the hierarchical habitat classification system, developed by ETC/BD (Davies, 2004). EUNIS codes (1st and 2nd level) used by the NFCs with the relation to the ecosystem classes used in comparing the critical load with depositions (forest, vegetation, and waters) are listed in Table 2-1.

Table 2-1. *Ecosystem types in use for critical loads.*

EUNIS classes	Description	Ecosystem class
G, G1, G2, G3	Forests	Forests
A, A2, A4	Marine habitats	
B1, B3	Coastal habitats	
C3	Littoral zones	
D, D1, D2, D4, D5, D6	Mire, bog and fen habitats	
E, E1, E2, E3, E4	Grassland and tall forb habitats	Vegetation
F, F1, F2, F3, F4, F5, F7, F9	Heathland, scrub and tundra habitats	
H4, H5	Inland unvegetated or sparsely vegetated habitats	
I1	Agriculture	
Y	Unknown	
C1,C2	Inland surface water habitats	Other (Average)

2.3 National responses

A total of 18 countries responded to at least one of the calls, among them the newly established National Focal Centres of Canada, Lithuania and Slovenia. The countries which submitted data are shown in Table 2-2, together with the number, areas and EUNIS level-1 classes of the ecosystems. The areas of the submitted ecosystems, stacked for the EUNIS classes are also plotted in Figure 2-1 as percentage of the total country area. This figure shows also the distribution of EUNIS classes in the countries, demonstrating the coverage of the ecosystems in each country. This land cover distribution is derived from the harmonised land cover map (see chapter 5).

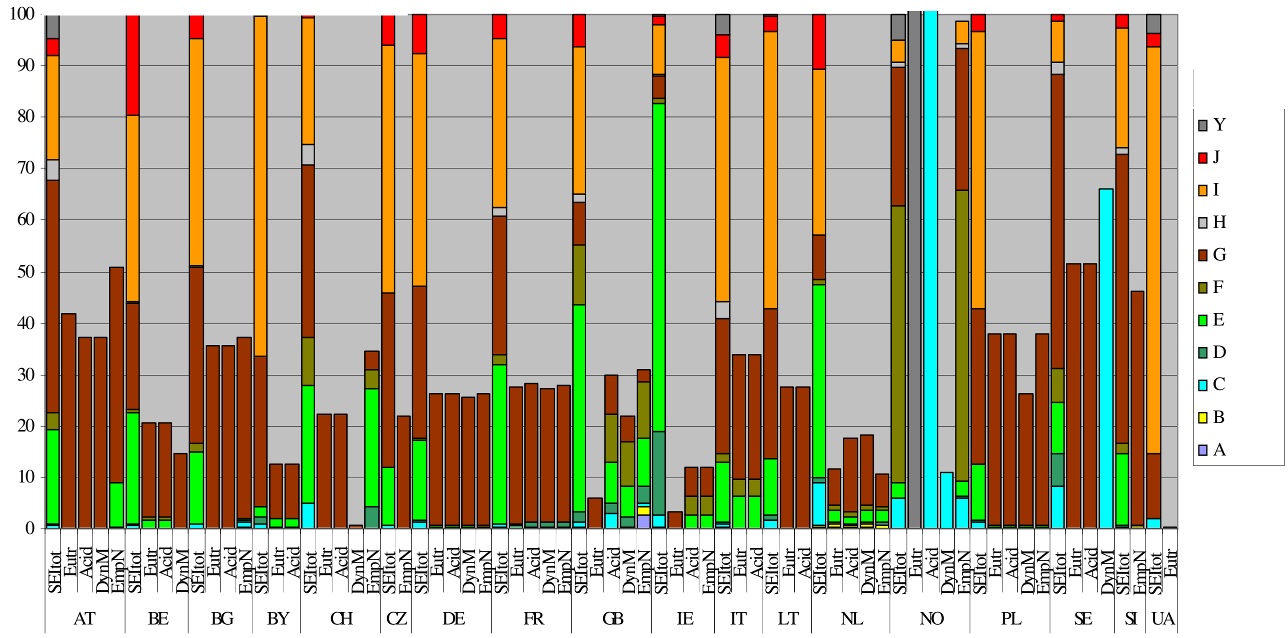

Figure 2-1. *National distributions of ecosystem types as percent of total country area according to the harmonised land cover map (SEItot) and for the submissions for CLnutN (Eutr), CLempN (EmpN), CLmaxS (Acid) and dynamic modelling (DynM).*

Whereas the focus for acidification is on forests and (Nordic) freshwaters, for empirical critical loads generally more ecosystem types are assessed. Dynamic modelling is mainly performed for ecosystems in countries where the critical loads for acidification are (or have been) exceeded. Keeping in mind the more prominent exceedances for nitrogen, other ecosystems and regions in Europe should be considered for dynamic modelling.

Table 2-2. *Number of ecosystems and area of the country submissions for modelled and empirical nutrient nitrogen, acidification and dynamic modelling.*

		Modelled Nutrient N		Empirical N		Acidification		Dynamic Modelling	
		#records	Area (km²)	#records	Area (km²)	#records	Area (km²)	#records	Area (km²)
AT	D			2720	339				
	E			2570	8297				
	G	18314	40254.56	7108	40308	496	35745	495	35732.5
BE	E	482	601.1099			482	601		
	F	79	136.0863			79			
	G	3281	6244.829			3281	6245	1584	4914.051
BY	D	223	471.45			223	471		
	E	1783	3813.4			1783	3813		
	G	8826	23837.23			8826	23837		
CA	C					496	6728	496	6728.257
CH	C			49	49				
	D			2090	2090				
	E			10937	10937				
	F			1816	1816				
	G	10607	10607	1684	1684	10607	10607	260	260
CZ	G			46933	19167				
DE	A	21	21	44	44	21	21	21	21
	B	134	134			134	134	65	65
	C	36	36			36	36	36	36
	D	1177	1177	714	714	1177	1177	1177	1177
	E	1493	1493	1053	1053	1493	1493	1493	1493
	F	309	309	149	149	309	309	304	304
	G	100483	100483	100601	100601	100483	100483	98003	98003
FR	B			156	2741	156	2741	156	2740.548
	D	67	5123.462	67	5123	67	5123	67	5123.462
	E	81	1580.297	81	1580	81	1580	81	1580.297
	G	3840	170657.4	3837	170620	3840	170657	3713	165994
GB	A			44	7246				
	B			10421	4068				
	C			64	1269	1717	7790	310	1153.423
	D			19342	8946	18682	5455	16423	5057.107
	E			119256	24099	99451	20010	69591	15111.23
	F			79237	28670	78550	24669	67323	22789.33
	G	113169	15792.78	38786	5282	150208	19748	85550	12316.59
IE	E			6895	2050	6895	2050		
	F			6847	2631	6847	2631		
	G	9195	2448.954	17242	4254	17242	4254		
IT	A	1	35			1	35		
	B	16	374			16	374		
	C	3	60			3	60		
	E	185	23027			185	23027		
	F	210	12822			210	12822		
	G	714	89560			714	89560		
LT	G	22261	18570.4			22261	18570		
NL	A	1159	73.017	456	29	1096	69	1159	73.017
	B	4598	289.674	4598	290	3160	199	4598	289.674
	C	417	5.034672						
	D	3251	204.813	2396	151	2786	176	3251	204.813
	E	15107	951.741	15107	952	8391	529	15107	951.741
	F	5788	364.644	5788	365	5576	351	5788	364.644
	G	44027	2773.701	39695	2501	91537	5767	87978	5542.614
NO	C			273	19045	2324	322150	201	34241.62
	D			12	694				
	E			288	9508				
	F			367	175378				
	G			474	85933	663	67124		
	H			77	3947				
	I			126	12865				
	Y	35418	318762						

		Modelled Nutrient N		Empirical N		Acidification		Dynamic Modelling	
		#records	Area (km^2)	#records	Area (km^2)	#records	Area (km^2)	#records	Area (km^2)
PL	D	1385	1385	1385	1385	1385	1385	1368	1368
	E	576	576	576	576	576	576	574	574
	F	38	38	38	38	38	38	38	38
	G	126399	126399	126399	126399	126399	126399	87150	87150
SE	C							2930	289509.9
	G	25442	225264.2			25442	225264		
SI	F			256	164				
	G			12435	10832				
UA	G	6	1925.2						
Total		586164	1235696	691489	906879	831988	1380035	557290	800908

2.4 Critical loads of nitrogen

The critical load for adverse effects due to excess of nitrogen deposition can be derived from the simple mass balance with a critical concentration of nitrogen in the leachate. This critical load is referred to as *CLnutN* or, more explicitly, *modelled critical load of nutrient nitrogen*. Empirical loads for nitrogen are derived from observed changes in structure and function of ecosystems, reported in a range of publications. For tens of EUNIS class-effect combinations a range for the critical load is given in the Mapping Manual (UBA, 2004) together with their reliability. It is possible to select a smaller range within the given range by the use of modifying factors like temperature, soil wetness and base cation availability. These critical loads are denoted as *CLempN*.

Figure 2-2 shows the 5th percentiles of the critical loads of nitrogen, modelled at the left, empirical at the right. The two lower maps present the same for forests only. For the modelled critical loads this does not differ much from the 5th percentile of all ecosystems, whereas the empirical critical loads for forests are generally higher then the loads for other ecosystems.

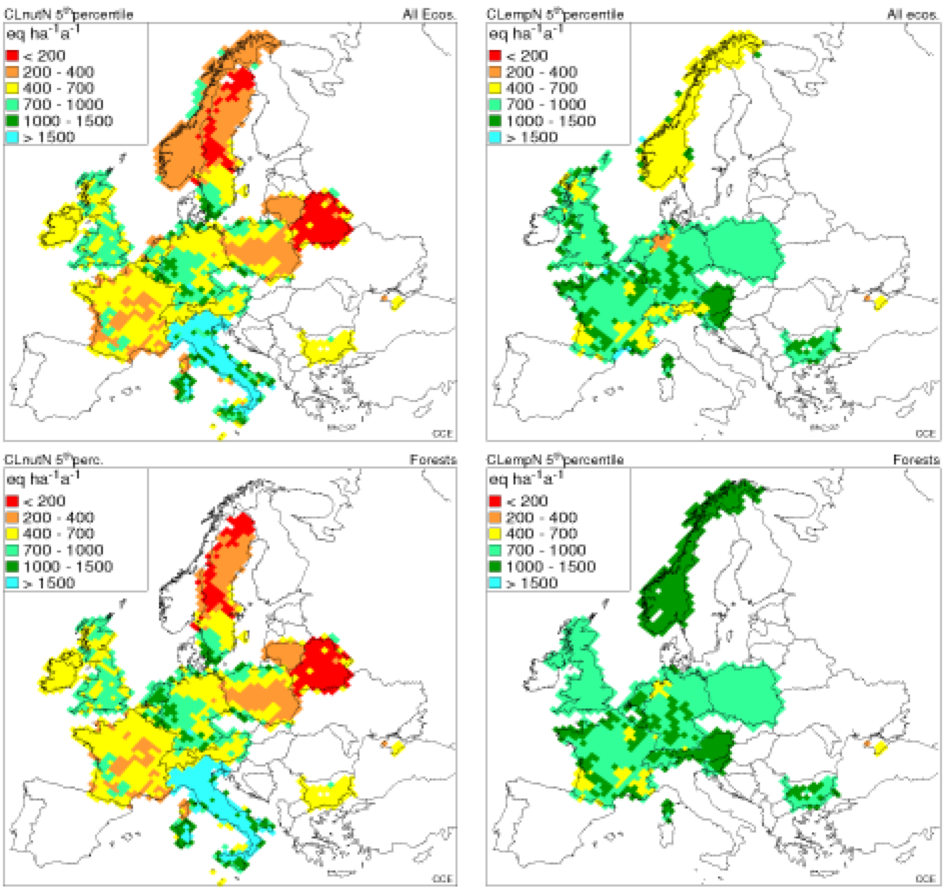

Figure 2-2. *Submitted critical loads of nitrogen, modelled at the left and empirical at the right; for all ecosystems at the top and for forests only at the lower half of the figure.*

The full range of both N critical loads for each country, opposed to only the 5th percentile in the maps, are plotted in Figure 2-3 for each EUNIS-1 class separately. The distributions are given as Cumulative Distribution Functions (CDFs).

As can be expected, ecosystem types with low empirical critical loads, like wetlands, are generally well represented in the lower parts of the graphs for empirical critical loads. But countries that modelled critical loads for wetlands show relatively low values for these ecosystems too. Not all countries have modelled the ecosystems that have generally low empirical critical loads.

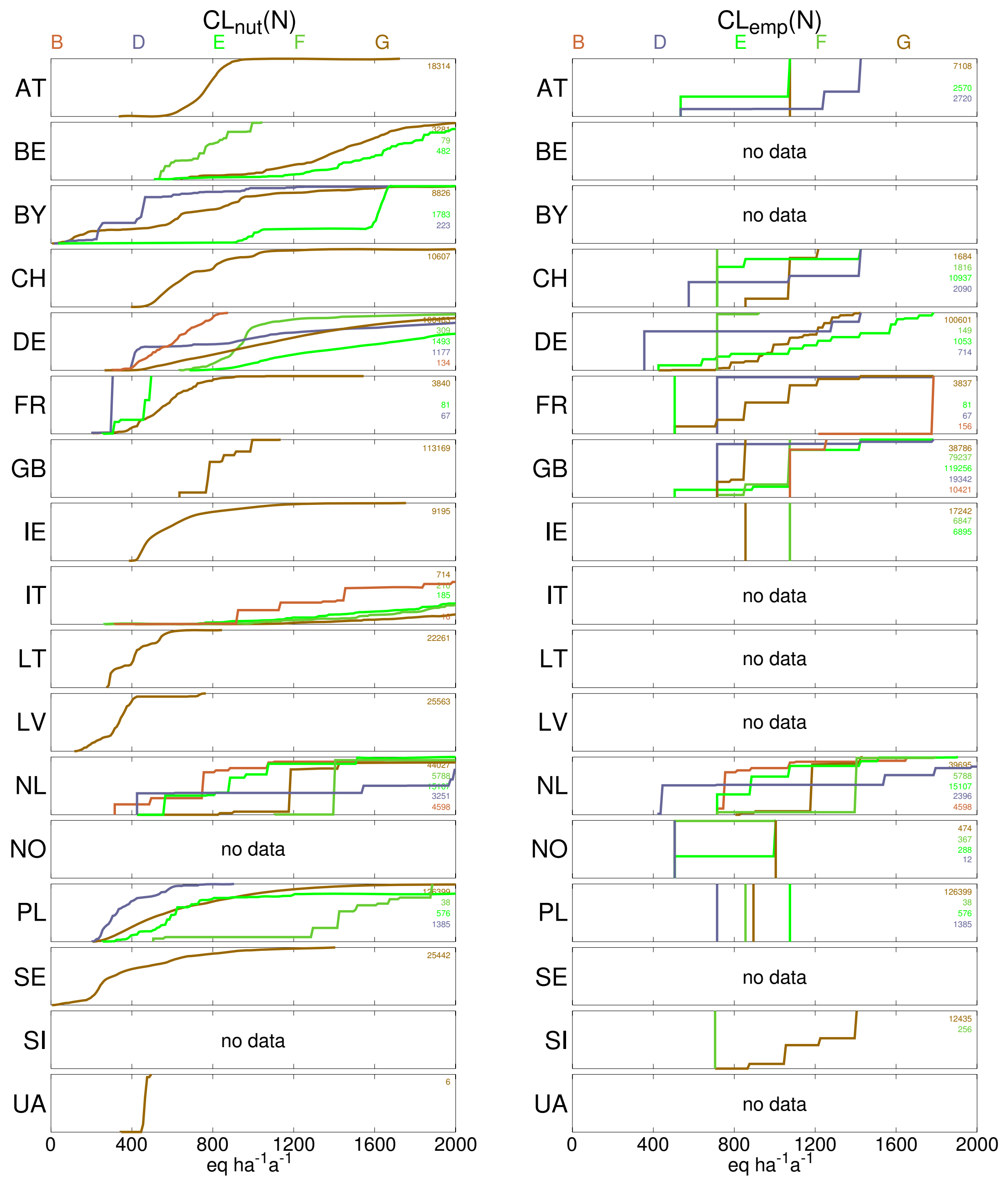

Figure 2-3. *National distribution of CLnutN (left) and CLempN (right) for most commonly considered EUNIS-1 ecosystems.*

For the empirical critical loads, information on the nature protection status has been provided by the NFCs. A distinction was made between the applicability of 1) the birds directive, 2) the habitats directive, 3) both the birds and habitats directive, 4) other (national protection) and 5) none. This distinction has been made in the distributions of empirical critical loads in Figure 2-4. The CDFs are clustered by the EUNIS-1 ecosystem types. Addition vertical lines indicate relevant loads from the Mapping Manual (in kg ha^{-1} a^{-1}).

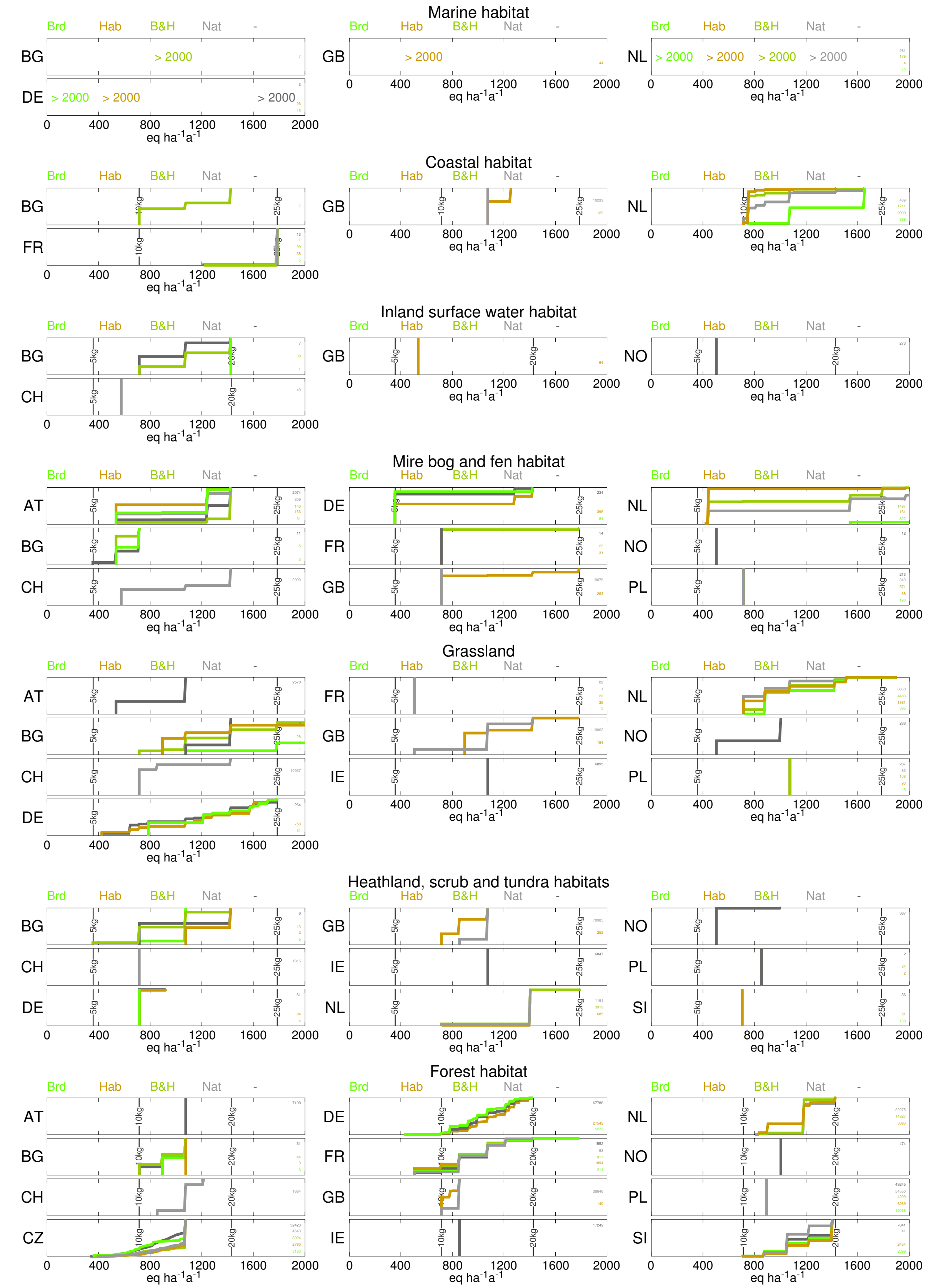

Figure 2-4. *Empirical critical loads of areas protected by the birds directive, the habitat directive, both the bird and habitat directive, other (national) nature protection legislation or no protection.*

The CDFs within a country are often closely together or even obscuring each other. The fraction of the area for which a certain load applies (vertical line segments) may differ with the protection status, but there is no apparent, systematic difference between empirical critical loads of non-protected ecosystems and any of the protected areas.

2.5 Critical loads of acidity

The critical load function of acidity is described by *CLmaxS*, *CLminN* and *CLmaxN*. Figure 2-5 shows the 5th and 25th percentile maps of *CLmaxS* and *CLminN*. *CLmaxN* is not shown here since it is computed from the other two quantities and denitrification; and more on denitrification can be found in section 2.8.

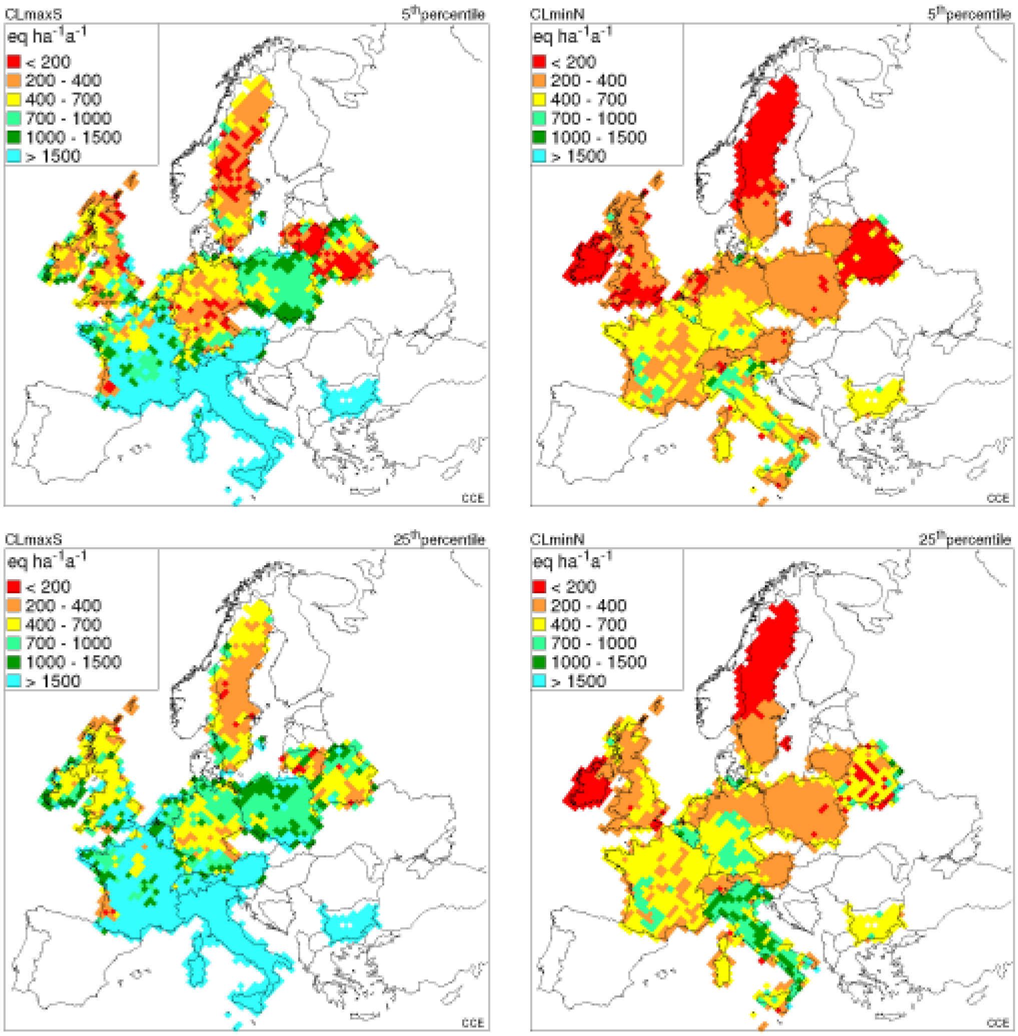

Figure 2-5. *The 5th (top) and 25th (bottom) percentile maps of CLmaxS (left) and CLminN (right).*

2.6 Exceedance of critical loads

If the deposition is larger than the critical load, i.e. if there is exceedance, there is a (future) risk of damage to the ecosystem. The exceedances of the critical loads of all ecosystems in an EMEP grid can be expressed as Average Accumulated Exceedance (AAE) (Posch et al., 2001; UBA, 2004).

Depositions to which the critical loads are compared are derived from emissions according to a) the Current LEgislation of the Gothenburg protocol in 2010 (CLE2010) and b) the implementation of Maximum Feasible Reductions in 2020 (MFR2020).

Exceedance of critical loads of nutrient nitrogen

Figure 2-6 shows the exceedances of nutrient nitrogen in the countries that submitted the critical loads. The exceedances of the modelled critical loads are in the top row of the figure, the exceedances of the empirical are in the bottom row. Modelled critical loads are more exceeded then empirical ones, except for a region close to the German-Dutch border. But although differences between the two approaches are apparent, the higher exceedances are situated in the same regions in Europe for both modelled and empirical critical loads. It can be clearly seen that with MFR it is possible to limit exceedances considerably.

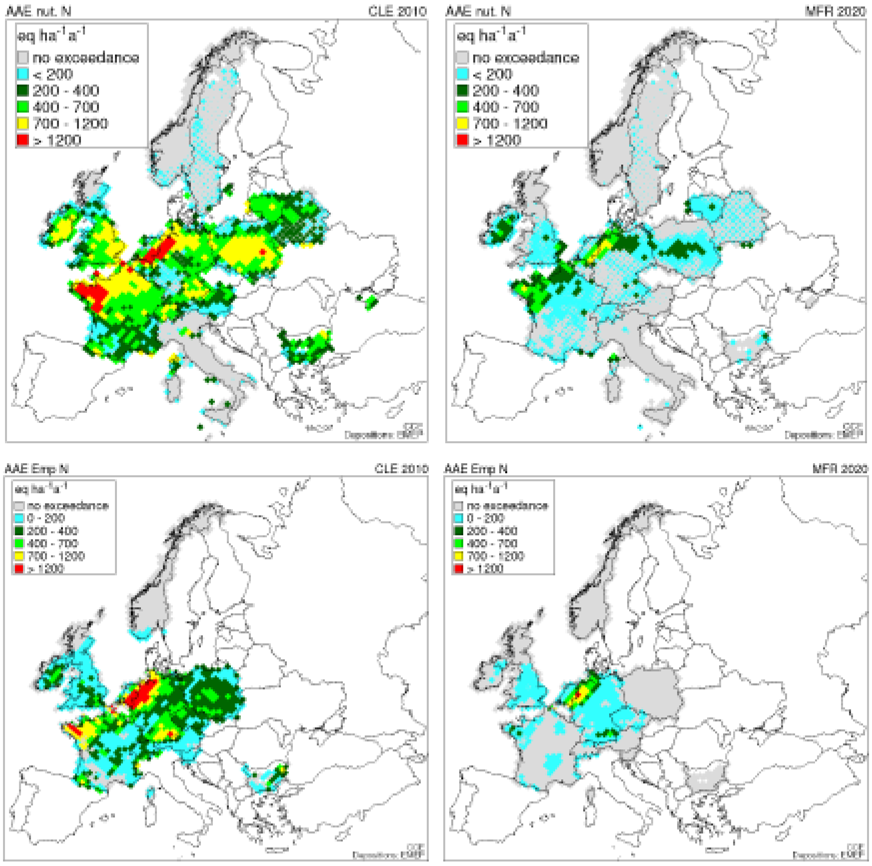

Figure 2-6. *Exceedances for CLE 2010 (left) and MFR 2020 (right) for modelled critical loads (top row) and empirical loads (bottom row) of nitrogen.*

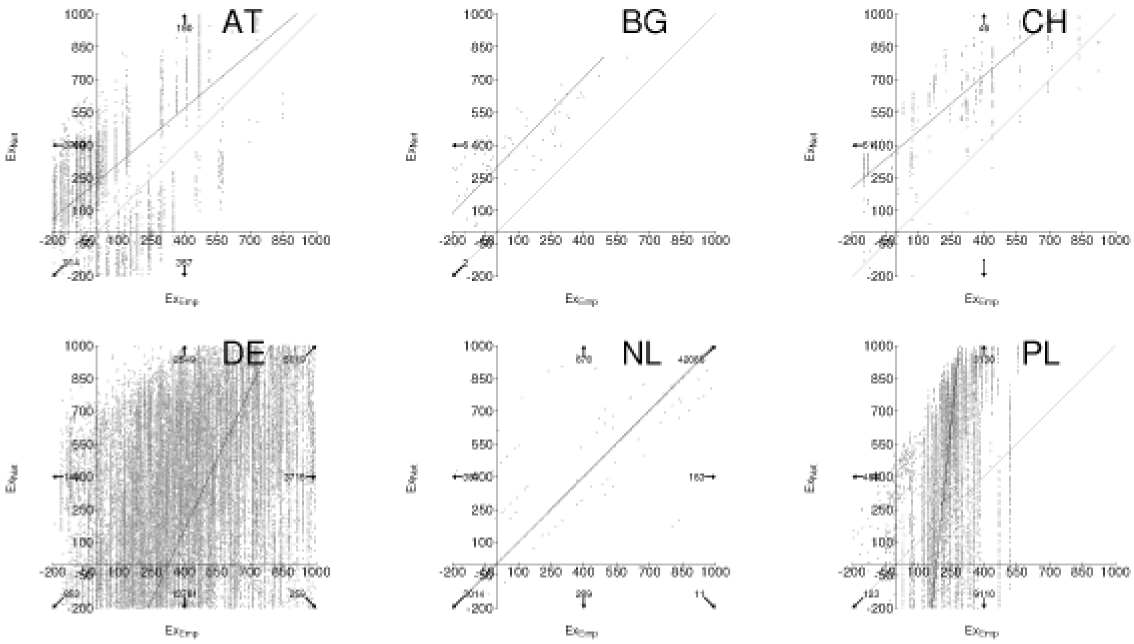

Figure 2-7. *Correlation of differences between deposition and a) modelled (y-axes) and b) empirical load (x-axes) for individual ecosystems (also shown is the 1-to-1 line).*

For individual ecosystems the differences between modelled and empirical loads are more prominent. For all countries that provided ecosystems with loads for *both* approaches the difference between load and deposition for both has been calculated. These are shown in Figure 2-7, and the black line is the correlation between these 'exceedances'. Although there is a positive correlation for all countries, the scatter shows the occurrence of many ecosystems for which the excess depositions are quite different for the two approaches. The modelled critical loads for the Netherlands have been limited to the range of empirical loads, giving a wrong impression of a seemingly fair correlation.

Exceedance of critical loads of acidity

Critical loads of acidity have hardly changed since previous submissions and the regions at risk in Europe are therefore about the same. The exceedances of the Current LEgislation of the Gothenburg protocol in 2010 (CLE2010) and for the implementation of Maximum Feasible Reductions in 2020 (MFR2020) can be seen in Figure 2-8. The effect of MFR is sufficient to eliminate exceedances almost everywhere, for example in Poland.

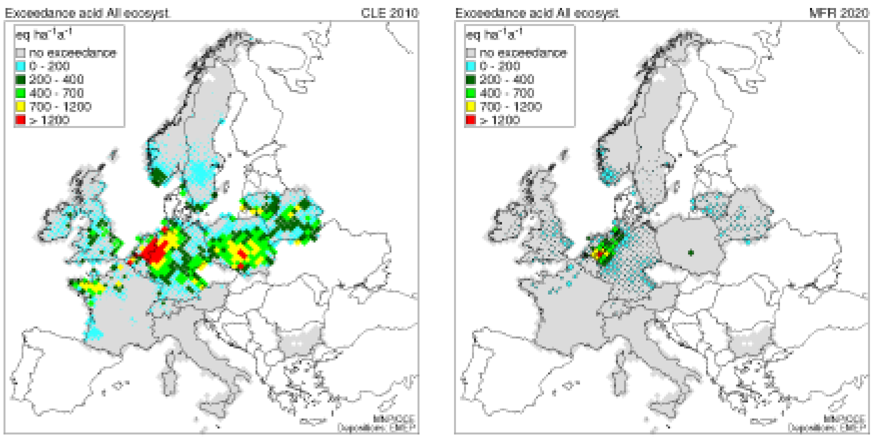

***Figure 2-8.** Exceedance of critical loads of acidity CLE 2010 (left) and MFR 2020 (right).*

2.7 Dynamic modelling results

In addition to the critical loads data described in the previous sections, NFCs were also asked to provide dynamic modelling output, preferably for all sites for which CLs have been submitted. Eleven countries responded and sent more then 550,000 records with dynamic modelling data, covering about 800,000 km^2 (see Table 2-2). NFCs were asked to submit dynamic modelling output for seven variables ([Al], [Bc], pH, ANC, bsat, CNrat, [N]) at nine points in time (1980, 1990, 2000, 2010, 2020, 2030, 2040, 2050, 2100). For the years after 2010, model output was asked for up to 27 N- and S-deposition pairs spread around the Current LEgislation (CLE) and Maximum Feasible Reduction (MFR) scenarios (see Appendix B for details). The choice of output variables reflects those used in (most) chemical criteria for CL calculations and the deposition scenarios were chosen to allow interpolation for any given pair of N- and S-deposition not too far off from the currently discussed CLE and MFR scenarios, thus allowing to estimate model output for any as yet unspecified scenario without having to re-run the dynamic models.

The large number of sites does not allow the presentation of results for individual sites. Thus percentiles are chosen to present the temporal development of chemical parameters, and in the following we are focussing on results for the CLE and MFR scenarios. In Figure 2-9 the temporal development of the molar Al:Bc ratio (computed from the submitted [Al] and [Bc] data) are presented. This parameter is chosen as it is the most commonly used chemical criterion for CL calculations for terrestrial ecosystems (see Table 2-3 below). The figure shows that almost everywhere the Al:Bc ratio is declining, obviously stronger for the MFR than the CLE scenario; only in Switzerland does the 95th percentile (i.e. the most sensitive sites) show a slight increase under the MFR scenario. It can also be seen that after 2010 most of the sites (with the exception of the Netherlands) have an Al:Bc ratio smaller than one, a widely used value for this criterion in CL calculations. One has to keep in mind, however, that this positive development of the chemical parameter says nothing on the timing of *biological* recovery (see Hettelingh et al., 2007).

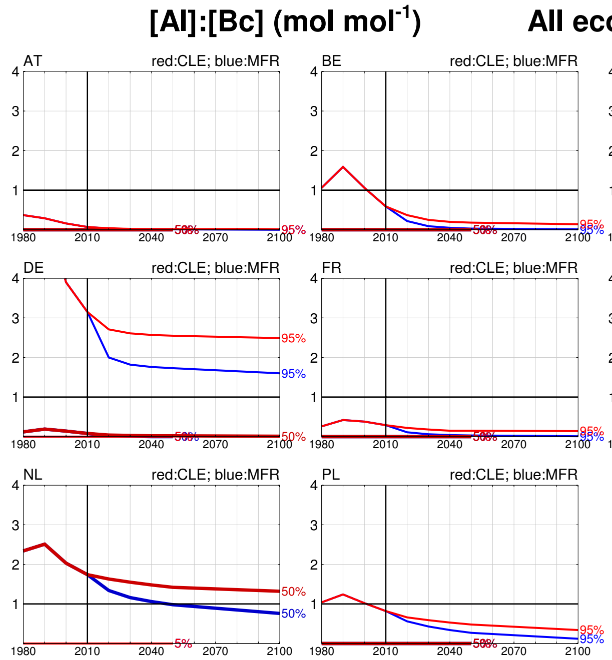

Figure 2-9. *Temporal development of the 5th, 50th and 95th percentile of the molar Al:Bc ratio for all ecosystems in eight countries for two scenarios: CLE (red) and MFR (blue).*

Four countries have carried out dynamic modelling for surface water ecosystems, using the MAGIC model. While three of them (Canada, Norway and Sweden) have *only* modelled surface waters (thus they are omitted in Figure 2-9), the United Kingdom has modelled 310 surface water sites (out of about 240,000 sites modelled in total). As can be seen, the future ANC, which is linked to fish status, stays constant or improves slightly over time for both scenarios. Note that for Canada a national equivalent to the European CLE and MFR scenarios has been used.

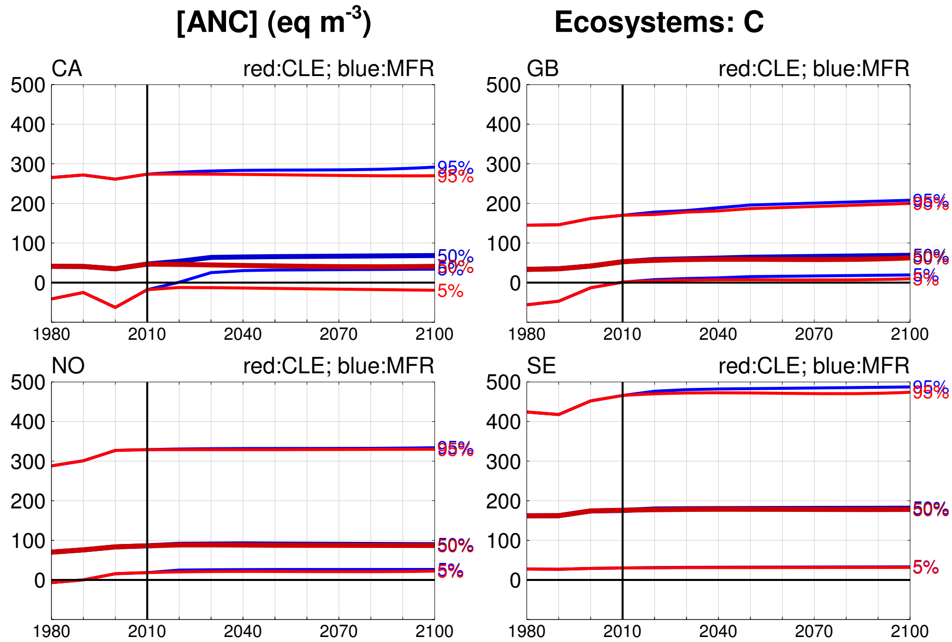

Figure 2-10. *Temporal development of the 5th, 50th and 95th percentile of ANC in surface waters (EUNIS-code C) in four countries for two scenarios: CLE (red) and MFR (blue).*

The emphasis of this Report is on critical loads and dynamic modelling of nitrogen. Two N parameters have been asked as dynamic modelling output: the C:N ratio, varying slowly over time, and the concentration of total N in the soil solution or surface water, a parameter that responds rather rapidly to changes in N deposition. Percentile traces of these variables are displayed in Figures 2-11 and 2-12. As can be seen, C:N ratios change slowly, and they decline over time (or stay constant). This is in line with the way they are modelled, e.g., in the VSD model: excess N input decreases the C:N ratio. Consequently the decrease is steeper for the CLE than the MFR scenario. However, the differences tend to be small for most sites, which can be explained by the (very) large size of the N pool compared to the annual (excess) N flux. In contrast, the N concentration (Figure 2-12) responds relatively fast to changes in the input: As soon as deposition levels off (in 2020), [N] becomes rather flat, i.e. it quickly (within years) assumes a steady-state. The slow increase [N], mostly in sensitive sites (95th percentile), is the consequence of larger leaching due to reduced N immobilisation for sites with increasingly lower C:N ratio.

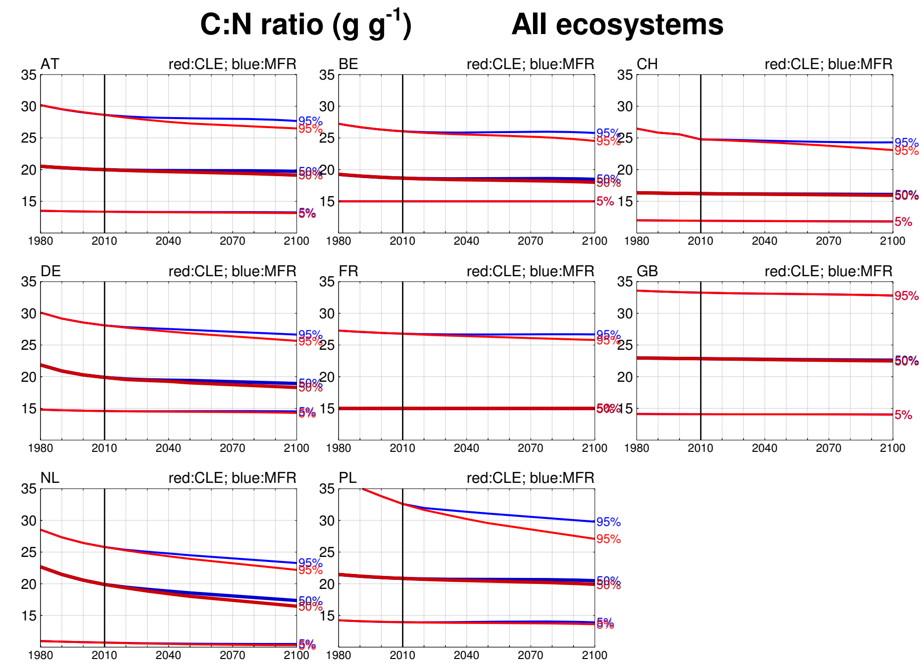

Figure 2-11. *Temporal development of the 5th, 50th and 95th percentile of the C:N ratio for all ecosystems in eight countries for two scenarios: CLE (red) and MFR (blue).*

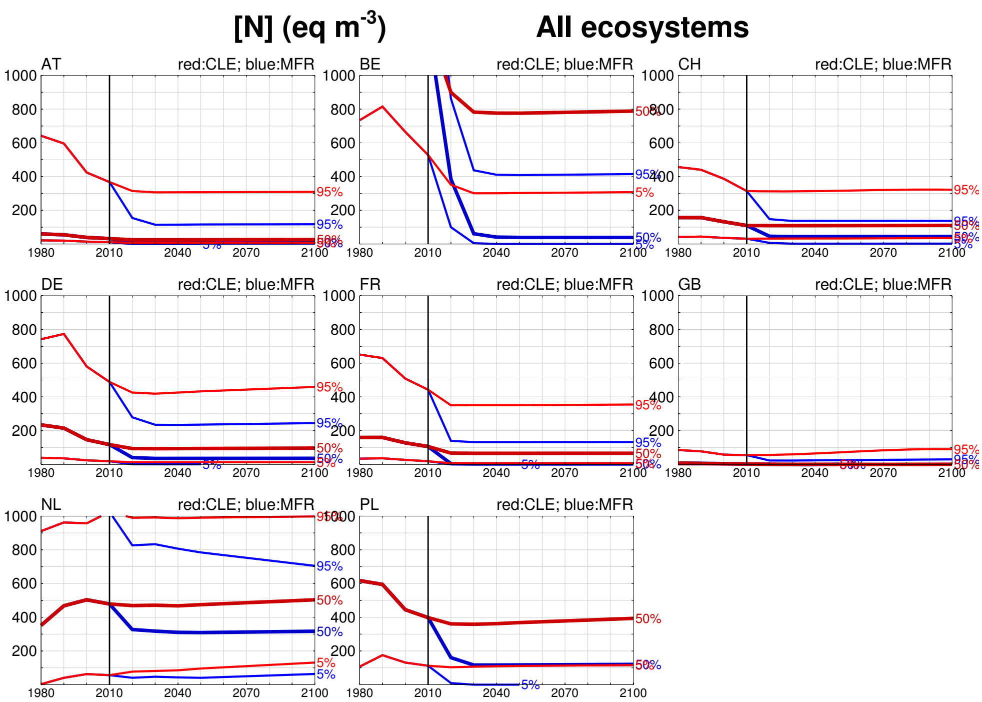

Figure 2-12. *Temporal development of the 5th, 50th and 95th percentile of the total N concentration in solution for all ecosystems in eight countries for two scenarios: CLE (red) and MFR (blue).*

In integrated assessment one is mostly interested in the ecosystem area exceeded, both its extent and by which amount. However, (non-)exceedance of a critical load does not necessarily imply the (non-) violation of the chemical criterion which links the critical load to 'harmful effects'. Dynamic models allow determining when a chosen value of a pre-specified variable is obtained. As an example, Figure 2-13 shows the temporal development of the ecosystem area (in % of country total) on which the total N concentration is below the limits of 0.3 and 3 mgN L^{-1} , respectively, for the CLE (red) and MFR (blue) scenarios. These limits span the range of critical limits for computing critical loads of nutrient nitrogen. The figure shows that historically (i.e. before 2010) the area exceeding the limit of 3 mgN L^{-1} ranges from almost 0% in the United Kingdom to (almost) 100% in Belgium. After 2010 a new plateau is reached after a few decades. In most cases the difference between the two scenarios has a greater influence than the difference between the critical values, although these differ by an order of magnitude. Except in the Netherlands, the future scenarios lead to a (substantial) improvement of the ecosystem status, but even the MFR scenario is only in a few cases sufficient to remove the threat to ecosystems from excess N deposition.

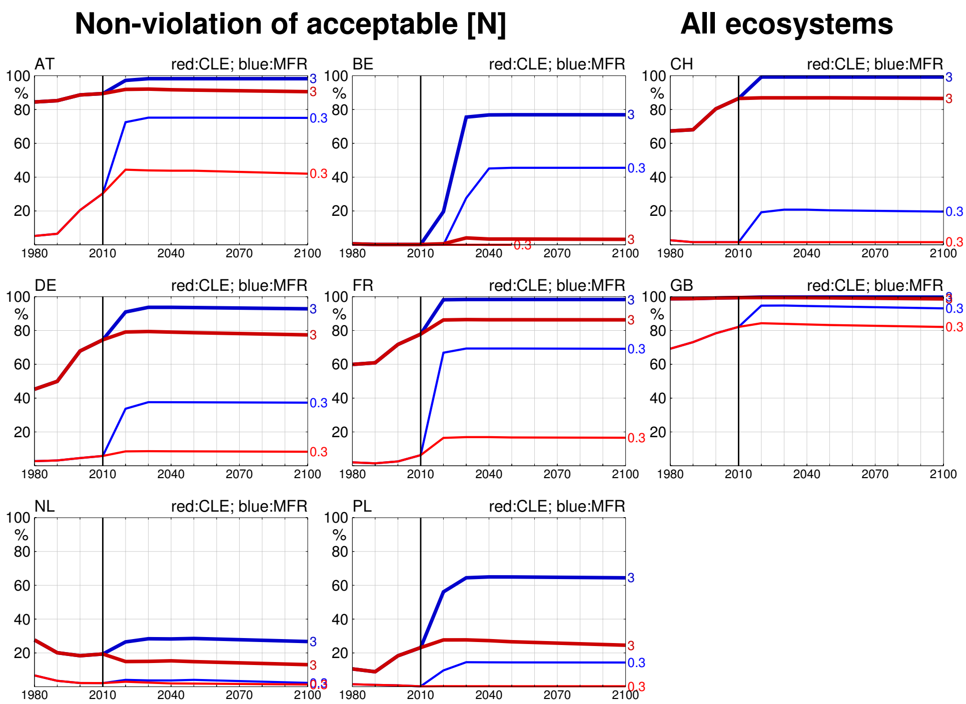

Figure 2-13. *Temporal development of the ecosystem area (in % of total) on which the total N concentration is below the limits of 0.3 and 3 mgN L^{-1}, resp., for the CLE (red) and MFR (blue) scenarios.*

Another way of looking at the temporal development of a dynamic modelling variable is to correlate them for two different points in time. In Figure 2-14 four such correlations are combined into a so-called 'windmill plot' for the soil/lake pH for all ecosystems in every country that submitted data using the CLE scenario. Such a windmill-plot allows a quick assessment of groups of sites, but also reveals outliers and unexpected behaviour. E.g. it is not surprising that the dots lie mostly below the 1:1-line, i.e. the pH increases for most sites between 1990 and 2010 (first quadrant), etc. More questionable is, e.g., the subsequent decrease in pH between 2010 and 2030 in the wetlands (class D) in the Netherlands, etc. The fourth (top-left) quadrant shows the correlations over the longest time, in this case between 1990 and 2050.

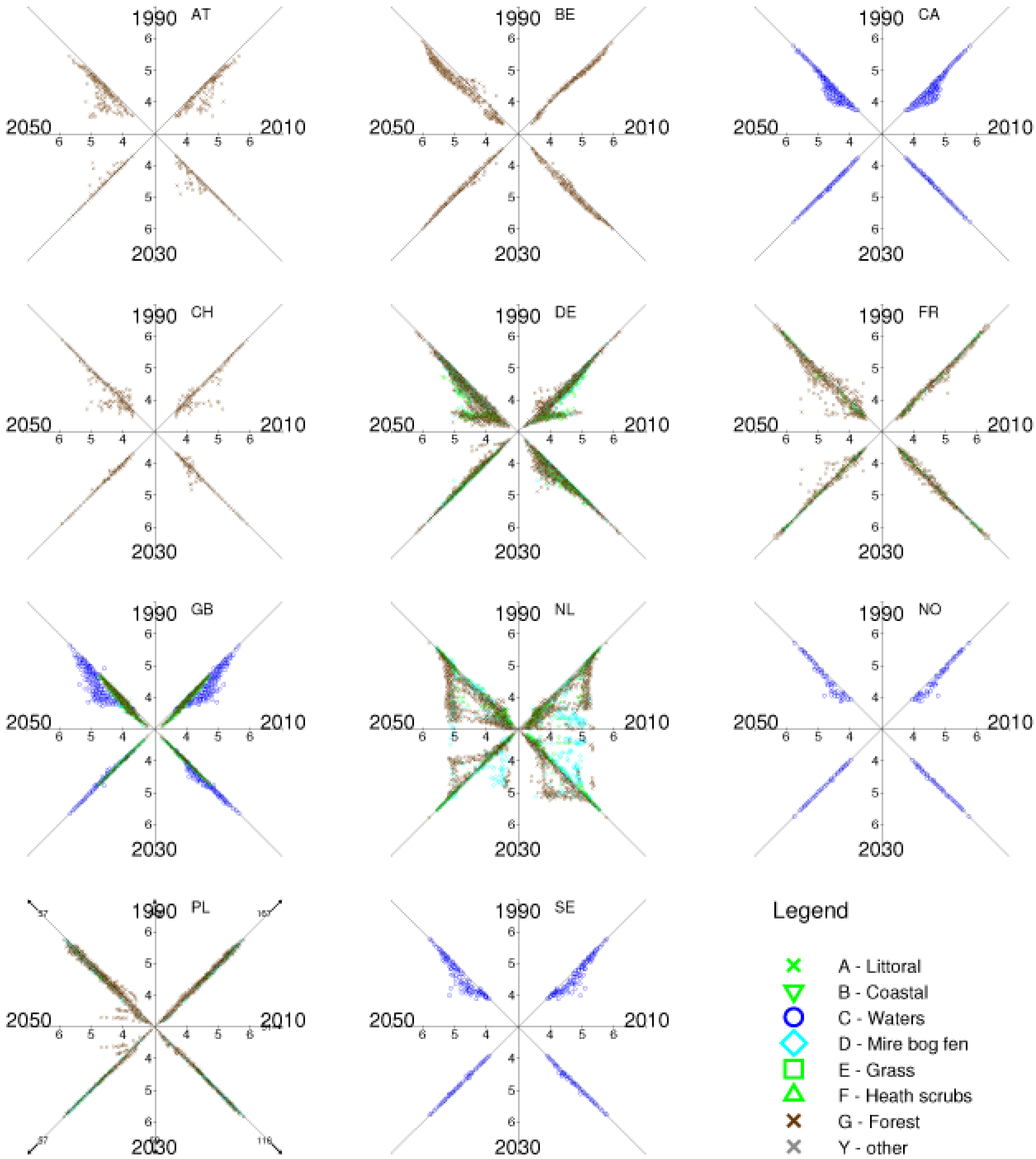

Figure 2-14. *Four year-to-year correlations (windmill plots) of the soil/lake pH from dynamic modelling of all ecosystems (ca. 550,000) and the CLE scenario, distinguished by their EUNIS class.*

The dynamic modelling output presented here has been asked for a number of pre-specified scenarios (see Appendix B for details). These scenarios were chosen in such a way to allow interpolation for any 'reasonable' new scenario of N- and S-deposition and thus relatively swift scenario analyses without having to re-run the dynamic models themselves. Examples demonstrating the quality of such interpolations are presented in chapter 3 using the European background database.

In addition to straight-forward scenario runs, dynamic models can also be used to compute target loads, i.e. future depositions that ensure that a certain chemical criterion is met in a given year (the target year), and delay times, i.e. the time it takes to meet a chemical criterion for a given deposition pattern. This type of model output has been provided by NFCs at earlier calls for data (see, e g., Posch et al., 2005). However, target load calculations are not easy – the dynamic model has to be run iteratively, which is time-consuming and does not always yield unique results. As an alternative, the submitted simulations for the set of scenarios can also be used to estimate target loads and delay times by way of interpolation. This is somewhat more involved – and less precise – than interpolating scenarios per se, but it allows computations for any target year in a consistent manner without having to run a dynamic model repeatedly. Again, examples are presented in chapter 3. A prerequisite is that for every site one knows the critical limit and (preferable) also the critical load. Although some further investigations and testing are required, this offers a versatile tool for assessing temporal aspect of alternative emission (reduction) scenarios.

2.8 Input variables for critical loads and dynamic modelling

Chemical criteria

National Focal Centres use different chemical criteria for determining critical loads (CLs) of acidity for soils (see Table 2-3). In some cases (not mentioned in the table) more complex criteria are used. For surface waters the concentration of ANC is used exclusively. As can be seen in the table, the Al:Bc ratio in soil solution is the most widely used one. In the following we look at the impacts of the different soil criteria on the value of the variables used to define alternative criteria and discuss some implications.

***Table 2-3**. Individual chemical criteria used by the NFC. The number indicates how many ecosystem types are distinguished within each EUNIS-1 class.*

	[Al]:[Bc] or [Bc]:[Al]						[Al]					pH						[ANC]			
Country	A	B	D	E	F	G	B	D	E	F	G	A	B	D	E	F	G	D	E	F	G
AT						4															
BE																	3				
BG						2															
CH						3															
CY												1			1	2	3				
CZ						2					3										
DE		2	5	6	2	15	2	3	4	4	14	2	2	8	15	4	21	5	2	1	5
FI						2															
FR		1	3	2		15							1	2	1		14				
GB																	2	1	4	2	
HU						2															
IE															1	1	2				
IT	1	2		8	5	12															
LT						3															
LV						3															
PL								1	1	1	3										
RU																	2				
SE						3															

We use the (critical) ANC flux reported by a country (variable *nANCcrit* in Table 1 of the data submission) as the starting point. Assuming the validity of the SMB model we compute from every ANC value the variables pH, [Al] and Al:Bc ratio; the respective equations can be found in chapter 5 of the Mapping Manual (UBA 2004). We also take into account that ANC contains a bicarbonate term (if *pCO2fac* > 0 is given; assuming $K_{HCO3} = 10^{-1.7}$ $(mol/m^3)^2/atm$, as in the VSD model) and an organic anion term (if *cOrgacids* > 0; assuming the Oliver dissociation model). The parameters needed to compute pH and [Al] are *Qle*, *lgKAlox* and *expAl* (if *expAl* was missing, we assumed it =3). In addition the net Bc flux (derived from Ca, Mg and K deposition, weathering and uptake fluxes) is required to compute Al:Bc. If exchange constants (*lgKAlBc* and *lgKHBc*) were provided, base saturation was computed as well, assuming Gapon exchange reactions (as realised in the VSD and SAFE models). In Figure 2-15 the results of these calculations for soil ecosystems are presented for those countries for which the necessary parameters were provided by the NFCs. The figure shows the cumulative distribution functions (cdfs) of the ANC concentration (ANC flux divided by runoff), the pH, the Al concentration, the molar Al:Bc ratio and – if computable – the soil base saturation. It should be noted that only sites with data for the first four cdfs were used.

For many countries one can clearly discern (see Figure 2-15) the criteria employed for calculating CLs; e.g., Austria, Switzerland, Latvia use Al:Bc = 1 for all sites, but also Hungary and France used it for many of them. Cyprus, the Czech Republic, Ireland, Poland and Russia have used one or more critical pH values, although in the some of these countries (CZ, PL) it could also be a critical Al concentration. In the other countries it is less clear which chemical criteria have been used to compute CLs. This could be due to (a) different criteria (e.g., the UK uses an Al:Ca ratio), (b) a large variation in the values of the criteria (ecosystem-specific criteria), (c) the use of multiple criteria and/or (d) because a different CL model has been used.

Considering that for surface waters the critical ANC used is zero or a positive value, it is remarkable in how many countries (very) low ANC values are obtained corresponding to the chosen chemical criterion. This lends credibility to the notion that surface waters are in general more sensitive than soils. Presumably these sites experience considerable buffering at lower soil depths before entering stream water, as it is generally accepted that ANC is conservative between soil solution and surface water (Reuss and Johnson, 1986). In fact, it is quite astounding that, at critical load, the ANC in Bulgaria and Hungary is less than –2000 μeq L^{-1} (= meq m^{-3}) for more than half of the area, and equally surprising is the fact that in some countries pH values below 3.5 are obtained at critical load (and thus supposed to pose no risk to the ecosystem). Similarly for many countries high Al concentrations are permitted (greater than 2000 μeq L^{-1}); concomitant high Bc concentrations ensure that Al:Bc ≤ 1. However such high Al concentrations may lead to deleterious impacts on other ecosystem components. It is also quite interesting how frequently the steady-state base saturation is very low (< 3% say) for all or many of the sites in most countries.

Looking at Figure 2-15, it seems that the enforcement of a criterion such as the Al:Bc ratio can lead to an unnecessary stringency: For some sites Al:Bc = 1 is attained although the corresponding Al concentrations is close to zero, because it is a base cation poor site and the ratio is obtained by dividing two very small numbers. As a consequence one could consider an auxiliary criterion, e.g. a lower limit for the Al concentration could be specified below which the Al:Bc criterion does not apply (since there is hardly any Al!).

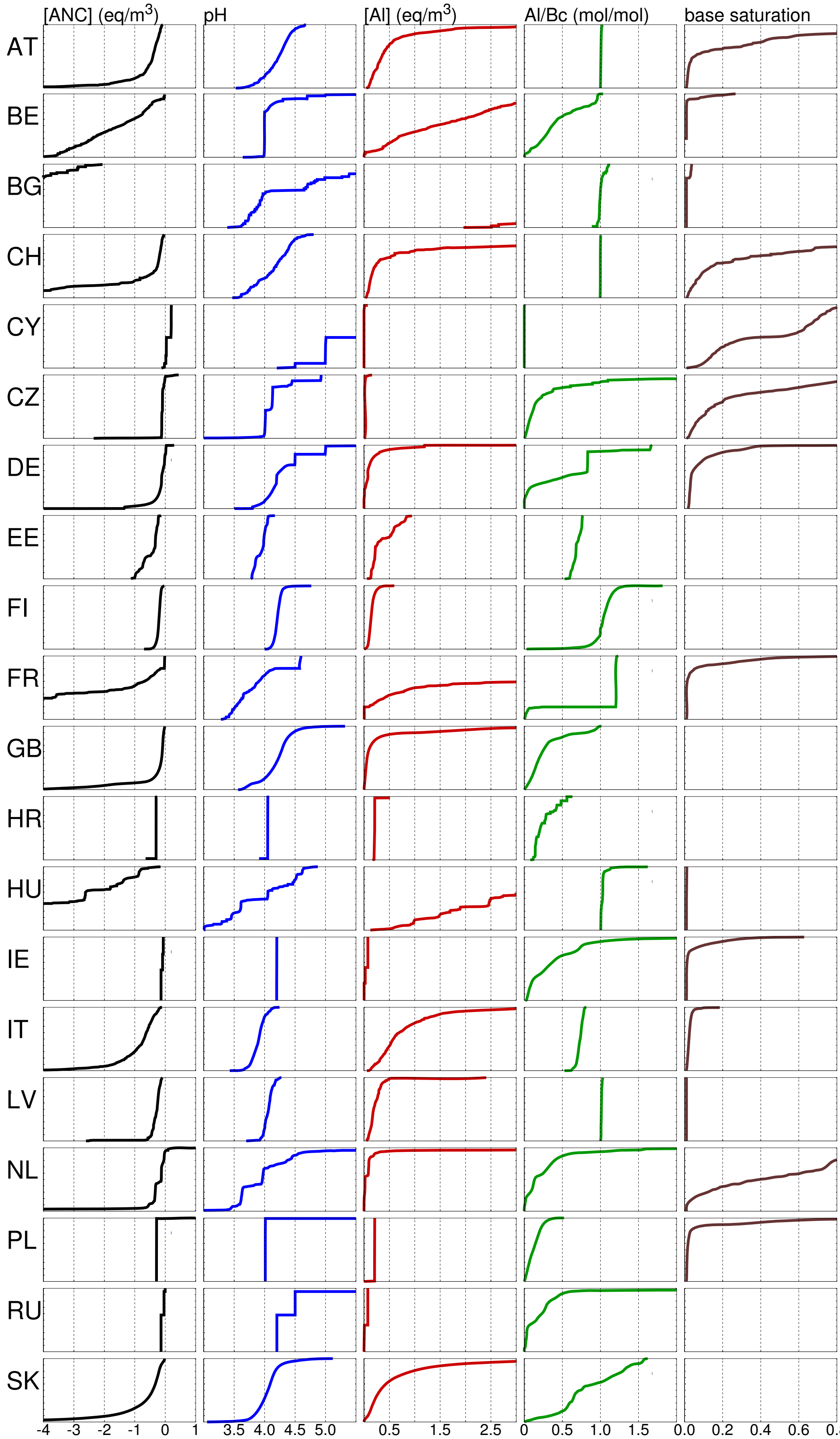

Figure 2-15. *Cumulative distributions of variables used as chemical criteria computed from the given ANC flux. The Oliver model was assumed for organic ion dissociation and the Gapon model for cation exchange. Base saturation is not shown if exchange constants were not available.*

We illustrate this with the critical loads computed from the data in the European background data base (EU-DB; see chapter 4 in Posch et al., 2004). Using Al:Bc = 1 the values of the other variables are shown in the top row of Figure 2-16 and the cdf of *CLmaxS* is shown in blue in Figure 2-17. Relaxing the condition Al:Bc=1 for sites with Al concentrations below 0.1 eq m^{-3} by setting $[Al]_{crit}$ = 0.1 eq m^{-3} results in the cdfs in the centre row of Figure 2-16. Obviously the Al:Bc ratio goes up for these sites, but the reason is not a high Al concentration — that equals 0.1 eq m^{-3} **!** — but a low base cation concentration. As a consequence, the high pH values disappear, whereas the other cdfs do not show much change. The corresponding cdf of *CLmaxS* is displayed in the left panel of Figure 2-17; a comparison with the original cdf shows that the very low critical loads disappear. This should not be construed as 'a trick' to get rid of very low critical loads, but rather an additional limit on sites that have an Al:Bc ratio of one not because of high Al concentrations but because of little base cations in soil solution. Low base cations are largely a site characteristic and are not directly influenced by S and N emission changes.

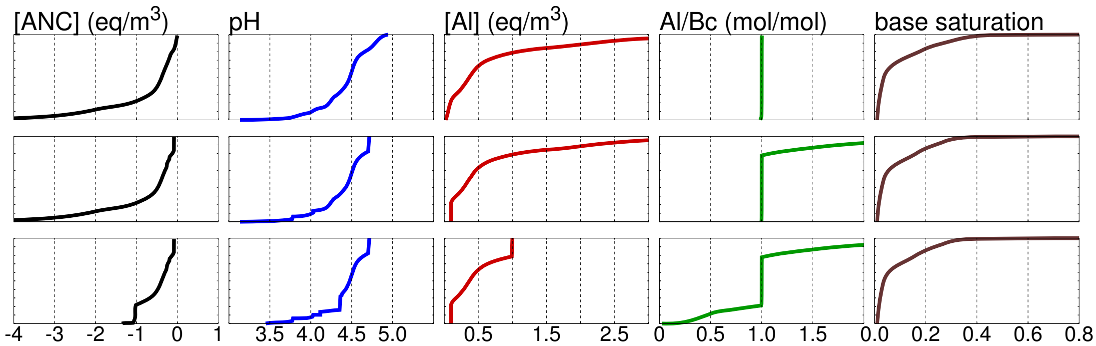

Figure 2-16. *Cumulative distributions of the variables in Figure 2-15 computed from the European background data base using Al:Bc = 1 (top row), Al:Bc = 1 only if [Al] > 0.1 eq* m^{-3} *(centre) and with the additional condition that [Al] < 1 eq* m^{-3} *(bottom).*

In addition to correcting sites at which Al:Bc = 1 is only due to their base-poorness (and not their Al abundance), one could think of correcting sites at which [Al] is very high despite the fact that Al:Bc = 1, e.g., by limiting the Al concentration to a large value (well above any suggested critical value, otherwise this would be tantamount to introducing an Al criterion). As an example, we show the consequences of limiting [Al] to 1 eq m^{-3} (= 1000 μeq L^{-3}) for the chemical variables and *CLmaxS* of the EU-DB in Figures 2.16 and 2.17, respectively. While the first measure was a relaxation, this measure is an additional constraint and thus the very low pH and ANC values disappear. In addition, the critical loads become smaller, albeit almost exclusively in the higher range, since these sites are rich in base cations (see left panel of Figure 2-17).

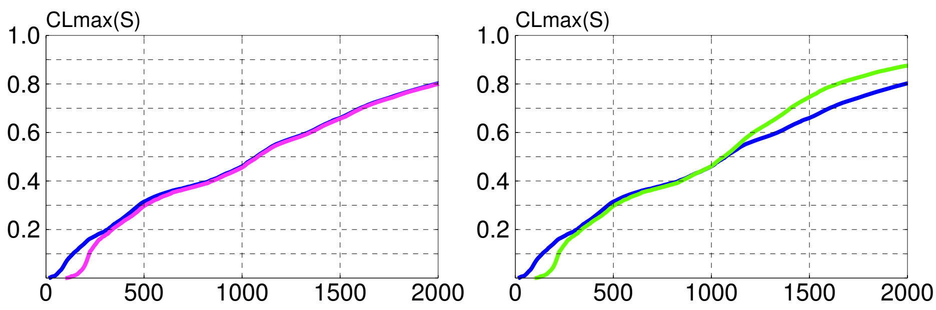

Figure 2-17. *Cumulative distributions of CLmaxS computed from the European background data base using Al:Bc=1 (blue), Al:Bc = 1 only if [Al] > 0.1 eq* m^{-3} *(magenta, left) and with the additional condition that [Al] < 1 eq* m^{-3} *(green, right).*

Other constraints could be specified to exclude undesirable cases, e.g., a lower limit (e.g. 3%) on the base saturation, although this requires the additional information on exchange constants. A combined set of (not too stringent) limits around the chemical criterion would ensure that apparently extreme chemical conditions do not occur at critical load.

Obviously, the models/assumptions used in the computations presented here do not hold for all NFCs. However, other models will hardly produce wildly differing results, and it is hoped that the comparisons presented here will stimulate a re-visit of the data bases and assumptions employed to date.

Acceptable nitrogen concentration

In the instructions for the call for data, updated values for the acceptable nitrogen concentrations (*cNacc*) were suggested, after De Vries et al. (2007). In the call *cNacc* has replaced the earlier variable 'acceptable nitrogen leaching' (*Nleacc*). Not all NFCs have submitted data for *cNacc*; but whenever possible values have been derived by the CCE from earlier submitted *Nleacc* and the leaching flux *Qle*. From Figure 2-18, which shows the distributions of *cNacc* for all countries for which data were available, it is obvious that most NFCs use methods different from the one suggested in the Mapping Manual. The differences in selection of method and/or values for *cNacc* (can) lead to peculiar changes in *CLnutN* across national borders.

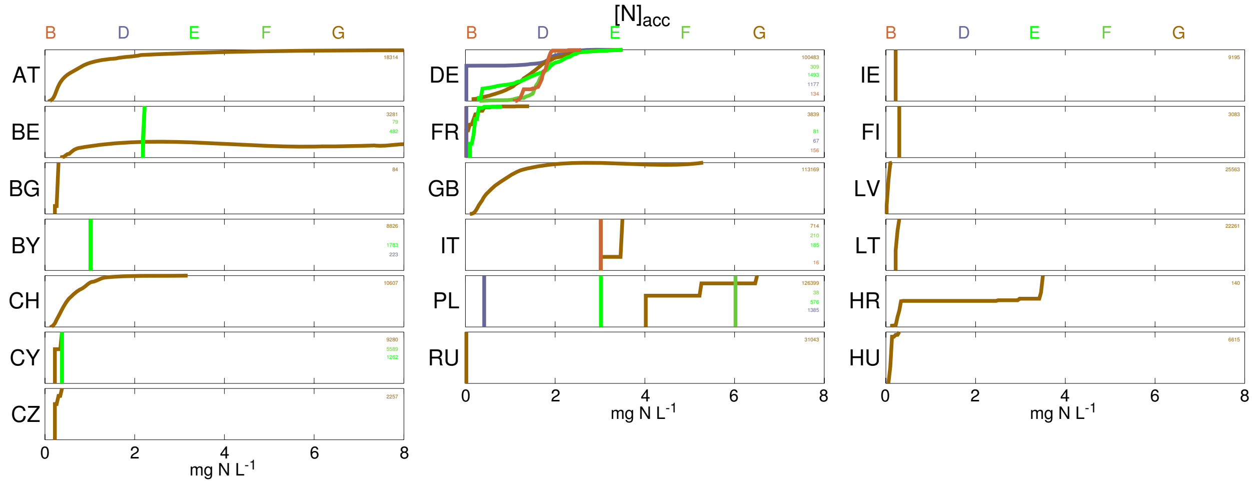

Figure 2-18. *Distribution of the acceptable nitrogen concentration submitted, or calculated from submitted acceptable leaching nitrogen flux and Qle, for the most often considered ecosystem types.*

The simplified nitrogen mass balance, as described in the Mapping Manual, can be applied to calculate a fictive nitrogen concentration at empirical critical load:

$$[N]_{emp} = (\,(1 - f_{de}) \cdot CL_{emp}(N) - N_i - N_u) \,/\, Q_{le}$$

The CDF of these fictive concentrations at sites for which both empirical critical loads and input parameters (f_{de}, N_i, N_u, Q_{le}) for modelled critical loads have been submitted are plotted in Figure 2-19.

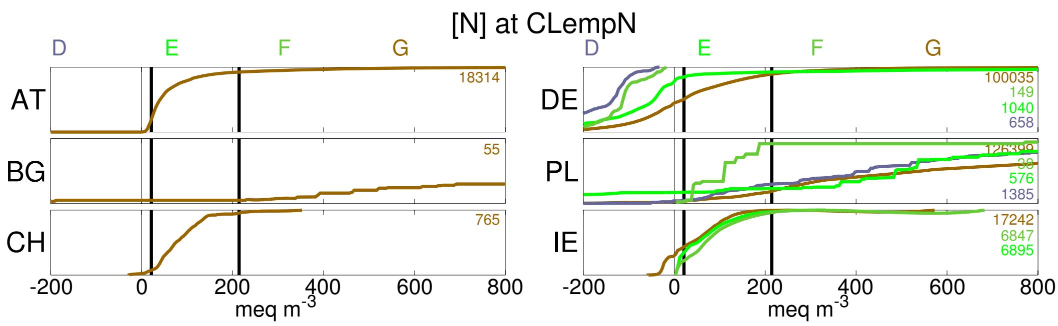

Figure 2-19. *Fictive nitrogen concentrations, based on empirical critical loads and SMB input parameters.*

Vertical lines of 0.3 mg N L^{-1} and 3 mg N L^{-1} are also shown to indicate typical values for *cNacc* from the Mapping Manual. Negative values for the concentration indicate that the totals of sinks of nitrogen (denitrification, immobilization and uptake) are larger than the empirical critical load.

Denitrification

Most NFCs using the SMB model assume denitrification as a fraction of the net input (=deposition minus immobilization minus uptake) of nitrogen. The fraction is most often made dependent on the soil moisture. Figure 2-20 shows that the denitrification fraction ranges from (almost) zero to 0.9, e.g. in the Netherlands. Some countries, like the United Kingdom, assume a fixed amount of N to be denitrified. Given the importance of this sink for nitrogen it would improve the critical loads and dynamic modelling results if this process would be better understood.

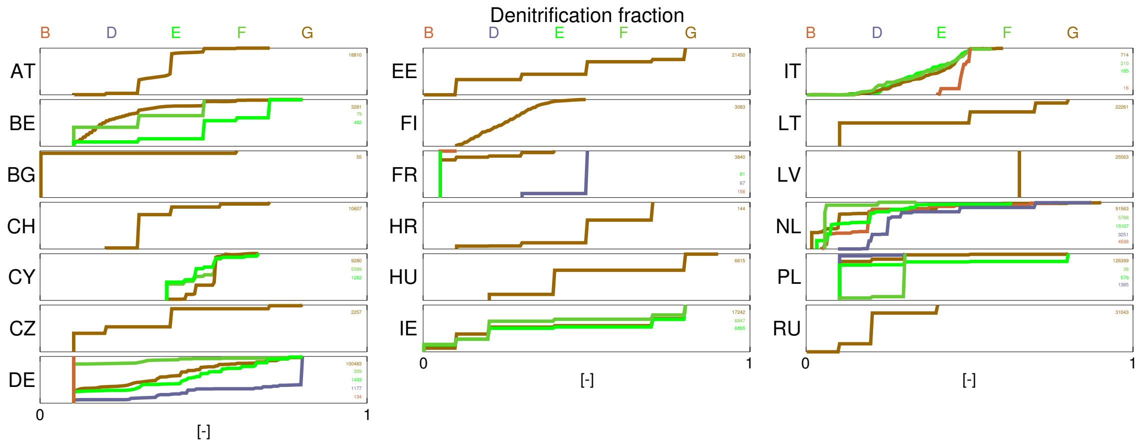

Figure 2-20*. Distributions of the denitrification fraction (fde).*

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3. Critical loads and dynamic modelling of nitrogen

Maximilian Posch, Jean-Paul Hettelingh, Jaap Slootweg

3.1 Introduction

Since the exceedances of critical loads of acidity have strongly declined over the last 20 years, mostly due to the substantial reductions in sulphur emissions, the emphasis has shifted to nitrogen, especially in its role as a eutrophying agent. Therefore, we look in this chapter at critical loads and dynamic modelling of nutrient N, investigate their sensitivity to the choice of critical limit and illustrate the possibilities and limitations of their use in integrated assessment modelling.

All calculations in this chapter will be done with the so-called European background database (EU-DB; see Posch and Reinds, 2005) which is maintained by the CCE to fill in for countries that have never submitted national data. Since 2005 the EU-DB has been substantially revised, making use of the recently finalised harmonised European land cover map (see chapters 5 and 6), and a comprehensive description can be found in Reinds et al. (2007).

3.2 Nutrient nitrogen critical loads and their exceedance

The European background data base (EU-DB) has been used to calculate critical loads (CLs) of nutrient nitrogen, *CLnutN*, and their exceedances (see Annex 3-A to this Chapter for the model formulation). Since the examples shown in this chapter are illustrative only, we restrict the calculations to ecosystems with an area >1 km^2, resulting in 653,962 sites with a total area of 3.74 million km^2. For forests (EUNIS code G) the long-term net growth uptake was obtained from data in EU-DB, for other vegetation classes (EUNIS codes D–F) the net uptake was set to zero; $N_{i,acc}$ was set to 1 kg N ha^{-1}a^{-1} = 71.43 eq ha^{-1}a^{-1} throughout; f_{de} was derived from the drainage status of the soil (see UBA, 2004); and runoff was modelled from 30-year climatic data (Mitchell et al., 2004). The sensitivity of the CLs (and dynamic modelling results) to the choice of the chemical criterion, i.e. the acceptable N leaching which avoids 'harmful effects', is studied by presenting results for two values, which are characteristic of the current set of criteria (De Vries et al., 2007): $[N]_{acc}$=0.3 and $[N]_{acc}$=3 mg N L^{-1}. For both criteria the 5th percentiles of the computed critical loads in the EMEP50 grid cells covering Europe are shown in Figure 3-1.

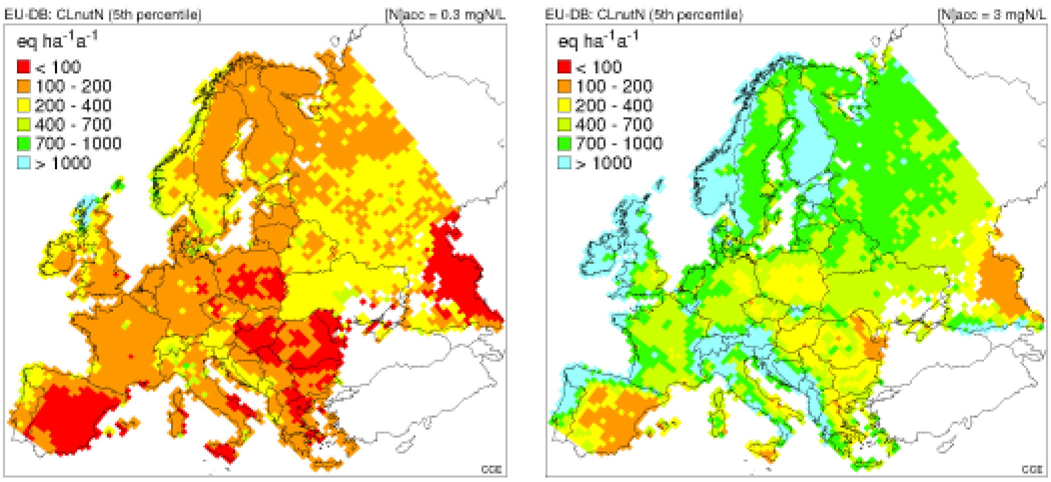

Figure 3-1. *5th percentile of the critical loads of nutrient nitrogen, CLnutN, on the EMEP50 grid computed with the European background data base (EU-DB) and two different acceptable nitrogen concentrations: 0.3 mg N L^{-1} (left) and 3 mg N L^{-1} (right).*

Obviously, the magnitude of the critical loads is strongly influenced by the choice of criterion. The influence is the stronger the greater the runoff Q and or f_{de} are, and the relative difference is greatest if N_u+N_i is small (see eq.A7 in Annex 3-A). The overall distribution of nutrient CLs in Europe for the two criteria is shown in Figure 3-2; it shows that, e.g., the median is about 350 eq ha^{-1}a^{-1} for the low and about 1000 for the high criterion.

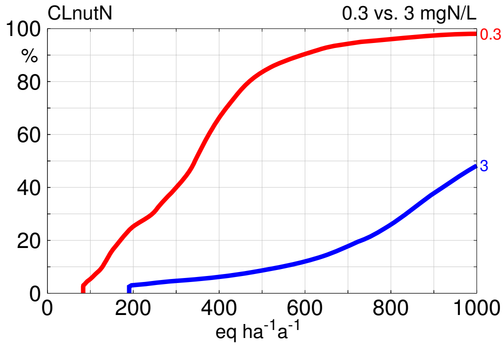

Figure 3-2. *Cumulative distribution functions (cdfs) of the European nutrient N critical loads (653,962 sites) computed with EU-DB and two different acceptable nitrogen concentrations: 0.3 mg N L^{-1} (red cdf) and 3 mg N L^{-1} (blue cdf).*

The regional distribution of critical loads, i.e. the sensitivity of ecosystems, is needed to determine whether the deposition of N needs (further) reductions so that 'harmful effects' are avoided. The quantity expressing that the deposition is, on average, too high, is the so-called 'average accumulated exceedance' (AAE; see Posch et al. (2001) and UBA (2004) for definitions and technical details). In Figure 3-3 the exceedance (AAE) is shown for the year 2020 and two deposition scenarios, the Current LEgislation (CLE) and the Maximum Feasible Reductions (MFR) scenario and for the two chemical criteria (0.3 and 3 mg N L^{-1}). As is to be expected, exceedances are higher for the lower criterion, but even for the high criterion exceedance is fairly widespread in Europe and only for the MFR scenario it becomes quite low.

Figure 3-3 gives a spatial overview of the extent and, to a lesser degree, the magnitude of exceedances, but it does not tell the actual percentage of the ecosystem area exceeded; in addition, such maps provide only snapshots in time. If one does not need the spatial details, temporal traces of the ecosystem area exceeded give a comprehensive overview, and they also allow easy comparison of different deposition scenarios. In Figure 3-4 such temporal trends are shown for the CLE and the MFR scenarios. The figure shows that the ecosystem area exceeded has decreased by less than 10% since 1980, i.e. reductions in N have been modest (when compared to sulphur) and even maximum feasible reductions would not change the picture dramatically. Only with the high criterion applied everywhere would the exceeded area fall to 5% under the MFR scenario. Under the CLE scenario the exceeded area does not change much after 2010, and thus the patterns shown in Figure 3-3 for the CLE scenario are fairly representative for that period.

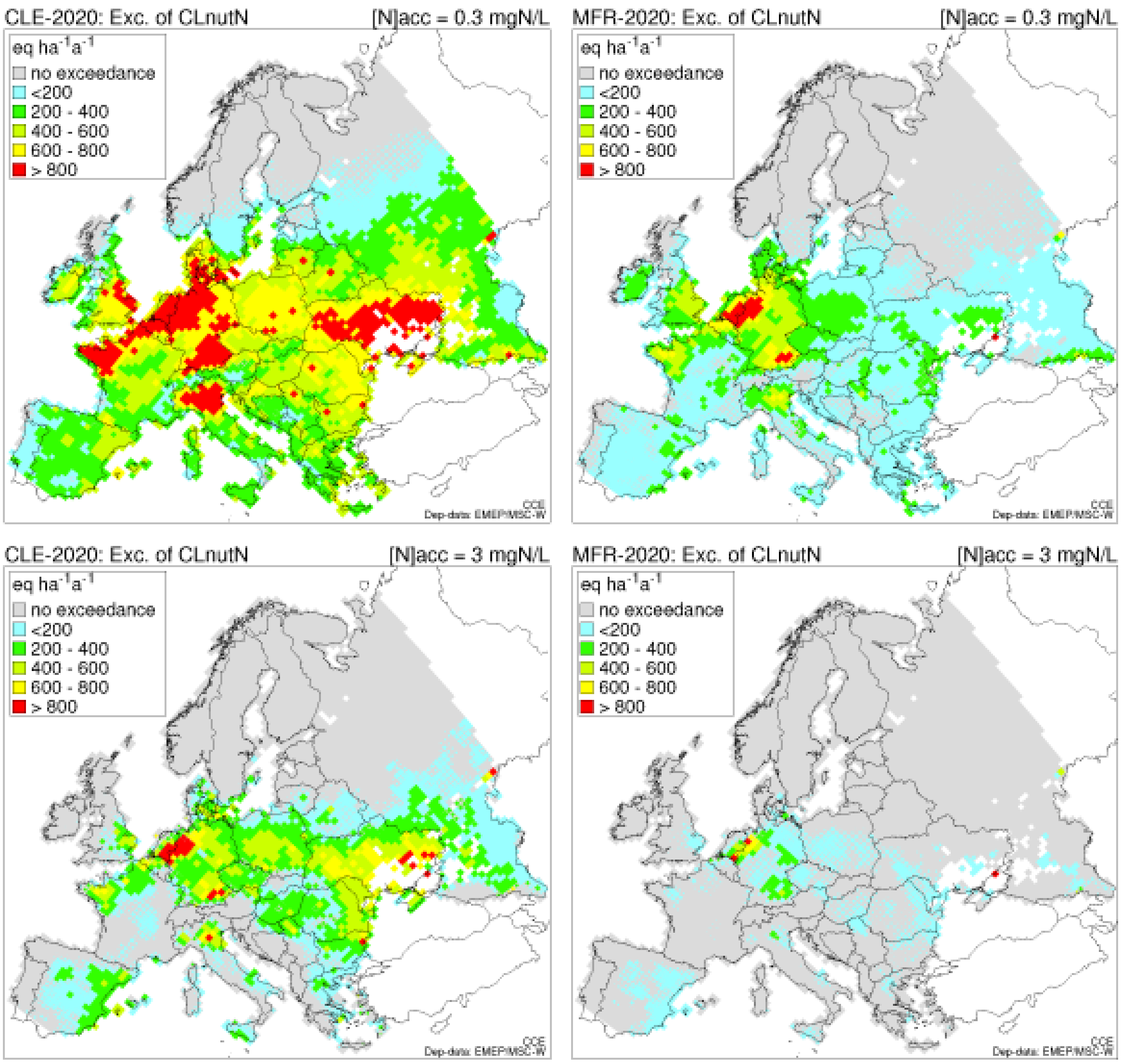

Figure 3-3. *Exceedance (AAE) of CLnutN in 2020 computed with the EU-DB for the CLE (left) and MFR (right) scenarios and two different acceptable nitrogen concentrations: 0.3 mg N L^{-1} (top) and 3 mg N L^{-1} (bottom). Note: The size of the coloured grids is proportional to the percentage of ecosystem area exceeded in the grid.*

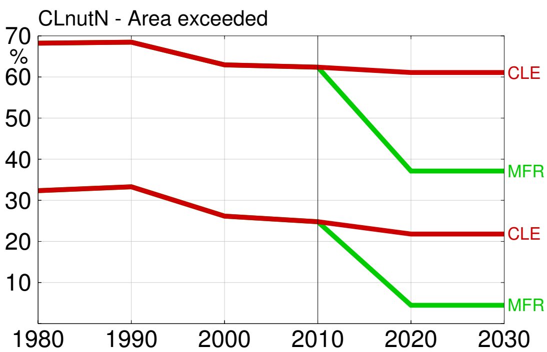

Figure 3-4. *Temporal development of the European ecosystem area exceeded (expressed as percent of total) for CLnutN using EU-DB and the CLE (red) and MFR (green) scenarios. The upper curve(s) are for $[N]_{acc}$ = 0.3 mg N L^{-1} and the lower ones for $[N]_{acc}$ = 3 mg N L^{-1}.*

3.3 Dynamic modelling of nitrogen pools and fluxes

Critical loads are, by definition, steady-state quantities, i.e. their (non-)exceedance does not tell when the (non-)violation of the chosen criterion will happen. In other words, once non-exceedance is achieved by a deposition reduction it may take many years before the chemical criterion is no longer violated, i.e. before the risk for 'harmful effects' is eliminated. The temporal aspects of recovery (and damage in case of a continuing exceedance) can only be investigated with the aid of dynamic models. Here we use the Very Simple Dynamic (VSD) model to investigate the temporal behaviour of soil chemical variables. A complete description of the nitrogen processes in the VSD model is given in Annex 3-A to this chapter.

We used the European background database as described above to run the VSD model to gain insight into the temporal development of N-related quantities. Simulations started in 1880 (assuming equilibrium with inputs) and are carried forward till 2100 for the CLE and MFR scenarios (until 2010 depositions are 'historical', scenarios are linearly phased in until 2020, and after that depositions are kept constant). There are two N-related variables which are of interest: the concentration of nitrate (=total inorganic N) in the soil solution and the C:N ratio in the upper layers of the soil. While the N-concentration is (still) the most widely used parameter for defining a critical chemical limit in CL calculations, the C:N ratio is an indicator for N saturation in soils. In Figure 3-5 the temporal development 1980-2100 of these two variables is displayed for the two scenarios as selected percentile traces. As can be seen, N-concentrations react strongly to changes in depositions, whereas the C:N-ratios decrease only slowly over time and they differ only slightly for the two scenarios.

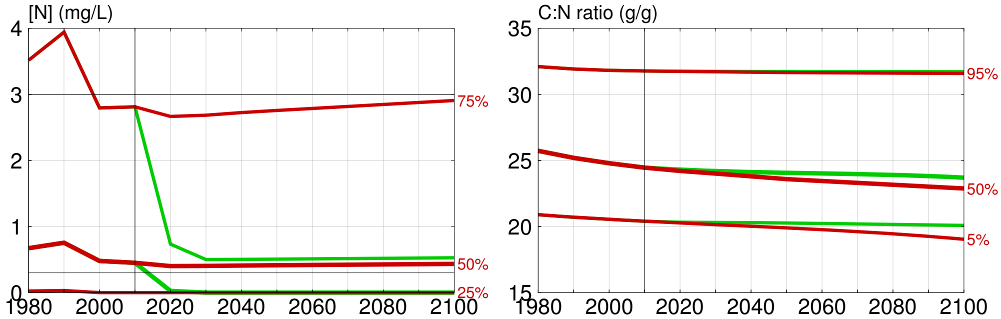

Figure 3-5. *25th, median and 75th percentile traces of the N concentration (left) and the 5th, median and 95th percentile traces of the C:N ratio (right) for the CLE (red) and MFR (green) scenarios.*

The percentile traces in Figure 3-5 give also an indication of the percentage of ecosystems for which a chemical criterion is violated. The two criteria used here (0.3 and 3 mg N L^{-1}) are shown as horizontal black lines, and it can be seen that for the CLE scenario less than 25% of the area is violating the high criterion, but more than 50% the low criterion. The reading of these percentages is not very precise, but in Figure 3-6 we present the temporal development of the area for which the criteria are violated.

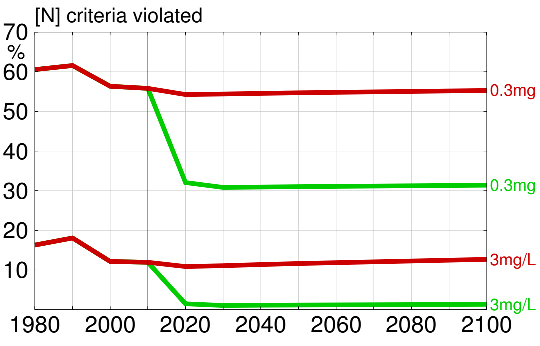

Figure 3-6. *Temporal development of the European ecosystem area (expressed as percent of total area) for which the N concentration violates two criteria ($[N]_{acc}$=0.3 and $[N]_{acc}$=3 mg N L^{-1}) for the CLE (red) and MFR (green) scenarios.*

Comparing Figure 3-6 with Figure 3-4 shows that N concentrations follow the deposition path quite closely. The slow increase in the N-concentration after 2030 is caused by the slow filling-up of the N-pool, resulting in a diminishing N immobilisation and thus more leaching (until the C:N-ratio CN_{min} is reached; see eq.A9 in Annex 3-A).

That the N-concentration is a 'fast' variable can also be seen from the model equations (see Annex 3-A): Assuming a constant input N_{in}, eq.A1 can be solved analytically, yielding for the concentration at time t:

(1) $$[N](t) = [N]_0\, e^{-t/\tau} + \left([N]_{ss} - [N]_0\right)(1 - e^{-t/\tau})$$

where $[N]_{ss}=N_{in}/Q$ is the steady-state concentration and $[N]_0$ is the initial concentration; furthermore the characteristic time τ is given by:

(2) $$\tau = \frac{Q}{\theta \cdot z}$$

The time τ measures the time needed to replace the soil water with net precipitation and is thus mostly in the order of a few years only. Consequently, the N-concentration equilibrates rather quickly with a constant N input. The filling-up of the N pool, on the other hand, is a slow process since the amounts immobilised per year (in the order of grams) is small compared to the pools themselves (in the order of kilograms); and this can bee seen in the small change of the C:N ratio in Figure 3-5 (CN_{seq}=0 was used in all simulations).

There are four possible cases an ecosystem can fall into with respect to CL (non-)exceedance and criterion (non-)violation. They are summarised for nutrient N in Figure 3-7; and this figure should be compared with a similar scheme for acidification (Figure 2-16 in Posch et al., 2005).

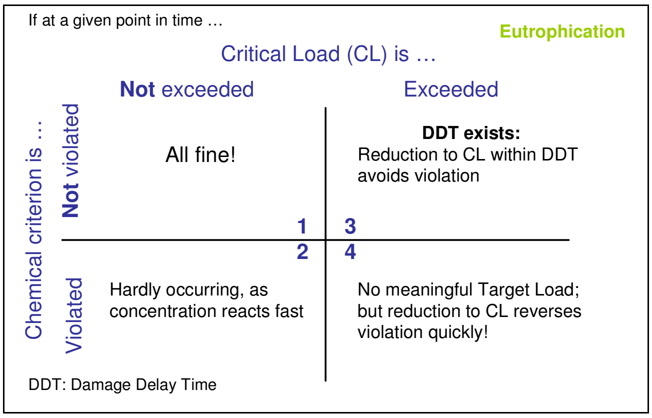

Figure 3-7. *Possible combinations of critical load (non-)exceedance and criterion (non-)violation.*

These four cases are investigated in combination with two different critical limit values for nitrogen concentration, 0.3 and 3 mg N L^{-1}. The critical limit of 0.3 mg N L^{-1} is associated with vegetation changes such as the substitution of lichens by cranberries but also with nutrient imbalances in deciduous forests. This critical limit leads to relatively low critical loads and relatively high exceedances. Conversely, the critical limit of 3 mg N L^{-1} leads to relatively high critical loads and low exceedances. The latter limit is associated with vegetation changes in coniferous forests, grass lands and heathlands, and with impacts on fine root biomass and sensitivity to fungal diseases (de Vries et al., 2007; Table 24). The use of low and high critical limits yields different combinations of European ecosystem areas with exceedances of critical loads and violations of critical limits. Table 3.1 shows the percent ecosystem area in 2020 falling into the four categories listed in Figure 3-7 for simulations with the EU-DB using the CLE and MFR scenarios. As can be seen, the majority of cases (more than about 89%) fall into either category 1 (no exceedance of CLs and no violation of criterion) or 4 (exceedance and violation) for both scenarios. This means that in the case of nutrient N the VSD model is not needed to compute target loads or recovery delay times; with VSD, non-exceedances rapidly lead to non-violation. MFR in combination with a critical limit of 3 mg N l^{-1} yields the highest percentage of safe ecosystem areas (95.5%) and lowest percentage of non-safe areas (1.5%).

Category 2 (no exceedance and criterion violated) is hardly occurring (except in case of steep deposition changes before the implementation year) and recovery times are short since concentrations react fast to deposition changes (see above). This leaves those areas in which the CL is exceeded but the criterion is not (yet) violated (category 3). In our simulations this covers between 2.1 and 9.4 percent of the total ecosystem area, which – in absolute terms – is still a sizeable area.

Table 3-1. *Percent of ecosystem area for the CLE and MFR scenarios in 2020 in the four categories defined in Figure 3-7.*

Category (see Fig.3-7)	CLE scenario $[N]_{acc}$=0.3	=3 mg N L^{-1}	MFR scenario $[N]_{acc}$=0.3	=3 mg N L^{-1}
1	38.9	78.2	62.5	95.5
2	0	0	0.4	0
3	6.8	10.9	5.4	3.0
4	54.3	10.9	31.7	1.5

Table 3-1 gives only a snapshot in time (here 2020); in Figure 3-8 we show the temporal development of the areal share of the four categories defined in Figure 3-7 for the two scenarios (CLE and MFR) and two criteria ($[N]_{acc}$=0.3 and $[N]_{acc}$=3 mg N L^{-1}). As Table 3-1 indicates, there are no (or hardly any) ecosystems in category 2, i.e. ecosystems recover (almost) immediately. The line separating the orange and blue colour gives the percentage of the exceeded area over time (and thus the same information as Figure 3-4).

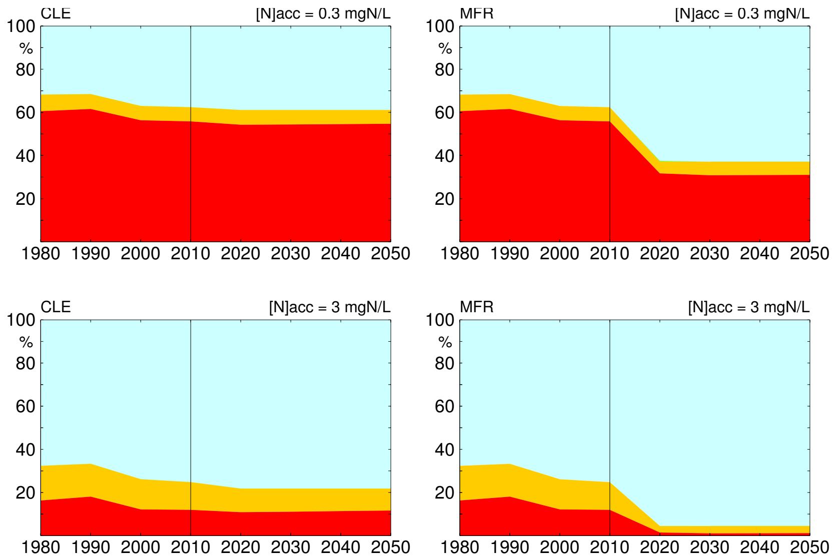

Figure 3-8: *Temporal development of the areal share of the four categories defined in Figure 3-7 for the two scenarios (CLE and MFR) and two criteria ($[N]_{acc}$=0.3 and $[N]_{acc}$=3 mg N L^{-1}). See Table 3-1 for colour codes (and exact values in 2020).*

The time delay between first occurrence of CL exceedance and first violation of the criterion – which exists if we are in a category 3 situation (see Table 3-1) – is called Damage Delay Time (DDT). In Figure 3-9 the cumulative distributions of the DDTs for those cases are shown for the two scenarios and two criteria. By 2100 the critical limit will be violated under CLE by about 15% (at 0.3 mg N L^{-1}) and by about 17% (at 3 mg N L^{-1}) of the areas of which critical loads were exceeded in 2010. Under MFR this percentage is reduce to about 7% and 6%, respectively. The order of the graphs depends on the percentage area in category 3 which varies over deposition scenarios and critical limits (see Table 3-1). The figure shows that DDTs are, in general, (very) long. This is due to the fact that only the slow filling-up of the N pool and consequent decrease in N immobilisation leads eventually to a violation of the criterion.

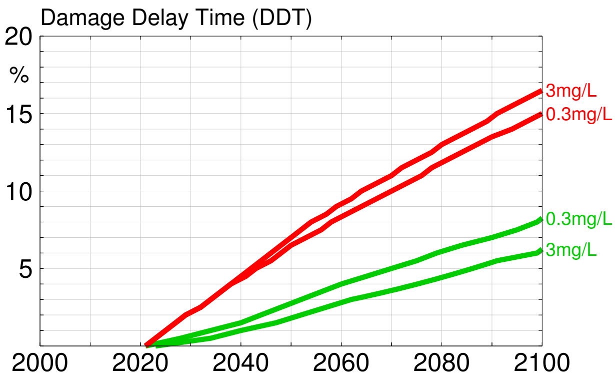

Figure 3-9. *Cumulative distribution of Damage Delay Times (DDTs) for the CLE (red) and MFR (green) scenarios and two criteria ($[N]_{acc}$=0.3 and $[N]_{acc}$=3 mg N L^{-1}). Note that the percentages in this figure are relative to the percentages for category 3 in Table 3-1.*

The spatial distribution of DDTs is illustrated in Figure 3-10 for the two scenarios and two criteria. It shows in which time range the minimum DDT in a grid square lies (if it exists); grid cells in which there is no ecosystem with a DDT are shown in pink if there is exceedance, otherwise they are shaded grey. Figure 3-10 shows that low critical loads (corresponding to low critical limits) result in a large area (pink) where critical loads are exceeded and critical limits already violated in 2020 under CLE (upper left map). At the same time areas with a DDT before 2030 (red shaded) are concentrated in Portugal, Austria and Switzerland. Under MFR (upper right map) the non-safe area is reduced and substituted by areas with a DDT beyond 2100 (grey shaded), while the areas with a DDT before 2030 are scattered over a few grid cells. For the high criterion, if there is exceedance there is a damage delay for the majority of grids. In that case many areas have a DDT before 2030 (red shaded) under CLE (lower left map), while under MFR most of the areas have a DDT beyond 2100. Areas that become non-safe already before 2030 under MFR are mostly located around the border area of the Netherlands and Germany.

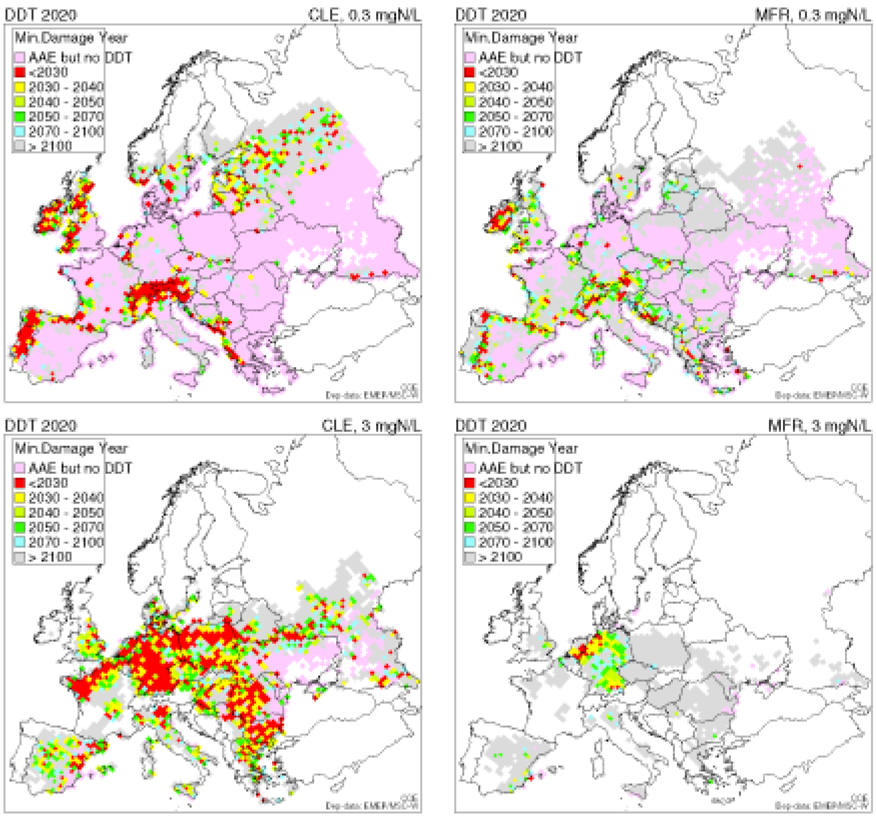

Figure 3-10: *Minimum Damage Delay Time (DDT) after 2020 in every EMEP grid cell. The pink area indicates grid cells with exceedance but no DDT, the white areas where there is no exceedance or no data (see also Figure 3-3).*

3.4 Interpolation of scenarios

NFCs were requested to provide dynamic modelling output for a number of scenarios, i.e. pairs if future N- and S-deposition. These scenarios are chosen such that any reasonable future scenario lies within the rectangle defined in the (N_{dep},S_{dep})-plane by the pre-defined scenarios (see Figure 1 in Appendix B). The European Background Database (EU-DB; see above), for which scenario runs according to the Call for Data as well as random other simulations are available for testing, has been used to check how good such interpolations perform in practice. Figure 3-11 shows examples of such comparisons for the N concentration in soil solution and the Al/Bc-ratio, a derived variable. While for Al:Bc the result is almost perfect, the (very) small interpolated N concentrations tend to be higher than the exact ones. The reason is that the interpolation cannot exactly catch when a concentration becomes zero, since this is inherently a non-linear process. Note that for [N] the S-scenarios do not play any role, the interpolation is actually one-dimensional. Overall, results are very encouraging – also for the other variables not shown here – and suggest that in many cases even less scenarios are sufficient for reasonable interpolations.

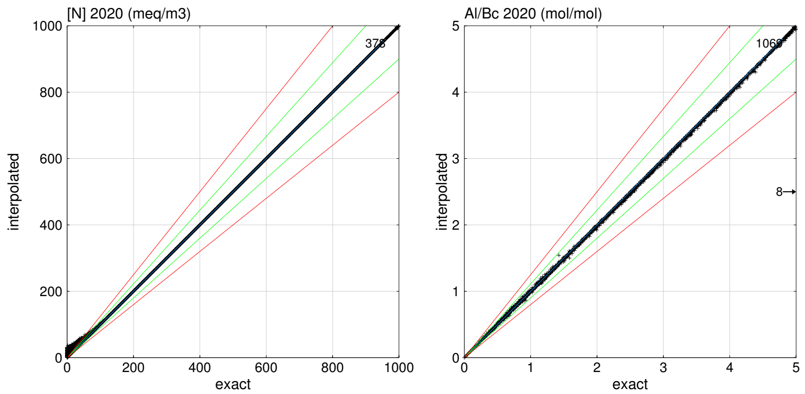

Figure 3-11. *Exact versus interpolated N concentration (left) and Al:Bc ratio (right). The green and red lines show the 10% and 20% deviation, respectively, from the 1-to-1 line.*

The scenarios provided by NFCs can not only be used to interpolate the chemical parameters (or combinations thereof) for any given reasonable future deposition, but also allows to estimate more involved quantities such as target loads and delay times. Obviously, not the full target load function can be reconstructed, but only the parts which lie within the rectangle defined by the scenarios. Thus, also target loads lower than the MFR scenario cannot be computed (only identified that they exist). As an example, Figure 3-12 shows the S-value of target loads entering that rectangle ('TLS', black crosses) and the N-value of those leaving it ('TLN', red crosses). While the TLS-values are reproduced quite well, the TLN-values are, for a certain cluster of sites, mostly underestimated. Nevertheless, given the complex nature of TL calculations and their sensitivity to certain parameters, the approximate determination of target loads from dynamic model simulations looks quite promising.

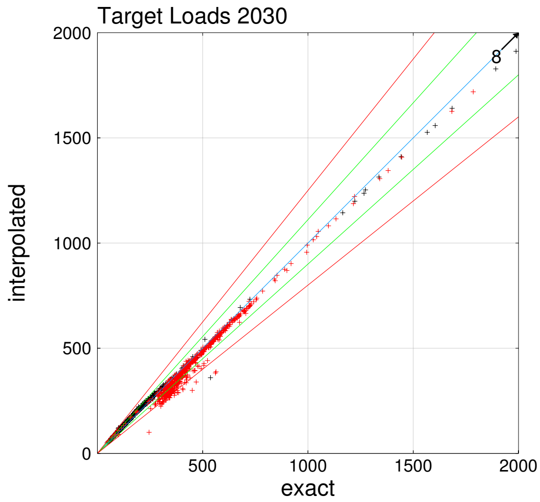

Figure 3-12. *Exact versus interpolated target loads (in eq/ha/a). The black and red crosses show TLs entering ('TLS') and leaving ('TLN'), respectively, the rectangle defined by the deposition scenarios. The green and red lines show the 10% and 20% deviation, respectively, from the blue 1-to-1 line.*

3.5 Concluding remarks

It has to be emphasized that all conclusions above are drawn from simulations with the VSD model. There are several points in which the model could be amended (if deemed necessary). For example, in the current version the N pool can only increase (and the C:N ratio decrease), which limits the possibility of recovery. Also, a (simple) description of the nutrient cycle might be useful to better capture the relationship with biota. In general, results presented here might have to be revised if more sophisticated models, such as described in De Vries et al. (2007), are employed.

As with critical loads, the use of dynamic modelling results has to be seen in the context of integrated assessments. In general, results of dynamic models provide insights in the spatial distribution of target loads, recovery delay times and damage delay times. Theoretically, these distributions could be used as (additional) constraints in optimization exercises of, e.g., the RAINS model. This chapter has illustrated that the use of VSD for the description of eutrophication does not yield (meaningful) recovery delay times nor target loads. The reason is that non-exceedance rapidly results in non-violation of the criterion. This may change when more sophisticated models are used, as planned in the work plan under the Working Group on Effects and the European Consortium for Modelling Air Pollution and Climate Strategies (EC4MACS). Meanwhile, the VSD exercise described here illustrates how the spatial distribution of DDT varies both with scenarios and with critical limits. This can also become relevant information in the future context of robustness analyses as described in chapter 4.

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Annex 3-A: Nitrogen processes in VSD

Here we describe the nitrogen processes as currently implemented in the VSD model. A basic assumption in the VSD model is that there is complete nitrification, i.e. all incoming (deposited) ammonium is converted into nitrate, i.e. it makes sense to use total N fluxes, and the only ion seen in the soil solution is nitrate, i.e. $[N]=[NO_3]$.

As for all other ions considered in the VSD model, the mass balance equation for N is given by:

(A1) $$\frac{d}{dt}N_{tot} = N_{in} - Q\cdot[N]$$

where N_{tot} (eq m^{-2}) is the total amount of N in the soil (per unit area), N_{in} (eq m^{-2}a^{-1}) is the net input flux into the soil, $[N]=[NO_3]$ is the concentration in soil solution (eq m^{-3}) and Q is the water leaving the root zone (m a^{-1}). N interactions between soil and soil solution are not modelled in the VSD model and therefore the total amount equals the amount in the soil water:

(A2) $$N_{tot} = z\cdot\theta\cdot[N]$$

where z the thickness of the soil compartment (m) and θ is the volumetric water content of the soil (m^3 m^{-3}). In the VSD model the net input flux is due to N deposition, N_{dep}, reduced by net growth uptake by plants, N_u, net immobilisation, N_i, and denitrification, N_{de}:

(A3) $$N_{in} = N_{dep} - N_u - N_i - N_{de}$$

Denitrification is modelled as fraction of the remaining N input:

(A4) $$N_{de} = f_{de}\cdot\left(N_{dep} - N_u - N_i\right)$$

where f_{de} is the denitrification fraction ($0\le f_{de}\le 1$); thus we get for N_{in}:

(A5) $$N_{in} = (1-f_{de})\cdot\left(N_{dep} - N_u - N_i\right)$$

The steady-state solution of eq.A1 is obtained by setting the time derivative to zero. Specifying an acceptable (critical) leaching of N, $[N]_{acc}$, the deposition becomes the critical load of nutrient nitrogen, $CL_{nut}(N)$:

(A6) $$CL_{nut}(N) = N_u + N_i + N_{de} + Q\cdot[N]_{acc}$$

or

(A7) $$CL_{nut}(N) = N_u + N_i + \frac{Q\cdot[N]_{acc}}{1-f_{de}}$$

Eqs.A6/7 are the SMB model for the nutrient critical load (see UBA, 2004); and N_i is the steady-state immobilisation and N_u the long-term average uptake of N.

Net immobilisation N_i is the sum of two terms: (a) a constant (acceptable, sustainable) long-term net immobilisation $N_{i,acc}$, which does not change the C:N ratio (i.e. a proportional amount of C is assumed to be immobilised concurrently), and (b) a time-dependent N immobilisation, $N_{i,t}$, calculated as a fraction of the net N input, depending on the C:N ratio in the topsoil. The N flux available, N_{av}, for time-dependent immobilisation is computed as:

(A8) $$N_{av} = \max\left\{N_{dep} - N_u - N_{i,acc}, Q\cdot[N]_{min}\right\}$$

where $[N]_{min}$ is a prescribed minimum N concentration in the soil solution. Between a maximum, CN_{max}, and a minimum C:N ratio, CN_{min}, the amount of N immobilised per time step is a linear function of the actual C:N ratio, CN_t:

$$\text{(A9)}\quad N_{i,t} = \begin{cases} N_{av,t} & \text{for} \quad CN_t \geq CN_{max} \\ \dfrac{CN_t - CN_{min}}{CN_{max} - CN_{max}} \cdot N_{av,t} & \text{for} \quad CN_{min} < CN_t < CN_{max} \\ 0 & \text{for} \quad CN_t \leq CN_{min} \end{cases}$$

The above equation implies that when the C:N ratio reaches CN_{min}, $N_{i,t}$ becomes zero, and the total amount of N immobilised per time step equals the constant value $N_{i,acc}$. This formulation is thus compatible with the SMB critical load model for $t \rightarrow \infty$ (see above).

The amount of N immobilised in every time step updates the amount of N in the topsoil, N_{pool}:

$$\text{(A10)}\quad N_{pool,t} = N_{pool,t-1} + N_{i,acc} + N_{i,t}$$

The amount of C in the topsoil, C_{pool} (in g m^{-2}), is also updated by two contributions: one due to $N_{i,acc}$ to keep the C:N ratio constant, and another which is controlled by the C:N ratio of the material immobilised according to eq.A9, CN_{seq}:

$$\text{(A11)}\quad C_{pool,t} = C_{pool,t-1} + CN_{t-1} \cdot N_{i,acc} + CN_{seq} \cdot N_{i,t}$$

Earlier versions of VSD did not include CN_{seq}, i.e. the C pool was not affected by time-dependent N immobilization. The new formulation follows Evans et al. (2006), who investigated the enhanced C sequestration due to elevated N inputs for some heathlands in the UK. The parameter CN_{seq} is a site-specific input for the VSD model, with default value CN_{seq}=0 (thus realizing the earlier VSD version). The updated pools, in turn, are used to update the C:N ratio:

$$\text{(A12)}\quad CN_t = \frac{C_{pool,t}}{14 \cdot N_{pool,t}}$$

where the factor 14 converts N_{pool} from eq (=mol) to g.

4. Tentatively exploring the likelihood of exceedances: Ensemble Assessment of Impacts (EAI)

Jean-Paul Hettelingh, Maximilian Posch and Jaap Slootweg

4.1 Introduction

Ensemble Assessment of Impacts (EAI) is presented in this chapter to tentatively explore the robustness of exceedances on a scale that could range from 'exceptionally unlikely' to 'virtually certain'. This, in analogy to the manner in which uncertainties are proposed to be addressed in the IPCC Fourth Assessment Report (IPCC-AR4) as summarized in IPCC (2005; reprinted in Appendix C of this report).

The chapter is a follow-up of a CCE proposal to the 25th session of the Working Group on Effects (WGE; Geneva, 29-31 August 2007) and of a proposal presented at the 17th CCE workshop and 23rd Task Force on Modelling & Mapping (Sofia, 23-27 April 2007) to explore the applicability of the IPCC-AR4 approach under the effects-based programme. Uncertainty analysis is an important part of the medium-term work programme of the WGE and of the work plan of the European Consortium for Modelling Air Pollution and Climate Strategies (EC4MACS) under the LIFE+ programme of the European Commission. This work is proposed as a first step to a report on uncertainty that is planned by 2010 under EC4MACS.

Ensemble Assessment

The term 'Ensemble Assessment' is borrowed from 'Ensemble Modelling', the latter indicating the pooling of model results to improve the accuracy of predictions. Ensemble Modelling is well established in particular in the field of atmospheric sciences (e.g. Builtjes, 2004), climatology (e.g. see http://www.precis.org.uk or Lenderink et al., 2007) but also in hydrology (e.g. Viney et al., 2005) and other fields of environmental modelling involving uncertainty.

We note that – in the context of impacts of exceedances – the biology behind exceedances is developing, while the number of established models in this field is limited. For this reason we introduce the term 'Ensemble Assessment of Impacts' rather than 'Ensemble Modelling of Impacts'.

Uncertainty of exceedances

The main aim of the critical load approach is the identification of the geographical location of an ecosystem of which the critical load is exceeded by atmospheric deposition. Ultimately it is the exceedance that matters, not the critical load as such. For the design of air pollution abatement policies it is important to know where (in Europe or in a country) adverse impacts can be expected to occur as a result of the dispersion of emissions and resulting excessive regionalized depositions. Moreover, policy analysts also wish to know the magnitude of the exceedance because it is assumed that an adverse effect may occur sooner when the exceedance is higher[2]. Therefore, when addressing

[2] The future occurrence of an adverse effect caused by exceedance, is not solely dependent on the magnitude of exceedances, but also varies over European regions depending on soil, vegetation and meteorological characteristics. Using combinations of these conditions as inputs, dynamic models can be applied on a regional scale (see chapter 3) to analyze Damage Delay Times (DDT) when critical loads are exceeded and Recovery Delay Times (RDT) otherwise. However, a rule of thumb is that adverse effects occur sooner when exceedances increase.

ecosystem impacts, integrated assessment modellers and policy analysts are primarily interested in the likelihood of (the occurrence of) an exceedance, and its emission scenario-dependent trend.

Of course, we know that the uncertainty of exceedances depends on variables and data in the chain from emissions to depositions, and their spatial and temporal resolution. These include data and emission factors behind national emission reports, input data, meteorology and climate conditions behind atmospheric dispersion models and input data, soil-vegetation characteristics and modelling methods behind critical loads. Uncertainty analyses in this context have been conducted and reported under the LRTAP Convention in, e.g. Hettelingh and Posch (1997) and Suutari et al. (2001).

Focus on critical loads of nitrogen

This chapter is not reiterating all the aspects of the uncertainty of integrated assessment modelling. This does not mean that Ensemble Modelling is disqualified as a (promising) method to also analyze the chain from emissions to exceedances. Rather, to keep a preliminary application of the IPCC-AR4 approach simple, we assume that the propagation of uncertainties of emission and dispersion modelling is a non-quantified constraint. This allows us to take computed ecosystem-specific depositions in a 50×50 km^2 EMEP grid cell as our unchallenged starting point.

This has implications for the assumptions that lie at the basis of this chapter. The first is that we do not extend our analysis to include changes in the *model structures* behind emissions and depositions, emission and deposition results are given. We simply use the emission assessment structure of the RAINS/GAINS model, while the modelling of dispersion is covered by the EMEP model. We use the EMEP source receptor matrices that are based on a 5 year average meteorology, and which are also embedded in the RAINS/GAINS model.

In this chapter, the variation of the distribution as well as of the magnitude of depositions is the sole result of emission reduction scenarios that are currently produced by the RAINS/GAINS modellers. Finally, in this chapter the focus is on the exceedance of critical loads of nitrogen by the deposition of oxidized and reduced nitrogen. The CCE background database is used to illustrate the Ensemble Assessment of Impacts.

4.2 Addressing uncertainty of exceedances in the context of IPCC AR4

The following is a preliminary attempt to interpret the IPCC Guidance note for lead authors of the IPCC AR4 on addressing uncertainties (IPCC, 2005; reprinted in Appendix C of this report) in the context of critical load exceedances.

- **Plan to treat issues of uncertainty and confidence**: We wish to explore the robustness of concluding that a grid-cell in Europe covers ecosystems at risk, under a particular emission scenario and related depositions. As stated above, in this chapter we do not address all kinds of uncertainties in the chain from emissions to depositions. On the basis of EMEP-depositions that are computed in a grid cell, aggregated to 3 ecosystem types, we wish to establish the likelihood that ecosystems in a grid cell have critical loads that are exceeded. More ecosystems in a grid cell are subject to risk of nitrogen effects as depositions are relatively high.
- **Review the information available**: The robustness of the occurrence of an exceedance could be increased by including more methods to compute critical loads (e.g. reverse dynamic modelling with geo-chemical and vegetation type models), or methods to assess exceedances (e.g. distinguish between special protection areas such as Natura 2000 from other sensitive areas). In addition one could extend the analysis to include deposition results of other emission scenarios. For the sake of experiment we restrict to the use of two, assumed independent, sets of critical loads, i.e. the empirical and modelled critical loads of nutrient nitrogen. If a deposition leads to exceedance using both sets of critical loads we feel that we can be more confident about the occurrence of an exceedance.

- **Make expert judgements:** We assume that an exceedance of an empirical critical load can be regarded as a measure for the risk to vegetation. Empirical critical loads are assigned to EUNIS and relevant geochemical classes of sensitive national ecosystems. Modelled critical loads are not qualitatively assigned, but computed using a mathematical model. An exceedance of a modelled critical load can be regarded as measure for the risk of eutrophication of soils. Of course, the risk of eutrophication can lead to vegetation effects. However, the critical limits used to compute modelled critical loads have not been derived from empirical critical loads, nor has one method be validated on the basis of the other. Therefore, we assume that both methods lead to critical loads of which the distributions (in on single grid cell) are independent, and that they reflect effects that are each others complement. Furthermore we assume that each of the two sets of critical loads in a single EMEP grid cell is representative for the (sensitive) ecosystems in that grid cell.
- **Use the appropriate level of precision to describe effects:** The guidance document proposes a hierarchy of 5 steps – with increasing specificity - by which statements for key findings can be substantiated (see Appendix C, paragraph 8). We can attempt to develop statements with respect to exceedances in the 4^{th} and 5^{th} category:
  - ‘A range can be given for the change in a variable as upper and lower bound, or as the 5^{th} and 95^{th} percentile based on objective analysis or expert opinion’; Think of the change of exceedances with respect to the 5^{th}, the 95^{th} or the highest percentile-critical load that is exceeded, when deposition changes. Depositions can change when alternative emission scenarios are compared.
  - ‘A likelihood or probability of occurrence can be determined for an event or for representative outcomes, e.g. based on multiple observations’; Think of the occurrence of an exceedance when using empirical or modelled critical loads. We propose the use of the scale provided in Table 4 of Appendix C as a basis for assessing the likelihood of exceedances in the next section.
- **Communicate carefully, using calibrated language:** In the past, when modelled critical loads were used in integrated assessment, the relative importance of exceedance was established through the comparison of emission scenarios. Areas where the critical load remained exceeded even after application of Maximum Feasible Reductions (MFR) could, tentatively, be judged as persistent. These could than be compared to areas which are exceeded under any base scenarios but become protected as further emission reductions are implemented in a sequence towards MFR. Communication generally revolved around the interpretation of scenario-dependent exceedances; are absolute magnitudes of exceedances as reliable as relative magnitudes in the context of a sweep of scenarios?

4.3 Deriving a scale to quantify the likelihood of exceedance

The IPCC guidance document defines likelihood (see Table 4 in Appendix C) ‘…as a probabilistic assessment of some well defined outcome having occurred or occurring in the future’ (IPCC, 2005, section 14, pp. 4). We address the likelihood of exceedance in an EMEP grid cell, meaning a grid cell of which AAE>0.

We assume the distribution of empirical critical loads to be independent of the modelled critical loads. Therefore, the distribution of linear transformations, i.e. exceedances of both types of critical loads, can also be assumed independent. Since we also assume each set of critical loads to be representative for the population of all ecosystems in an EMEP grid cell, we can state that the probability of the occurrence of an exceedance can be reflected by the percentage of the ecosystem area in an EMEP grid cell that is at risk. This implies that the joint probability of an exceedance of empirical and modelled critical loads is the product of both percentages of ecosystem areas at risk. This product can then be used to characterize likelihood of the occurrence of an exceedance and introduce a typology of scales as proposed by the IPCC as follows.

The likelihood of AAE>0 in an EMEP grid is said to be 'likely', 'very likely' or 'virtually certain' if the square root of the product (i.e. the geometric mean) of the exceedance percentages based on empirical and modelled critical loads are in the ranges 0-33%, 33-67% and >67% respectively (Figure 4-1). The likelihood is 'unlikely' when exceedance percentages based on both critical loads turn out to be zero. If only one of the two percentages is equal to 0 then the likelihood of an exceedance is said to be 'as likely as not'. As in the guidance document we consider the categories that are thus defined to have 'fuzzy' boundaries, i.e. allowing some undefined extent of small overlap.

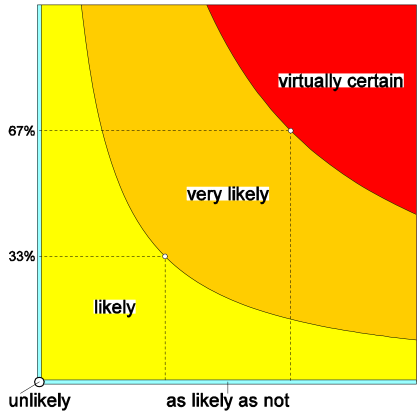

Figure 4-1. *The likelihood scale indicating the simultaneous probability of an exceedance of the empirical critical load and the modelled critical load of nutrient nitrogen.*

4.4 Tentative results

The use of the assessment methodology to scale the likelihood of exceedances in Europe yields Figure 4-2. The legend corresponds to probabilities depicted in Figure 4-1.

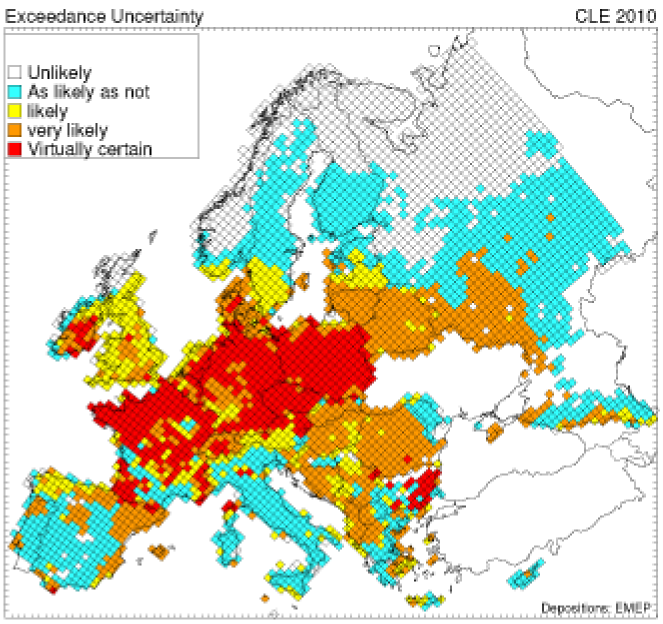

Figure 4-2*. The likelihood that the Average Accumulated Exceedance of an EMEP grid cell exceeds zero, i.e. that it contains at least one ecosystem of which the critical load of nutrient N is exceeded with current legislation.*

Figure 4-2 illustrates that ecosystem areas of which critical loads are 'virtually certain' to be exceeded (red shaded) cover broad parts of Austria, Belgium, Bulgaria, Denmark, France, Germany, Ireland, The Netherlands, Poland, The Czech Republic and Switzerland. Countries and regions that have ecosystem areas that are 'very likely' (orange shaded) to be at risk include Belarus, Lithuania, the southern part of Russia and the south-eastern and south-western part of Europe. Areas where exceedances are 'as likely as not' (blue shaded) cover important parts of northern and southern Europe as well as Russia. Finally, areas where exceedances are unlikely are computed to be mostly in northern Europe.

4.5 Conclusions and recommendations

This chapter tentatively summarizes the Ensemble Assessment of Impacts (EIA) methodology. The objective of EIA is to improve the accuracy of exceedance assessments by pooling different kinds of constituents of exceedance calculation and scale the likelihood of exceedances in analogy to the treatment of uncertainties under the IPCC (see appendix C). In this chapter two different kinds of critical loads, i.e. empirical critical loads and computed critical loads were used. Using EIA in this way, exceedances are assessed to be 'virtually certain' or 'very likely' in central and western Europe.

This chapter provides a first indication that EIA may contribute to the assessment of the uncertainty of the location of exceedances. Whether EIA needs to – or can – be further developed to include the uncertainty of the magnitude of exceedances depends on a number of issues that are relevant for the description of the variability of modelled phenomena in general, and exceedances in particular.

Uncertainty analysis is particularly important for the assessment of phenomena that are difficult to validate. This is the case for forecasted changes to the biology caused by modelled critical load exceedance as much as it holds for forecasted changes to our climate system caused by modelled changes of carbon dioxide concentrations. Standard methods of uncertainty analysis include statistical variation of model drivers and parameters since about five decades. Since the nineties, also qualitative methods were introduced which aim to take into account expert judgements and alternative ways and pedigrees to parameterize uncertainty. These methods have an understanding in common, i.e. that the system that underlies the model is not subject to structural change. The methods and models that are designed to represent a particular part of a (natural) system cannot deal with fundamental system changes. The introduction of ensemble methodologies, based on the pooling of methods and models, has further improved the treatment of uncertain assertions by including different models of the same system. Recently, Beck (2004) addressed the challenge to construct and apply models 'to generate environmental foresight in the presence of structural change'.

Further work is needed to further assess the likelihood of exceedances and the risk of impacts. This could include the elaboration of EIA by incorporating the pooling of other drivers that are relevant to assess the likelihood of exceedances of ecosystems in EMEP grid cells, subject to:

- Different land cover classes,
- Natura 2000 areas and its biological characteristics (habitat/birds directive),
- Different methods to establish the relationship between (national) emissions and depositions on ecosystems in EMEP grid cells,
- The (statistical) variation of 'modelled' critical loads,
- The distinction of 'importance' of EMEP grid cells using knowledge on the sensitivity of its ecosystems, i.e. its Damage Delay Times or Recovery Delay Time urgencies.

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5. LRTAP land cover map of Europe

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5.1 Introduction

The Long-range Transboundary Air Pollution (LRTAP) Convention's harmonized land cover map (formerly the SEI European Land Cover Map, 2006 Revision) is a digital spatial dataset designed for environmental modelling applications requiring continental scale land cover information. The dataset has been compiled for use by modellers for assessing the impacts of air pollutants on European ecosystems and agriculture. The information is being used by the Working Group on Effects and EMEP of the LRTAP Convention in assessing tropospheric ozone impacts.

The data has been compiled from a mixture of existing digital and paper sources including the European Environment Agency (EEA) Corine Land Cover 2000, SEI Land European Cover Map (2002 Revision), FAO Soil Map of the World, EEA European Biogeographical regions (2005).

The data have been modelled and combined to generate classes differentiating between various European Nature Information System (EUNIS) codes (http://eunis.eea.europa.eu/). The dataset contains information down to EUNIS level 3 for specific habitat types. The specific EUNIS codes included (with differing levels of detail) are:

- A: Marine habitats
- B: Coastal habitats
- C: Inland surface waters
- D: Mires, bogs and fens
- E: Grasslands and lands dominated by forbs, mosses or lichens
- F: Heath land, scrub and tundra
- G: Woodland, forest and other wooded land
- H: Inland unvegetated or sparsely vegetated habitats
- I: Regularly or recently cultivated agricultural, horticultural and domestic habitats
- J: Constructed, industrial and other artificial habitats

The dataset also contains additional information on dominant crop types and forest species across Europe. More detailed information on the distribution of crops and irrigation intensity has been generated and is available from SEI for research purposes.

The production of the dataset has been funded by the UK Department for Food and Rural Affairs (DEFRA). The dataset is freely available for download and use with acknowledgement.

5.2 Background to the 2006 revision

The previous SEI land cover dataset, generated in 2002, has been used successfully in air pollution modelling – particularly in the assessment of the impacts of ozone on crops and forests. The map has been accepted as dataset suitable for air pollution modelling work under the LRTAP Convention and has been heavily utilised by EMEP.

However, the map has significant differences in the location and distribution of land cover types when compared with other European maps in particular the European Environment Agency (EEA) Corine Land Cover dataset. The Corine map has become the default land cover map for most agencies requiring European scale land cover mapping for example, the Coordination Centre for Effects, Bilthoven. However, the classification structure of the Corine dataset has been determined partly through the data and methodology used to generate the map – namely remotely sensed imagery classified using automated and manual reclassification procedures. This classification structure did not fully meet the requirements of the air pollution modelling community.

In order to address the criticisms of the existing SEI information being incompatible with the Corine data and to improve the level of detail in the classification structure of the Corine dataset to meet the needs of the modelling community it was therefore decided to merge the two dataset and reclassify the information in line with the EUNIS classification structure.

5.3 Generic methodology for vertical merge

The SEI European Land Cover Map (2006 Revision) has been produced through the vertical merging of a variety of existing spatial datasets.

Merging methodology

- Simple transparent methodology required
- Create merged class boundaries
- Thiessen – most probable land cover classes – used to merge SEI information with EEA Corine data

Brief description of datasets

The new SEI land cover data has also incorporated new spatial datasets to improve the range and reliability of information it contain.

EEA Corine

The Corine Land Cover 2000 dataset (CLC2000) is an update of the original European Environment Agency European map for the reference year 2000.

The dataset has been produced using remotely sensed imagery to produce a land cover database at a scale of 1:100,000, a positional accuracy of 150m and a minimum mapping unit of 25ha. The CLC map contains 50 land cover classes (see figure 5.1 below) – with 22 of these being relevant to terrestrial effects mapping. The extent of the map is for the EU 25 (with the exception of Sweden, Cyprus, and Malta), AC 3 (with the exception of Turkey), Albania, Bosnia and Herzegovina, Macedonia- the Former Republic of Yugoslavia.

SEI land cover map

The SEI dataset was compiled from existing digital land cover datasets and digitised paper maps to produce a land cover database suitable for pollution effects modelling.

The map was classified to represent dominant species or land use activity and the resulting 450 plus classes have a nominal scale (based on the combined data) of approximately 1:2,500,000 to 1:4,000,000 (dependent on which area of the European region is being utilised). The map will be referred to as SEI2002 in the remainder of this document.

Figure 5-1. EEA Corine Land Cover 2000 map legend.

Combination of SEI2002 and CLC2000

The two datasets have been compiled from very different methodological and dataset origins. Due to the difference in spatial resolution and classification structure it has not been possible to simply overlay the two maps to combine them into one unified dataset. In order to ensure that the combined dataset merges spatially and categorically a hierarchical approach to the merger has been used.

- Hierarchy level 1

At the top level of the dataset are the 46 CLC2000 land cover codes – these polygons have been used to define the boundaries of all the lower hierarchical level land cover classes. On the completed dataset it is therefore possible to display the data in the original CLC2000 code – for example, class 3.1.2 Coniferous forest.

- Hierarchy level 2

Beneath these level 1 polygons – the SEI land cover map has been used to determine more detailed land cover types. The existing SEI2002 land cover polygons do not precisely match the CLC2000 boundaries. For example, the CLC2000 map contains polygons of class 12 – non-irrigated arable land. The SEI2002 polygons that correspond spatially contained a mixture of agricultural classes, some grassland classes and some forest areas. The difficulty therefore has been the allocation of SEI2002 classes to each CLC2000 land cover polygon. The methodology used in this allocation has been a two-stage process:

SEI2002 – direct conversion

Where the SEI2002 polygon corresponds to the CLC2000 boundary the data contained in the SEI map was transferred directly to the merged SEI-CORINE dataset. For example, the CLC2000 map has polygons coded 2.2.2 – Fruit and Berry Plantations. From the SEI2002 database the polygons that corresponded to the definition of CLC code 2.2.2 were extracted. The definition for this EEA class is: 'Parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces. Includes chestnut and walnut groves and hop plantations' (EEA, 2000). SEI land cover classes corresponding to this definition were extracted from the existing spatial database. This corresponded to SEI2002 horticultural codes and mixed agricultural codes such as, class 219 – 'Wheat, orchards and vineyards'. The CLC2000 polygon boundaries were then used to clip the SEI2002 agricultural and horticultural polygons to determine the more detailed land cover class for the merged map. For example, in the example above the boundaries of CLC2000 code 2.2.2 clipped SEI2002 class 219 polygons. This created new polygon boundaries identifying – fruit and berry plantations which could now be additionally classified as orchards (the orchards definition was extracted from the description of class 219 as it is the only component of the original class which matches the definition from the CLC2000 dataset for code 2.2.2).

SEI2000 – slivers

As was previously described – for a number of areas the boundaries of the SEI2002 dataset and CLC2000 dataset were not contiguous. Various approaches could have been employed in order to generate the most probable class for these sliver polygons. However, in order to expedite the generation of the merged map a simple methodology was employed – this had an additional benefit in that the origin of the final result was relatively transparent (original data or most probable class). This transparency means results could be improved upon in subsequent revisions.

In order to generate a complete surface of the most probable corresponding land cover class for all CLC2000 polygons – with no slivers of no-data, centroids for the SEI2002 polygons were generated. Centroids are the point located in the centre of the polygon that was used to generate them. In order to reduce the influence of polygons representing small areas a thinning process was employed. Centroids generated for polygons with areas less than 2.5 km^2 were excluded from the dataset. Thiessen polygons were then generated from the remaining centroids to produce data for the full extent of the point coverage – and beyond to a specific boundary specified in the GIS. The boundary chosen were specific zones used to clip the SEI2002 map for distribution and corresponded approximately with country boundaries.

Centroids generated from small polygons (less than 2.5km^2) were excluded from the Thiessen process in an attempt to improve the probability that the resulting polygons represented the most probable land cover class for the area. This was particularly important in areas of high diversity – where land cover was diverse but certain classes were more dominant (by area) than others.

Obviously this thinning process was problematical. In areas where the majority of polygons are of the same class, but they were all small due, to the high diversity of land cover in that region – it is likely that a large number of small polygons will have been excluded. The 2.5km^2 threshold was identified as removing the smallest area fraction of the SEI 2002 polygons – whilst at the same time removing the greatest number of centroids (see Figure 5.2.).

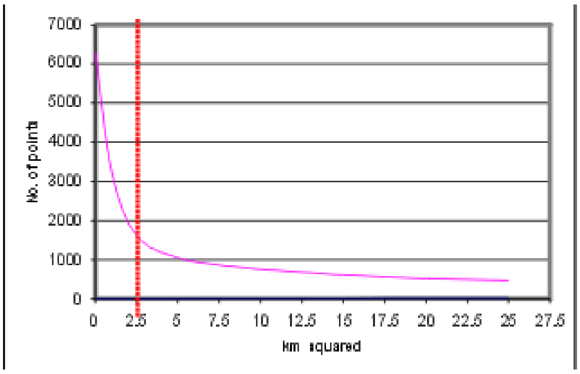

Figure 5-2. *Comparison of centroid numbers and area of originating polygons.*

The Thiessen polygons generated from the SEI2002 dataset were then clipped to the boundary of the corresponding CLC2000 code. The resulting layer was then merged with the clipped polygons generated from the original SEI2002 boundaries to produce the final merged layer. The merging process is presented graphically below in Figure 5.3.

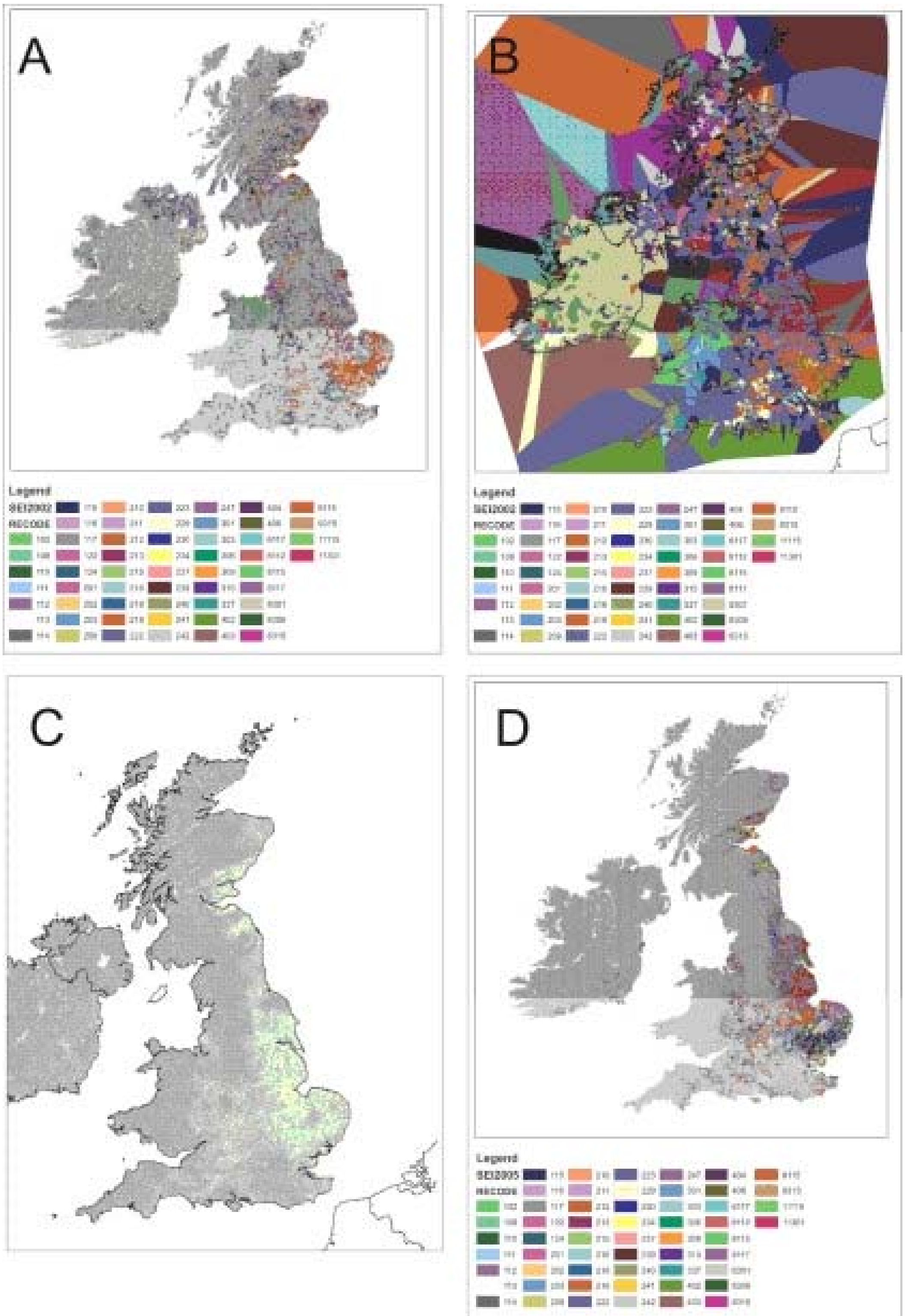

Figure 5-3.*Clipping of merged SEI2002 original polygons and Thiessen polygons to the CLC2000 class boundaries. Map A is the original distribution of agriculture according to the SEI2002 dataset. Map B shows the Thiessen polygons generated from the SEI200 data. Map C displays the distribution of arable land on the CLC2000 dataset. Map D shows the result of clipping the SEI data to produce the merged SEI 2006 Revision database.*

5.4 Forests species and distribution

Joint Research Centre (JRC) forest species data

The JRC Forest Species Map for Europe was produced to address the needs of climate and biogenic modellers. Previously most spatial datasets had classified forests into three broad categories – broadleaved, coniferous and mixed (for example the EEA CLC2000 dataset). This was insufficient detail for models that had functions related to specific species.

The distribution of forests used by the JRC was taken primarily from the Corine dataset (the 1990 base year version of this dataset). For areas outside the Corine extent the PELCOM database was used. The datasets were standardised to a 1km grid resolution. The UNECE had site inventory information for 5513 sample plots across 30 European countries. The JRC project interpolated from these sample plots using an inverse distance weighted procedure to determine the percentage cover of 115 tree species occurring across Europe. The map was then clipped to the distribution of forests from the merged CLC90/PELCOM dataset to determine the percentage coverage of tree species across Europe.

Derivation of dominant species classes

The updated SEI dataset did not intend to replicate the detailed breakdown of 115 species across Europe. The reason for this was that ultimately the SEI dataset was to be merged with information for Eastern Europe indicating dominant species only. It was therefore decided to produce a complimentary dominant forest species dataset for Western Europe. The dominant species map was intended to compliment the new information on forest extent being generated by the CLC2000 dataset from the EEA.

The derivation of dominant tree species as a five-stage process

The first stage was to group species into specific tree types. This was done to reduce the data to be analysed in the GIS whilst retaining enough detail to make the dataset useful for air pollution impact assessment modelling. 115 species were reclassified categories into 46 which were then assessed in the next stage.

The next stage was to assess the relative dominance of the reclassified tree groups across Europe. Tree groups with a local dominance of eighty percent or higher were considered to be spatially important across Europe. These can be seen below in Table 5.1. Four species were excluded from this process even through they met the eighty percent criteria. These were olive trees, which were included in a separate layer in the CLC2000 map and would therefore be assessed independently of other tree types in the merged SEI/CLC dataset. The other four groups - Plane trees, Black Locust, Strawberry trees and Tree Heath – whilst locally dominant covered a small area of Europe. In order to expedite the GIS processing these four groups were excluded from the assessment of dominant European tree groups.

Having identified the dominant tree species by percentage cover the next stage was to identify their spatial distribution and relative local dominance. This was done in order to determine the locally dominant tree groups that could then be combined with the existing SEI data for Eastern Europe in order to produce a complete spatial coverage. Individual raster layers for tree groups were reclassified in the GIS into their decile classes and overlaid. In order to facilitate the processing of these layers they were combined in batches of five decile rasters at a time. The local dominance of these combined rasters was then assessed. If a tree group comprised 33% or more of the trees in the combination groups in the combined raster the tree group was considered locally important and passed onto the next phase of sifting. This process produced interim rasters for each batch of tree groups that were ultimately combined to produce the final combination map of local importance. The same sifting process based on local dominance was then performed on this final combination raster to produce the finished map of tree groups across Europe. This process was performed three times for broadleaf, coniferous and mixed forests to correspond with the data layers in the CLC2000 and SEI2002 datasets.

Table 5-1*. Dominant (by % cover) tree groups across Europe*

Group Name	Dominance %	Group Name	Dominance %
Alder	100	Poplar	100
Ash	99	Privet	79
Beech	100	Sclerphyllous Oak	100
Birch	94	Aleppo Pine	100
Cherry	80	Cedar	80
Chestnut	100	Cypress	84
Cork Oak	100	Fir	100
Eucalyptus	100	Larch	95
Hornbeam	100	Maritime Pine	100
Juniper	100	Norway Spruce	100
Lime	92	Pine	100
Maple	80	Scots Pine	100
Oak	100	Sitka Spruce	100
Olive	99	Stone Pine	100

The next stage in the production of a merged forest map was to produce a Thiessen layer for each completed tree group combination map. This Thiessen process (described previously) was required as the JRC map had been clipped to the 1990 Corine dataset. The merged SEI/Corine map was to be based on the CLC2000 dataset. This meant that a simple merge of the tree group maps and the CLC2000 forest layers would have resulted in areas of forest that have developed since 1990 being classified as no-data. The Thiessen process was used to avoid this problem by assigning the most likely tree group combination – based on local dominance – to sliver polygons.

The final stage production of the SEI 2006 Revision layers was to merge the combined tree group maps and Thiessen tree group maps and clip them based on the boundaries CLC2000 forest extents. This process can be seen below in Figure 5-4.

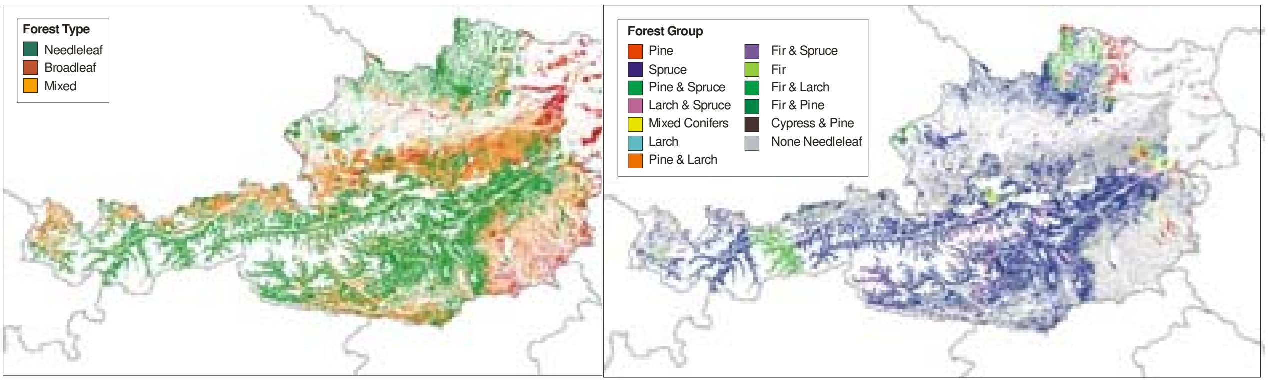

Figure 5-4*. Clipping of Thiessen polygons based on Corine 2000 class boundaries to derive forest species and type information.*

5.5 EUNIS reclassification

A preliminary reclassification of the SEI 2006 revision forest information has been performed. This reclassification has yet to be agreed with the CCE and all the partner organisations of SEI. The reclassification of the SEI 2006 revision dataset can be seen in Table 5.2.

Table 5-2. *CLC2000 forest classes and corresponding EUNIS codes.*

CLC2000 Class	CLC Description	EUNIS Level 1 Class	EUNIS Level 2 Class
3.1.1	Broad leaved forest	G Woodland and forest habitat	G1 Broadleaved deciduous woodland
3.1.1	Broad leaved forest	G Woodland and forest habitat	G2 Broadleaved evergreen woodland
3.1.2	Coniferous forest	G Woodland and forest habitat	G3 Coniferous woodland
3.1.3	Mixed forest	G Woodland and forest habitat	G4 Mixed broadleaved and coniferous woodland

EUNIS Level 3 Broadleaved woodland classes

Unfortunately the third level of the EUNIS classification for broadleaved forests (G1 and G2) did not correspond well to the dominant tree species classes identified on the SEI 2006 Revision data layer. The third level of EUNIS codes for forests contained classes described by additional parameters not yet included in the SEI 2006 Revision dataset. For example, EUNIS code G1.2 – Mixed riparian floodplain and gallery woodland or G1.9 – Non-riverine [Alnus] woodland. The inclusion of additional information such as proximity to rivers means that it was not possible to translate all the SEI 2006 Revision forest classes into EUNIS level 3 classes.

EUNIS Level 3 Coniferous woodland classes

The SEI2006 codes translate considerably better into the EUNIS Level 3 coniferous classes. Overall 69 coniferous forest classes were identified on the SEI 2006 Revision dataset.

EUNIS Level 3 Mixed woodland classes

In total 148 classes of mixed woodland combinations were classified in the SEI 2006 Revision dataset. A subset of these can be translated into EUNIS level 3 codes.

5.6 Agriculture and horticulture

SEI2002 Agricultural Data

The spatial delimitation of agricultural areas formed one component of the SEI2002 land cover map. The delimitation of agricultural areas was achieved through the linkage of three data layers:

- Data Layers IGBP Global Land Cover (GLC) agricultural information
- SEI Land Cover agricultural information
- Bartholomew Country and NUTS region boundaries

Areas of potential agriculture across Europe were identified by excluding polygons classified on the updated SEI2002 land cover map as forest, semi-natural vegetation, urban and water. The extent of agriculture in the remaining areas was then determined by combining the GLC agricultural data with the SEI1998 agricultural map.

The GLC classification of agricultural classes was the dominant data source used to spatially delimit the distribution and type of croplands across Europe. The SEI1998 land cover map only contained information on the dominant crop by country generated from FAO and EU statistics.

The GLC map was converted into three data layers. Firstly, the areas which were purely agricultural were identified, for example, 'Cropland (Winter Wheat, Small Grains)'. Secondly the areas that were of mixed classes combined with forestry were delimited, for example, 'Cropland (Rice, Wheat) with Woodland'. For these polygons the areas that overlapped with forestry (as previously identified on an updated land cover layer) were excluded with the remaining areas classified as agriculture (with the classification obtained from the GLC land cover class). Thirdly, areas that were mixed classes of agriculture, forestry and grassland were identified, for example, 'Cropland and Pasture (Wheat, Orchards, Vineyards) with Woodland'. In these polygons the area that overlapped with the existing forestry layer were excluded. The existing SEI agriculture map was then used to differentiate the extent of cropland from pasture.

The SEI2002 land cover map was used to identify the extent of agriculture across Europe but with no classification of the type of cropland. The distribution and classification of horticulture was derived from the SEI1998 land cover database.

The five maps were combined in the GIS using unique conditions modelling and the resulting table exported in a spreadsheet to determine the classification and distribution of agriculture and horticulture. The classes obtained from the GLC map took precedence in the revised data set except for the areas 'horticulture' that were identified from the SEI data layer. The reclassified data contained approximately 250 discrete classes.

Merge with CLC2000

The CLC2000 dataset contains eleven agricultural classes (see Figure 5-1). Of these original classes three are of equivalent detail to the information contained in the SEI2002 database. These three classes are: 2.1.3 Arable land – Rice Fields; 2.2.1 Permanent Crops –Vineyards; 2.2.3 Permanent Crops – Olive Groves. For these areas the CLC2002 polygon boundaries have been left unchanged and this data forms the information on the spatial extent on these agricultural land cover types in the SEI 2006

Revision dataset

For the remaining eight classes, additional detail on the type and distribution of agriculture across Europe has been generated by combining the SEI2002 data with the CLC2000 polygon boundaries. This has been achieved using the methodology described earlier – through the extraction of existing polygon extents and the generation of Thiessen maximum probability layers to infill the slivers.

Generation of completed agricultural layers is still ongoing at time of preparation of this document. This delay has been caused by partly caused by timing of the release of the CLC2000 dataset. This was made available for download by the EEA in February in sections. New sections, such as Sweden, are still being released leading to additional processing in the GIS. It is predicted the complete agricultural layers will be available in a suitable GIS export format in May.

EUNIS reclassification

The EUNIS classes for agriculture can be seen below in Table 5.3. As the table indicates the EUNIS structure is not very useful for identifying different types of crops or their corresponding yields. This information is important for assessing the economic and food security impacts of pollutants. The CLC2000 dataset already reclassifies well into the EUNIS level 3 codes as can be seen in Table 5.4. The SEI 2006 Revision dataset will provide additional information on the type of crop grown at a location, for example, small grains. This information can be linked to agricultural census information on the actual distribution and yields for particular crops in specific years. This information can be linked to the SEI 2006 Revision dataset to provide an assessment of the actual distribution of crops in a particular year – with the caveat that the distribution of land cover is based on the base years for the CLC2000 dataset and the SEI2002 dataset.

***Table 5-3**. EUNIS agricultural classes.*

EUNIS Level 1	EUNIS Level 2	EUNIS Level 3
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	I1 – Arable land and market gardens	I1.1 – Intensive unmixed crops I1.2 – Mixed crops of market gardens and horticulture I1.3 – Arable land with unmixed crops grown by low-intensity agricultural methods I1.4 – Inundated or inundatable croplands, including rice fields I1.5 – Bare tilled, fallow or recently abandoned arable land
	I2 – Cultivated areas of gardens and parks	I2.1 – Large-scale ornamental garden areas I2.2 – Small-scale ornamental and domestic garden areas I2.3 – Recently abandoned gardens

***Table 5-4**. EUNIS agricultural classes and corresponding CLC2000 classes.*

EUNIS Level 3	CLC2000 Class
I1.1 – Intensive unmixed crops	2.1.1 – Non-irrigated arable land
I1.2 – Mixed crops of market gardens and horticulture	2.2.1 – Vineyards 2.2.2 – Fruit trees and berry plantations 2.4.2 – Complex cultivation patterns
I1.3 – Arable land with unmixed crops grown by low-intensity agricultural methods	2.1.1 – Non-irrigated arable land 2.4.2 – Annual crops associated with permanent crops 2.4.3 – Land principally occupied by agriculture
I1.4 – Inundated or inundatable croplands, including rice fields	2.1.2 – Permanently irrigated land 2.1.3 – Rice fields
I1.5 – Bare tilled, fallow or recently abandoned arable land	
I2.1 – Large-scale ornamental garden areas	1.4.1 – Green Urban Areas 1.4.2 – Sport and leisure facilities
I2.2 – Small-scale ornamental and domestic garden areas	1.4.1 – Green Urban Areas
I2.3 – Recently abandoned gardens	1.4.1 – Green Urban Areas

5.7 Agricultural production

SEI2002 agricultural data

Linking the revised agricultural map to agricultural production statistics The SEI 2006 Revision dataset can also be used to generate information on the distribution of dominant crop types across Europe. In order to combine the spatial database with the statistical crop information the agricultural map was overlaid with data sets showing the distribution of country boundaries and the EMEP 50km grid using unique condition modelling. This produced a database onto which country specific information on yield and crop coverage could be appended and the results analysed by EMEP grid square. This data was then combined with statistical information from the FAO AGROSTAT Agricultural Statistics.

For each country a specific database of the percentage coverage of crops and yields linked to the agricultural map was produced using the FAO Agrostat data for the base year of 1999. The breakdown of crop classes included in the databases can be seen in Table 5-5 below.

Table 5-5. *Crop classes contained in the SEI agricultural databases.*

Crop Type	Included in FAO Agrostat	Crop Type	Included in FAO Agrostat
Barley	Yes	Potatoes	Yes
Carrots	Yes	Pulses	Yes
Cotton	Yes	Rape	Yes
Flax	Yes	Rice	Yes
Fresh Vegetables	Yes	Rye	Yes
Fruit	Yes	Soya	Yes
Grapes	Yes	Sugar Beet	Yes
Hops	Yes	Sun Flowers	Yes
Maize	Yes	Tobacco	Yes
Millet	Yes	Tomato	Yes
Oats	Yes	Vineyards	Yes
Olives	Yes	Water Melon	Yes
Orchards	Yes	Wheat	Yes

For the general agricultural class, ‘Cropland’, the statistics were used to determine the actual percentage of different crop types grown (excluding horticulture) in that country. The cereals class on the map was defined as wheat, barley, rye, oats, millet, maize and rice. The grain class from the map was defined as wheat, barley, rye, oats and millet with small grains being the subset of wheat, barley, rye and oats. From this classification an assessment of the actual percentage of each crop grown in that country was determined. The example of the small grains class in Austria is illustrated below:

Table 5-6. *Example of the distribution of crop types for the ‘small grains’ class.*

Crop Type	% of Total Agricultural Area	% of Small Grains
Wheat	22.3	22.3/53.3 = 43.7
Barley	21.8	21.8/53.3 = 40.9
Rye	5.0	5.0/53.3 = 9.0
Oats	3.2	3.2/53.3 = 6.0
Total	53.3	100.0

The breakdown of the actual split of crop types by country in each polygon of the agricultural map was then used to calculate the actual area and yield of crops in each EMEP 50km grid square.

Irrigation

Information on the extent of irrigation across Europe has been obtained from the Doll and Siebert ‘Map of Global Irrigation’. The data set indicates for 0.5^o by 0.5^o grid cells the fraction of each cell that is irrigated. The distribution of irrigation was overlaid with the revised agricultural layer. For each grid cell the percentage crop cover according to the FAO Agrostat database was then combined with the estimation of irrigation levels.

For thirteen European countries the specific irrigation preferences were known (Institute for European Environmental Policy, 2000), for the remaining areas a generic irrigation decision rule was applied. From the information on crop distribution, irrigation patterns and irrigation practices it was then possible to create a database for each grid cell on the crop irrigated and the area within each cell covered by that crop type. From this data, a map of dominant irrigated crop distribution was produced. A more detailed database of the intensity of irrigation has also been produced and is available for collaborative research with SEI.

5.8 Availability of the harmonized land cover map

The harmonized land cover map is freely available for collaborative research use at www.sei.se. National datasets are split into layers, one for each EUNIS – 1 level. The land cover map has been converted to a single layer with singular EUNIS classes for the application of the map in relation to critical loads. This map (in EMEP – projection) can be obtained by contacting the CCE.

6. Application of the harmonized land cover map

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6.1 Introduction

A harmonized land cover map for the bodies under the LRTAP Convention has become available, see Chapter 5. The CCE applied this map throughout its work on critical loads. This chapter describes a comparison between harmonized land cover map and the ecosystems in the NFC submission, the creation of a European background database of empirical critical loads for nutrient nitrogen, and the comparison of this background database with the empirical critical loads from the NFCs. Some preparatory steps were necessary to apply the harmonized map as it was made available by SEI. These steps are described in the first paragraph below.

Other use of the new land cover map, which is *not* further described here, is the application in the background database for modelled critical loads. Also several NFCs have requested and used the map for their submission.

6.2 Preparatory steps

Figure 6-1 shows an aggregated representation of the compiled European land cover map.

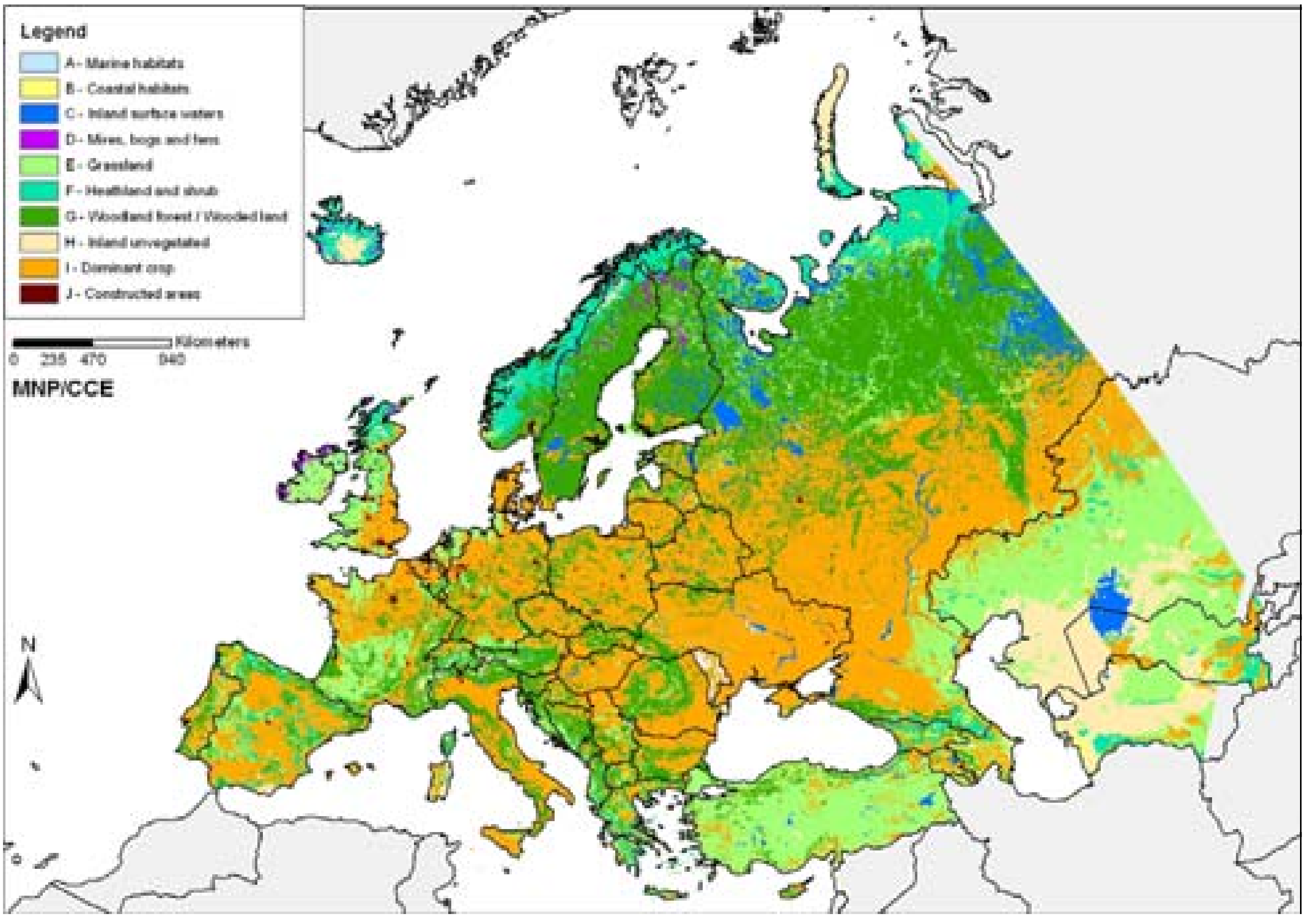

Figure 6-1*. The harmonized land cover map, aggregated to EUNIS level 1.*

For their map SEI used the land cover codes from the European Nature Information System habitat classification (EUNIS) (Davies et al., 2004). The EUNIS classification is a hierarchical typology of the habitats in Europe and its adjoining seas. The classes on the Land cover map mainly correspond to the second EUNIS level (e.g. D1, F1, etcetera). However, also vegetation types grouped to the first EUNIS level (e.g. B for all coastal habitats), combination of different EUNIS levels (e.g. A1 or A2 without A2.5), or a classification to the third EUNIS level were used. On the land cover map, forests (EUNIS class G) kept their former code version, but a preliminary classification to a third level EUNIS classes was in addition provided by S. Cinderby of SEI. The table in the annex 6-A to this chapter gives an overview of the EUNIS habitat classes distinguished on the SEI-map. Further preparatory (technical) steps include classification to singular EUNIS-codes, conversion to EMEP projection, clipping to countries borders and, in case of big countries, merging the parts in which the country were originally split. The resulting (100×100 m. grid) maps have been made available to the NFCs. The set of map of all European countries is hereafter referred to as the *(harmonized) land cover map.*

6.3 Comparing to the ecosystems of the NFC data

The comparison between the EUNIS-classes of the land cover map and the ones provided by the NFCs has been executed in two ways. Firstly, the point information of the NFCs has been compared with the polygon information from the SEI-map. Secondly, the compositions of EUNIS-classes in EMEP50-grid cells have been compared between the NFCs and the land cover map.

Comparison between NFC-ecosystems and land cover polygons

Until now most NFCs only produce critical loads for forest sites (EUNIS-code G). To make a meaningful comparison for most of the countries, we only considered the NFC forest sites. We analyzed for these NFC forest points, which EUNIS-classes are found on the SEI-map. We expected of course that the NFC forest points correspond to EUNIS-class G (forest) on the SEI-map. For this comparison we made a point in polygon overlay. For this we used the latitude and longitude information of the NFC forest sites. The EUNIS-codes of the land cover map were aggregated to the first level. Figure 5.2 shows that there is in general a large discrepancy between the NFC information and the land cover map information. For some countries like the Check Republic (CZ) the accordance is good (>90%), but for other countries like the United Kingdom (GB) it is poor (<20%).

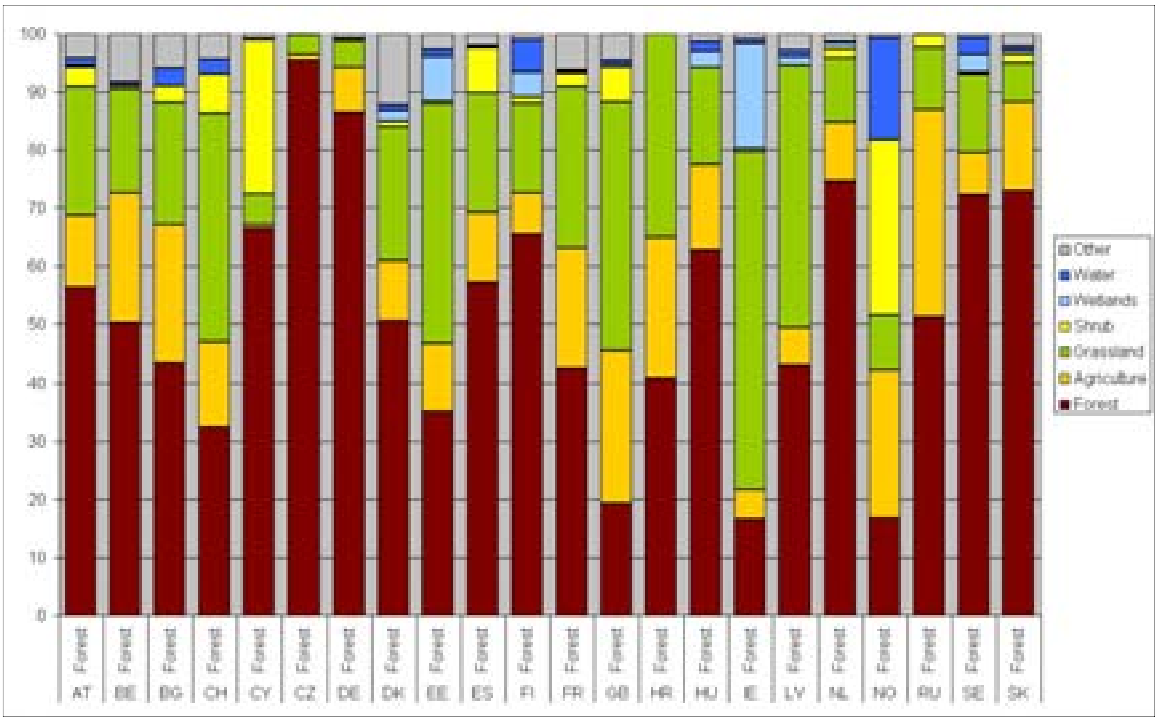

Figure 6-2. *Composition of EUNIS-classes of land cover map for NFC-forest points per country.*

Possible reasons for low agreement between the NFC forest site point information and EUNIS-classes from the land cover map could be:

- a NFC point (ecosystem) is in several countries the centroid of a polygon that may be clustered or somehow aggregated. The probability of this centroid to match the same land use class resembles the histogram of the harmonized map, especially for a submission based on a coarser map, and in a scattered region. (Compare the distribution of the total land cover classes of the countries in Figure 2-1 with Figure 6-2).

- Assigning classifications that originate from sources like Corine to EUNIS-classes can make the result fuzzy, for example the classes shrub (F) and forest (G) may overlap.
- NFC point co-ordinates are not always accurate (differences up to 10 km have been found).

Although the point-to-polygon comparison may show little accordance, a NFC submission could still represent the ecosystems in a region very well. To test this, the histograms of land use within each EMEP grid of the land use map are compared to the NFC submissions.

Comparison between histograms of NFC-ecosystems and the land cover map

A comparison of the composition of EUNIS-classes of larger areas between NFCs and the land cover map does not have the abovementioned drawbacks. Therefore, we compared the areas of different EUNIS-classes by EMEP50-grid cell. As already mentioned in the former section, most NFCs only produce critical loads for forest sites. To make a meaningful comparison for most of the countries, we compared the area of forests by EMEP50 grid cell between NFCs and the land cover map. We used the most *recent* NFC data submission for acidification (partly 2007). We used the Kappa-Histo-statistic as measure for correspondence. A high Kappa-statistic means a high similarity area of the EMEP50-grid cell between NFCs and the land cover map and vice versa. In Figure 6-3 the result of this comparison is depicted.

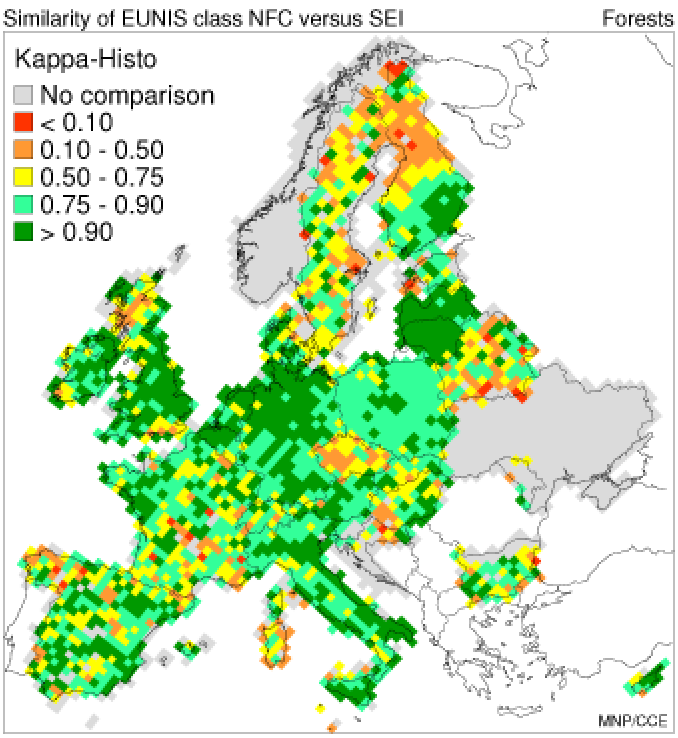

Figure 6-3 *Correspondence (Kappa-Histo statistic) in area forest per EMEP50-grid cells between NFCs and the land cover map.*

This map shows that for most countries the correspondence in area of forest is quite high, with exception of some areas like Scandinavia and the Czech Republic. Possible reasons for the low correspondence in these latter areas were investigated by studying both source maps for forest

(Figure 6-4). From this figure it is clear that the magnitude of the forest area differ but that the forest patterns look similar. In general the area of forests in the NFC-map seems to be higher then in the land cover map. A possible explanation for this may be that EUNIS-classes like shrubs (F) are included in the NFC-information.

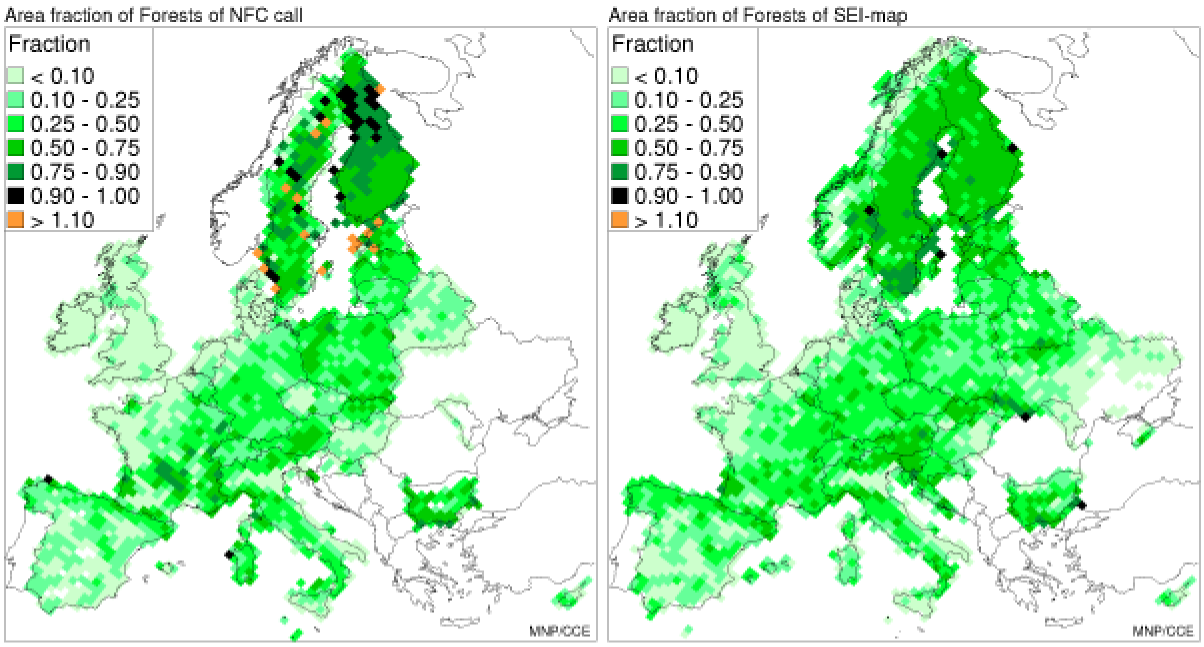

Figure 6-4. *Distribution of forest by EMEP50 grid cell, left: source NFCs, right: source land cover map.*

6.4 Adaptation of European empirical critical loads for EUNIS habitat classes of the land cover map

Existing and European empirical critical loads

Until 2006 the NFCs have calculated critical loads for acidity and eutrophication, mostly based on soil properties and steady-state mass balance methods (Posch et al., 2005). In the call of 2007, for the first time NFCs have also been asked to submit *empirical* critical loads for eutrophication. These empirical critical loads (*CLempN*) are based on Achermann and Bobbink (2003) and were derived from scientific studies or expert knowledge on the effects of long term (at least 2-3 years) increased nitrogen deposition on the structure and function of natural and semi-natural ecosystems. For the descriptions of ecosystems the EUNIS habitat classification (Davies et al., 2004) was used. The empirical critical loads are presented as ranges (in kg N $ha^{-1}a^{-1}$).

Not for all EUNIS habitat types *CLempN* are available, since no or not yet enough published scientific studies exist from which *CLempN* could be derived (Bobbink, personal comment 2007). No additional literature studies were conducted to fill gaps in missing *CLempN* values for other EUNIS codes. For forest systems Dorland and Bobbink (2005) prepared *CLempN* data, however these have to be approved yet in an expert workshop. During this project Dr. R. Bobbink was consulted to discuss possibilities for the application and differentiation of empirical critical load ranges.

Adaptation of empirical critical loads for EUNIS-classes to the land cover map

To convert the European empirical critical load data to the land cover codes distinguished on the land cover map (see chapter 5), four steps are recognized:

1. check consistency of used EUNIS codes on SEI-map;
2. check necessity and availability of empirical Critical Loads (*CLempN*) for EUNIS classes distinguished on the land cover-map;

3. analyse and study application of differentiation of the *CLempN* ranges according the general relationships mentioned in Achermann and Bobbink (2003);
4. analyse possibilities to adopt *CLempN* for present SEI-EUNIS codes without *CLempN*.

Check the consistency of applied EUNIS codes on SEI land cover map

In this first step the EUNIS codes and descriptions from the land cover map were compared with the EUNIS classification by Davies et al. (2004). On this land cover map EUNIS-codes were applied, except for forests and agricultural lands. In most cases second level EUNIS-codes or combinations of these codes were used, while for grasslands EUNIS-classes E1 and E2 combinations of third level codes were used. All coastal habitats are grouped to the first EUNIS class (B). Forest were coded on the land cover map according SEI codes from a former EUNIS version (1000 till 1072, 2000 till 2270 and 3000 till 3177), though those had already been preliminary grouped in second level EUNIS classes G1, G3 and G4 according to the most recent EUNIS classification. Agricultural land, other than grassland, was coded I1 by SEI with numbers 1-1031, of which the numbers refer to the dominant crop that was cultivated on the agricultural land. These agricultural codes were grouped for this project in EUNIS class I1 (Arable land and market gardens).

In this project two numeric classifications have been used to describe all present EUNIS codes on second and on third level in the Land cover map and in the data submitted by the NFCs. These classifications have to be created because the Land cover map contains also codes which are combinations of EUNIS classes, like ‘A3 or A4’. The classification on the second level makes it possible to compare the EUNIS-codes of the Land cover map with the EUNIS-codes in the NFC-dataset. The classification on the third level will be used for the assignment of empirical critical loads. Annex 6-A contains the overview of the classes in the second level and third level numeric EUNIS-classification present on the land cover map.

Check of necessity and availability of empirical critical loads for EUNIS-classes on the land cover map

To check the necessity and availability of *CLempN* for the EUNIS classes on the land cover map the following sources were used:

- The overview of the EUNIS codes on the land cover map (the result from Step 1);
- The report with the descriptions of the EUNIS classes by Davies et al. (2004);
- The overview with available *CLempN* per EUNIS class by Achermann and Bobbink (2003).

The EUNIS classes distinguished on the SEI land cover map are presented with the short habitat description in Table 6-1. For each of these EUNIS code the necessity for considering this habitat in CL analysis was evaluated by assessing the descriptions of the EUNIS class (Davies et al. (2004). E.g. the A3/A4 EUNIS class in the SEI land cover map is described as Infra- and Circalittoral rock and other hard substrata. These habitats are variable saline, dominated by kelp, seaweed or animals and variable influenced by wind, tidal streams and wave action. We considered that probably little effect of nitrogen enrichment via nitrogen deposition will occur in these habitat types. All Coastal habitats on the SEI land cover map are grouped in EUNIS class B. This class on the SEI map therefore combines among others the unvegetated coastal dunes and sandy shores, with coastal dune heaths and dune slacks, coastal shingles, soft and rock cliffs. For most classes, though not all (e.g. B1.1 and B3.2), CL analysis is recommended. However, this distinction is not possible on the SEI land cover map. EUNIS class C3 refers to littoral zones of inland surface water bodies. Nitrogen enrichment may also affect these habitats.

In Table 6-1 the necessity for CL analysis of each EUNIS habitat from the SEI map is represented; ‘-’ refers to the habitats for which CL analysis is not necessary (e.g. A3/A4); ‘+/-’ refers to habitat class for which part of the habitats are sensitive to nitrogen enrichment and should be considered in CL analysis (e.g. B); ‘+’ refers to habitats that are probably nitrogen sensitive and CL analysis are recommended (e.g. C3).

***Table 6-1**. Overview of EUNIS vegetation classes distinguished on the SEI land cover map and information on necessity for CL analysis, availability and ranges of empirical Critical Load. Necessity for CL analysis and availability of CLempN is represented by: - = no; + = yes and +/- = for part of the EUNIS class. Bold black CLempN ranges are based on identical EUNIS classes reported by Achermann and Bobbink (2003), grey values represent CLempN (ranges) adopted from known CLempN information based on expert knowledge. In the most right column the source of the CLempN range and/or additional comments are represented (B2002: Achermann and Bobbink (2003) and EUNIS code).*

EUNIS CODES SEI MAP	SHORT DESCRIPTION (DAVIES *ET AL.* 2004)	NECESSITY FOR CL ANALYSIS	IS *CLempN* INFORMATION AVAILABLE	*CLempN* RANGE (KG N/HA.A) MIN	MAX	BASED ON / REMARK:
A1 or A2 without A2.5	Littoral rock/sediment and other hard substrata without A2.5	-	-			
A2.5	Coastal salt marshes and saline reed beds	+	+	**30**	**40**	B2002: A2.54; A2.55
A3 or A4	Infra- and Circalittoral rock and other hard substrata	-	-			
A3 or A4 or A5	Infra-, littoral rock, sediments and other hard substrata	-	-			
A5	Sublittoral sediment	-	-			
B	Coastal habitats	+/-	+/-	ND (10)	ND	
C1	Surface standing waters	+	+/-	ND (5)	ND	* *CLempN* class C1.1 (or C1.16) not representative for C1
C2	Surface running waters	+	-	ND	ND	* not enough background information
C1 or C2	Surface standing and running waters	+	+/-	ND (5)	ND	* *CLempN* class C1.1 (or C1.16) not representative for C1/ C2
C3	Littoral zone of inland surface water bodies	+	-	ND	ND	* not enough background information
D1	Raised and blanket bogs	+	+	**5**	**10**	B2002: D1
D2 or D4	Valley mires, poor fens, transition mires or base-rich fens, calcareous spring mires	+	+	**10** **15** **15**	**20** **35** **25**	B2002: D2.2; B2002: D4.1; B2002: D4,2
E1 without E1.2, E1.7, E1.8, E1.9, E1.A	Dry grasslands without E1.2, E1.7, E1.8, E1.9, E1.A	+	-	15	25	* all base-rich vegetation types; therefore *CLempN* adopted from B2002: E1.26
E1.2	Perennial grasslands and basic steppes	+	+/-	15	25	* variety of wetness in class E1.2; best estimate *CLempN* of subclass B2002: E1.26
E1.7 or E1.9	Non-Mediterranean dry acid and neutral grassland	+	+	**10**	**20**	B2002: E1.7; E1.94; E1.95
E1.8 or E1.A	Mediterranean dry acid and neutral closed/open grassland	+	-	15	20	* value adopted high value range temperate equivalent B2002: E1.7; E1.94; E1.95
E2 without 2.3	Mesic grasslands without E2.3	+	+/-	20	30	* value adopted from E2.2, though different habitats are represented by E2
E2.3	Mountain hay meadows	+	+	**10**	**20**	B2002: E2.3
E3	Seasonally wet and wet grasslands	+	+/-	ND (10)	ND	* trophic gradient in E3; *CLempN* E3.51 and E3.52 not appropriate for whole E3
E4	Alpine and subalpine grasslands	+	-	5	15	B2002: E4.2; E4.3; E4.4
E5	Woodland fringes and clearings and tall forb stands	+	-	ND	ND	* diverse vegetations affected by agriculture or saline influences
F1	Tundra	+	+	**5**	**10**	B2002: F1
F2	Arctic, alpine and subalpine scrub	+	+	**5**	**15**	B2002: F2
F4	Temperate shrub heathland	+	+	**10** **10**	**20** **(25) 20**	B2002: F4.11; B2002: F4.2
F5 or F6	Maquis, arborescent matorral and	+	-	ND	ND	* not enough background

EUNIS CODES SEI MAP	SHORT DESCRIPTION (DAVIES *ET AL.* 2004)	NECESSITY FOR CL ANALYSIS	IS *CLempN* INFORMATION AVAILABLE	*CLempN* RANGE (KG N/HA.A) MIN	MAX	BASED ON / REMARK:
	thermo-Mediterranean brushes or Garrigue					information
F9	Riverine and fen scrubs	-	-			
G2000..2279 (G1)	Broadleaved deciduous woodland	+	+	**10**	**20**	B2002: comb. forest layer, dependent on the process of interest
G1000..1072 (G3)	Coniferous woodland	+	+	**10**	**20**	
G3000..3177 (G4)	Mixed deciduous and coniferous woodland	+	+	**10**	**20**	
H3	Inland cliffs, rock pavements and outcrops	-	-			
H4	Snow or ice-dominated habitats	-	-			
H5	Miscellaneous inland habitats with no or sparse vegetation	-	-			
I1	Arable land and market gardens	-	-			
I2	Cultivated areas: gardens/parks	-	-			
J	Constructed, industrial and other artificial habitats	-	-			

In addition, the availability of empirical Critical Loads (*CLempN*) for the present EUNIS codes[3] on the SEI land cover map was examined. The empirical Critical Loads from Achermann and Bobbink (2003) were used. In Table 6-1 the availability of any *CLempN* information for this EUNIS habitat is represented by '+' (= available), '-' (= not available) or '+/-'; which refers to available *CLempN* information for part of the on the SEI map used EUNIS codes. When *CLempN* information is available for a EUNIS class that is identical to the EUNIS class distinguished on the SEI land cover map, the *CLempN* ranges are applied and reported in bold black figures in Table 6.1. For other classes *CLempN* information is available for only part of the EUNIS class from the SEI land cover map (e.g. a *CLempN* is known for the third level EUNIS, while second or first level EUNIS is on the SEI map). The *CLempN* from Achermann and Bobbink (2003) are often set to sensitive ecosystems and these systems are often only a small representative of the whole second or first level EUNIS class. Evaluation of the appropriate *CLempN* range for these EUNIS habitats form the land cover map and adoption of *CLempN* values is discussed in the following section. Besides, for some other EUNIS classes no *CLempN* are available from Achermann and Bobbink (2003).

Analysis and study of differentiation of the ranges

The third step describes the analysis and the study of the application of differentiation of the *CLempN* ranges according the general relationships, mentioned in Achermann and Bobbink (2003). They described several factors which may lead to differentiation within the *CLempN* ranges for non-wetland systems (EUNIS classes E, F and G; Table 6-2). There is not a specific order of importance for these factors (Bobbink, personal comment 2007), though the factors act at different scales. For differentiation of the *CLempN* ranges on a European scale not all factors can be used here. Management activities, or P limitation act on smaller, more local scales. For NFCs this specific information is or could be available and can be used by them. Other factors like temperature or base-

[3] Remark that the EUNIS table was revised and the version of 21-07-2005 was used in this report. The code A2.6 from Achermann and Bobbink (2003) coincides with A2.5 in the revised report.

cation availability are applicable on larger scales and can therefore be used to differentiate the ranges on European scale.

Table 6-2. *Overview factors differentiation CLempN range non-wetland systems (Achermann and Bobbink, 2003).*

Action	Temperature / frost period	Soil wetness	Base-cation availability	P limitation	Management intensity
Move to lower part	COLD/LONG	DRY	LOW	N-LIMITED	LOW
Use middle part	INTERMED	NORMAL	INTERMED	UNKNOWN	USUAL
Move to higher part	HOT/NONE	WET	HIGH	P-LIMITED	HIGH

Table 6-3. *Overview of differentiation of the available CLempN ranges for non-wetland systems cross the biogeographical regions (Cultbase, 2005).* * *For forests (G) a CLempN is available, though the height of the CLempN is dependent of the process.*

		Alpine North	**Boreal**	**Nemoral**	**Alpine South**	**Continental**	**Pannonic**	**Atlantic North**	**Atlantic Central**	**Mediterranean mountains**	**Mediterranean North**	**Lusitanian**	**Mediterranean South**
EUNIS class	gr. seas. (days)	130	157	196	220	227	250	255	296	298	335	353	363
D2 or D4		10-15					15-20						
E1 without E1.2, E1.7, E1.8, E1.9, E1.A		15-20					20-25						
E1.2		15-20					20-25						
E1.7 or E1.9		10-15					15-20						
E1.8 or E1.A						15-20							
E2 without 2.3		20-25					25-30						
E2.3		10-15					15-20						
E4		5-10					10-15						
F1						5-10							
F2		5-10					10-15						
F4		10-15					15-20						
G1 (2000..2279)		ND*											
G3 (1000..1072)		ND*											
G4 (3000..3177)		ND*											

To differentiate the *CLempN* range for non-wetland habitat across Europe by application of differences in temperature/frost period we propose to use biogeographical regions as a first step. From these biogeographical regions information (Cultbase, 2005) is available, among other on the length of the growing season, as a proxy for long winters and frost periods. Table 5-3 shows the different biogeographical regions with the average length of the growing season. The empirical critical loads are differentiated linearly in ranges of 5 kg $N{\cdot}ha^{-1}{\cdot}a^{-1}$ over the biogeographical regions according the length of the growing season. In general, this leads to a division of the range in two groups (Figure 6.5).

The subranges of 5 kg N $ha^{-1}{\cdot}a^{-1}$ were chosen, since no better accuracy can be obtained as several factors affect the *CLempN* for a specific habitat. A more accurate decision for differentiation could be made when several factors are used. On European scale application of base cation availability, in addition to temperature/frost period would enhance the decision for differentiation. For forests the *CLempN* are not divided in two subgroups, since the *CLempN* range of 10-20 is dependent on the (biological) process one focuses on for nitrogen sensitivity.

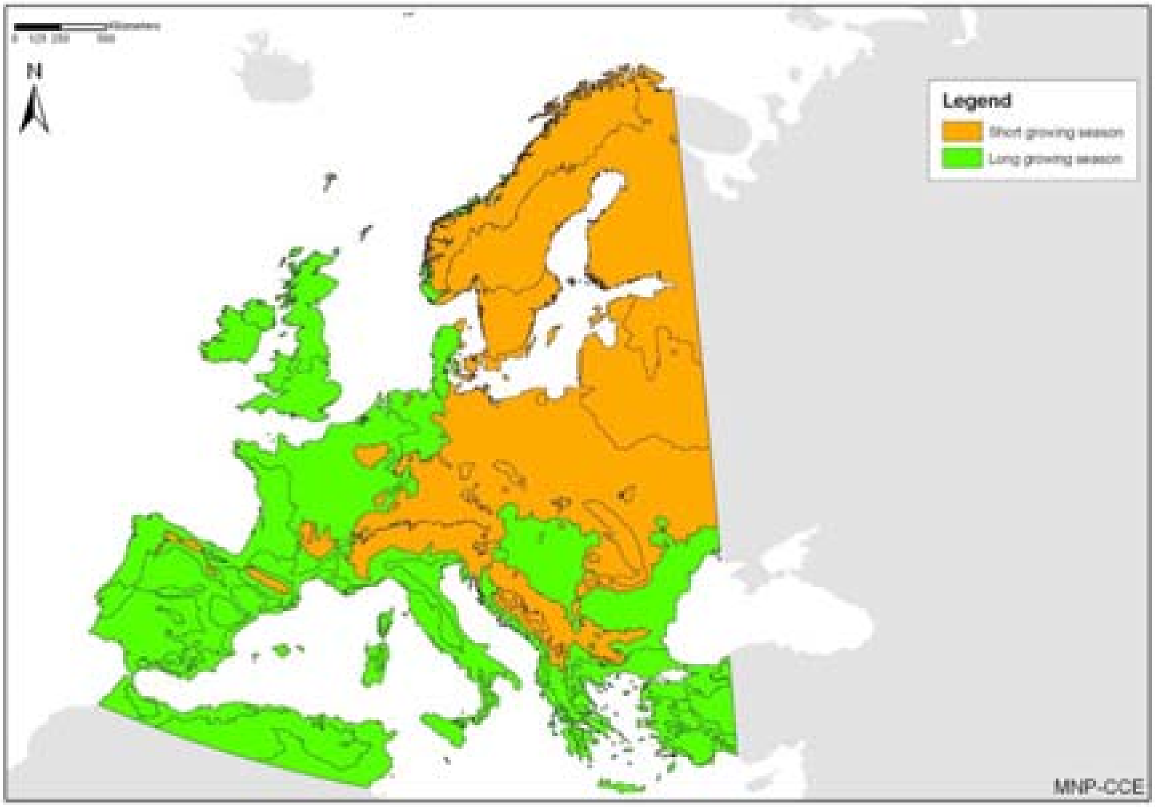

Figure 6-5. *Overview of two groups of biogeographical regions across Europe (Cultbase, 2005).*

Analysis of possibilities to derive missing *CLempN*

The last step is the analysis of the possibilities for derivation of missing *CLempN* for a number of SEI-EUNIS codes. From Table 2 it is clear that there exist gaps in the knowledge on the *CLempN* for almost all EUNIS classes. Achermann and Bobbink (2003) remarked that there is limited knowledge on the effects of enhanced nitrogen enrichment for specific habitat types, especially for steppe grassland, all Mediterranean vegetation types, wet-swamp forests, many types of mires and fens, several coastal habitats and high altitude systems. However, also for other vegetation types additional information is needed to be able to apply *CLempN* on the SEI-map.

For some EUNIS classes *CLempN* ranges are available, but also complications arise because on the SEI-map some EUNIS classes were grouped with other EUNIS classes for which no *CLempN* is available or necessary. Based on expert knowledge we filled the gaps by adoption of *CLempN* from comparable systems, or adopting the values from a third level EUNIS group within the EUNIS class. In adopting *CLempN* we apply the precautionary principle. From a conservation point of view it is recommended to apply the lowest *CLempN* available to protect also the more sensitive habitat types. Therefore, we advise to choose the lowest *CLempN* value. For each adopted value, the motivation is added below and shortly commented in Table 6-1.

Additional information on the assignation of *CLempN* ranges from Table 6-1 is given here:

Inland surface waters (EUNIS class C)

- We choose not to set a *CLempN* range for waters of C1. The known *CLempN* (Achermann and Bobbink, 2003) is only assigned to permanent oligotrophic waters (C1.1) and to a subgroup of these waters (C1.16). These water types are only a small representative of the whole C1 level, while other C1-waters have generally a higher nutrient availability. One could choose to set the *CLempN* range based on the most sensitive system (here C1.1), however this is probably a too low estimate for most waters. Setting a higher value for the C1 level would result in an inaccurate value for the waters within the C1 level belonging to C1.1.
- For surface running waters and the littoral zone of these waters, C2 and C3, respectively, no *CLempN* could be set due high variability of systems within these groups.

Mires, bogs and fen habitats (EUNIS class D)

- On the land cover map the grouped EUNIS classes 'D2 or D4' are distinguished. For both D2 and D4 *CLempN* information is available from scientific research. However, it is impossible to discriminate between D2 (poor fens) or D4 (rich fens) on the land cover map. Since many of these systems are vulnerable for N-enrichment, we suggest using the lowest *CLempN* range for the combined group.

Grasslands and tall forb habitats (EUNIS class E)

- On the SEI-map the EUNIS second EUNIS level E1 was split in the following classes: 'E1 without E1.2, E1.7, E1.8, E1.9, E1.A', 'E1.2', 'E1.7 or E1.9' and 'E1.8 or E1.A'. Only for 'E1.7 or E1.9' *CLempN* information is available.
  - The subgroup of dry grasslands, 'E1 without E1.2, E1.7, E1.8, E1.9, E1.A' on the SEI-map consists mainly of base-rich soils. High base cation availability lowers the vulnerability for nitrogen enrichment (table 5.1). For E1.26, a subgroup of the base-rich groups within E1, a *CLempN* is known. Therefore, we adopt the *CLempN* of E1.26 for the whole 'E1 without E1.2, E1.7, E1.8, E1.9, E1.A group' on the SEI-map.
  - For E1.2, the *CLempN* from the E1.26 is the best estimate, therefore this *CLempN* was adopted.
  - The systems E1.8 or E1.A are Mediterranean equivalents of E1.7 or E1.9. For the latter systems a *CLempN* was set. In general Mediterranean systems have longer growing seasons and higher temperatures compared to temperate systems. Therefore nutrient turn-over rates are higher. The *CLempN* for the Mediterranean systems E1.8 or E1.A, distinguished on the SEI land cover map, was therefore set on the high end of the range of the *CLempN* for E1.7 or E1.9.
- The mesic grasslands grouped under 'E2 without E2.3' are often cultivated by men. They contain lowland and montane mesotrophic and eutrophic pastures and hay meadows of the boreal, nemoral, warm temperate humid and Mediterranean zones, but also sports fields and agricultural improved and reseeded grasslands (Davies *et al.* 2004). The *CLempN* from 'E2.2 low and medium altitude hay meadows', is not the best representative for the whole E2 group. However, no better *CLempN* information is available and therefore this *CLempN* range was adopted for this whole group.
- No *CLempN* was set for E3. Within 'E3: Seasonally wet grasslands' a gradient of nutrient availability exists. E3.51 and E3.52, for which *CLempN* were set by Achermann & Bobbink, (2003), represent oligotrophic systems and are not representative for whole E3. Other systems in this group are generally more eutrophic or Mediterranean (i.e. potentially higher *CLempN* due to higher nutrient turnover and longer growing seasons).
- In E5 woodland fringes and clearings and tall forb stands many different circumstances (nutrient availability and wetness) are grouped. In addition, no *CLempN* information is available for this class. Therefore no *CLempN* was set.

Heathland, scrub and tundra habitat (EUNIS class F)

- For F4 *CLempN* are distinguished on the second and third level. F4 represents wet, dry and macaronesian heaths. The macaronesion have probably higher *CLempN* values than wet and dry heaths for which *CLempN* are known. However, across Europe wet and dry heaths are more present. Since no different classes within F4 can be distinguished on the land cover map, we suggest setting the *CLempN* for this habitat type to the lowest *CLempN* range for the combined group.

In some cases no appropriate *CLempN* range could be adopted. For some EUNIS classes for which CL analysis is sensible, one could, however, choose to add the minimum value of the available *CLempN* information for this class. A maximum *CLempN* can, however, not be set. Absence of any *CLempN* will result in no evaluation for exceedance of nitrogen deposition of a habitat at all, though it is to some level sensitive to nitrogen deposition (Hettelingh, personal comment 2007). The minimum *CLempN* -values are added in brackets in Table 6-1.

Assigning CLempN to the land cover map to create a European background database

For each continuous region of the land cover map, the minimum and the maximum *CLempN* from Table 5.3, or if the differentiation does not apply, Table 6-1 can be assigned as the critical load. This way, two datasets are created, the minimum and the maximum *CLempN*. The datasets are onwards referred to *EmpBGMin* and *EmpBGMax*. Maps of the 5th percentile of each dataset are shown in Figure 6-6. For this maps EUNIS-classes B and C were not included, since for these classes no maximum had been determined The lowest *CLempN* are found in the mountainous areas, in Scandinavia and western Ireland.

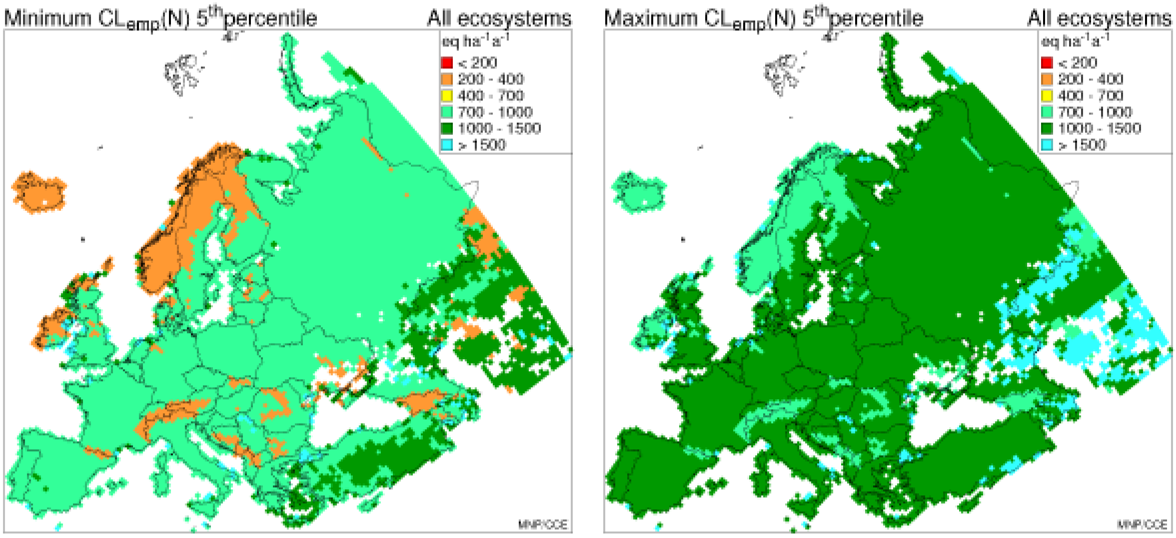

Figure 6-6. *Minimum (left) and maximum (right) CLempN -map (EMEP-grid, 5th percentile).*

Comparison with methodology of SEBI-project

On 22 November 2006 the methodology of adaptation of the European empirical critical loads to EUNIS classes of the land cover-map and the differentiation of the *CLempN* ranges across Europe was discussed with A. van Hinsberg, MNP, Bilthoven, Netherlands. Van Hinsberg is working at the National Focal Centre of the Netherlands and has done a comparable analysis for Dutch habitats as part of the SEBI-project. The approach of applying empirical critical loads to EUNIS classes of the SEI-map and the differentiation of the *CLempN* ranges across Europe was comparable between our and the SEBI-project.

The NFCs have more detailed information available on different habitats than are present on the land cover map. In addition to the *CLempN* from Achermann and Bobbink (2003), A. van Hinsberg applied also the formulated *CLempN* from Dorland and Bobbink (2005). To differentiate within the *CLempN* ranges in the Netherlands Van Hinsberg applied a model in which temperature difference, hydrology, soil properties, etc were put. The outcome of this model determined the height within the *CLempN* range. The approach followed in this project is comparable. Application of the forest *CLempN* from Dorland and Bobbink (2005) in this study would improve the result only slightly, since only limited EUNIS classes are described. However, these *CLempN* have not yet been set officially. The use of biogeographical regions, as a basis for temperature differences across Europe is a good alternative approach. Adding base-cation availability would enhance the possibility to differentiate the *CLempN* range more accurately. Good maps on temperature/frost period and soil properties are available at CCE. Van Hinsberg also formulated the wish to differentiate *CLempN* ranges in smaller steps, to stimulate the use of empirical critical loads across NFCs in Europe. However, since several factors influence the prevailing *CLempN* for a specific habitat, an exact value for a specific biogeographical region is inappropriate. In addition, these *CLempN values* are based on scientific research that has a certain variation.

6.5 Comparison of the critical loads

General

We compared the empirical critical loads from the land cover map (minimum and maximum of the ranges, EmpBGmin and EmpBGmax respectively, see previous paragraph) with the critical loads from the NFCs. Figure 6-7 shows the EMEP50 grid minimum of EmpBGmin, the grid maximum of EmpBGmax, and the grid minimum of the modelled and the empirical critical load of nitrogen. The three maps with empirical critical loads show similar regional distributions of relatively low and high values.

From the NFCs modelled critical loads as well as empirical critical loads were available from a 2007 call. So, we compared the *CLempN* from the land cover map with both the *CLnutN* and *CLempN* from the NFCs submissions. The comparison was made in two steps. Firstly, we checked whether the *CLnutN* and *CLempN* from the NFCs are within the *range* of the *CLempN* of the land cover map. Secondly, we compared the minimum values of critical loads for nitrogen for each of the EMEP50 grid cells.

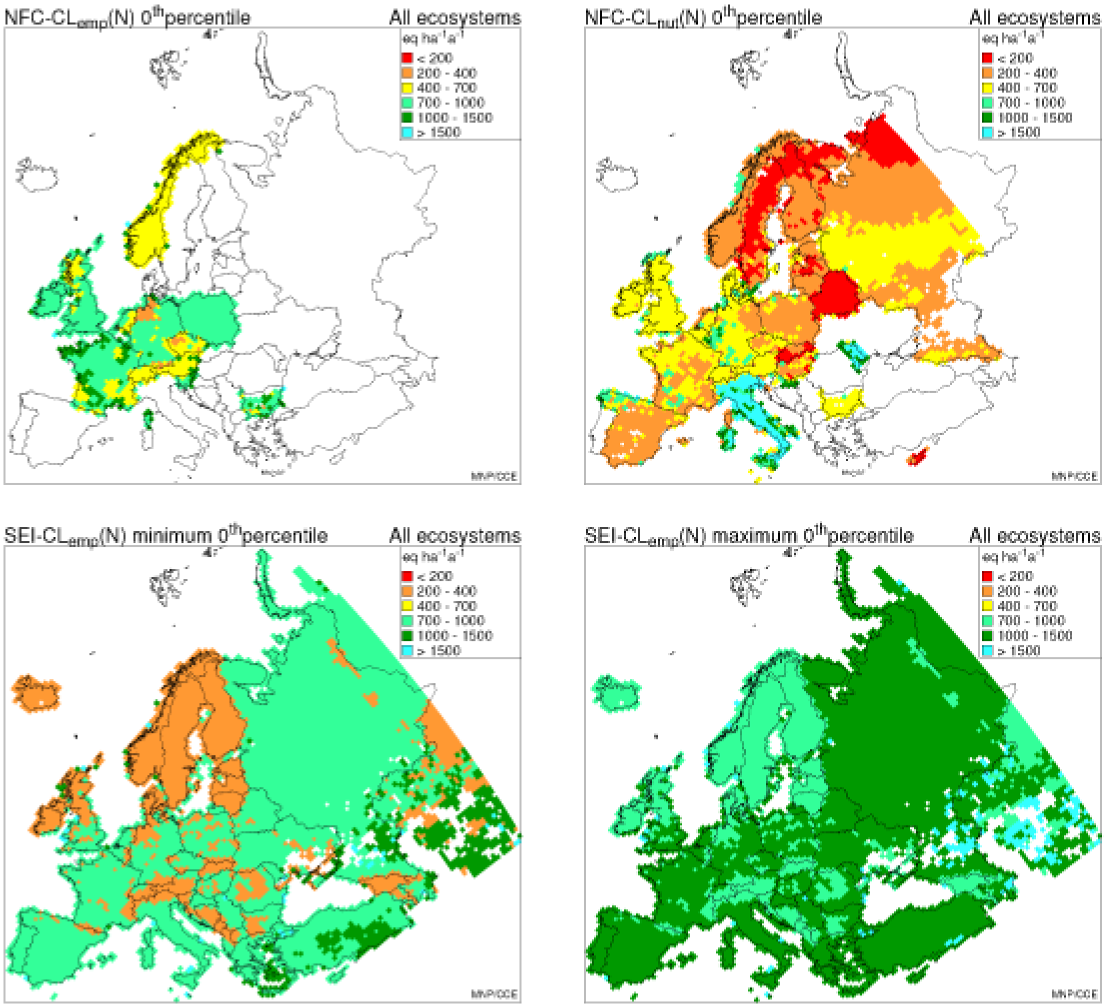

Figure 6-7. *Minimum (0th percentile) of CLnutN and CLemp of the NFC submission (top row), the 0th percentile of the minimum of the land cover derived empirical load ranges (EmpBGmin, bottom left)) and 100th percentile of the maximum of the land cover derived empirical load ranges (EmpBGmax, bottom right).*

Check CLnutN of NFCs within range of CLempN of land cover map

A first comparison is made between the critical loads of the NFCs and the empirical critical loads from the SEI-map at the level of EMEP50 grid cells. For this comparison we used the lowest and highest CLempN per EMEP50 grid cell as range. EUNIS-classes B and C were excluded from this analysis, because for these classes no maximum could be derived (see Table 6-1). In Figure 6-8 (left) the percentage of NFC-sites with critical load values within the range of *CLempN* of the land cover map are presented. In north-west and central Europe most of the NFC *CLnutN* values are within the range of the *CLempN* from the land cover map, in contrast to the Mediterranean countries, North Sweden, Finland and Russia. Of course this figure does not indicate whether the NFC *CLempN* is lower or higher than the *CLempN* from the land cover map. Therefore we compared in addition the minimum *CLnutN* from the NFCs with the minimum *CLempN* of the land cover map (Figure 6-8 right), since the minimum critical loads are the most important protection levels to be taken into account.

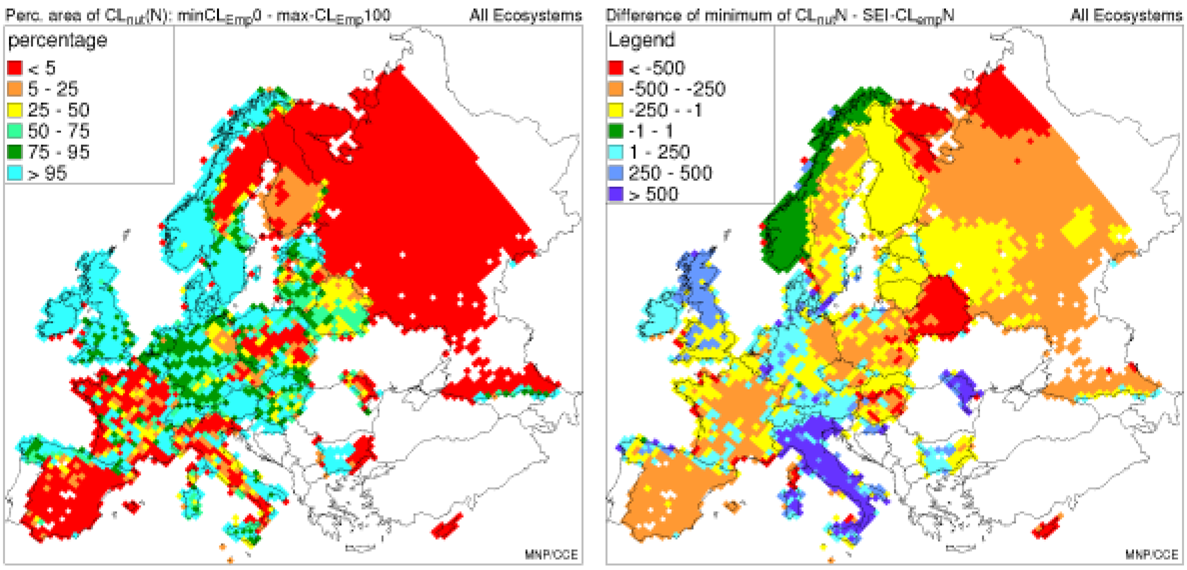

Figure 6-8. *Left: Percentage of NFC-sites of which the CLs lie within the range of CLempN of the land cover map; Right: Difference of minimum critical load (eq* ha^{-1} a^{-1}*) between the NFC CLnutN and the CLempN of the land cover map.*

From Figure 6-8 (right) it is clear that in most parts of Europe, modelled critical loads are lower than the *CLempN* from the empirical background dataset, except for Italy, Moldavia and parts of the United Kingdom.

We can conclude that in most of Spain, France and the North-East part of Europe the modelled critical loads are much lower then the empirical critical loads from land cover dataset, and in Italy and Moldavia much higher values are found for modelled critical loads.

Check *CLempN* of NFCs within range *CLempN* of SEI-map

In the same way a second comparison is made between the *empirical* critical loads of the NFCs and the empirical critical loads from the SEI-map at the level of EMEP50 grid cells (Figure 6-9 left). In Figure 6-9 (left) we see that the *CLempN* from the NFCs are generally within the range of *CLempN* from the land cover map. This could be expected because all *CLempN* were derived from the same scientific source, using the same guidelines. We did an additional analysis by comparing the minimum *CLempN* from the NFCs and the land cover map (Figure 6-9 right). From Figure 6-9 (right) it is clear that the *CLempN* from the NFCs are generally higher than the *CLempN* from the land cover map, probably because most NFCs do not use a minimum but the average *CLempN*.

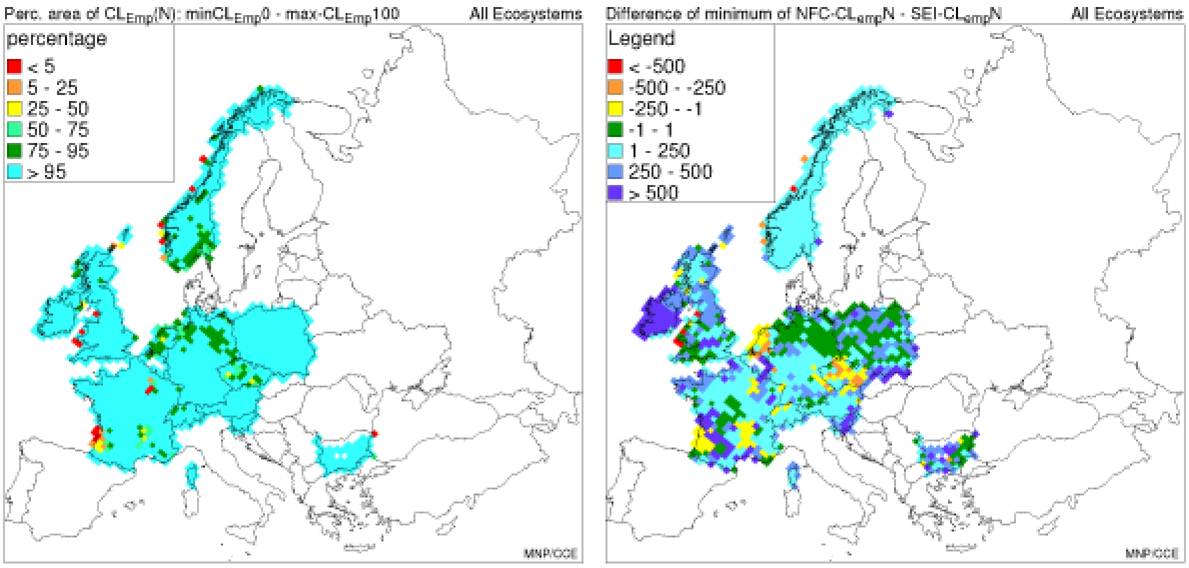

Figure 6-9. *Left: Percentage of NFC-sites of which the CLempN is within the range of CLempN of the SEI-map; Right: Difference of minimum critical load (eq ha^{-1} a^{-1}) between the NFC-CLempN and the CLempN of the SEI-map.*

6.6 Conclusion and recommendations

Conclusions

For the harmonization of the input of the NFCs, European data on critical loads for nitrogen and distribution of ecosystems have been compared with the national input from the NFCs. The European empirical critical loads for nitrogen from Achermann and Bobbink (2003) have been adapted for the critical load calculations. Empirical critical loads are lacking or not yet available for a large number of ecosystem types. The necessity and possibilities to derive and diversify information on empirical critical loads are evaluated. In addition a 100 m grid European land cover map have been produced, based on information of SEI, presents information on the distribution of ecosystems according to the second and third level of the EUNIS-classification, the harmonized land cover map. A European critical load map based on the European empirical critical loads and on the land cover map is presented. From the comparison between the distribution of ecosystems according to the NFCs and the land cover map, which was only possible for forest ecosystem, appeared that for a number of countries there is a moderate correspondence in the forest areas, although the spatial distribution of the forest in both maps are similar. From a second comparison between the critical loads from the NFCs and the empirical critical loads from the land cover map, it appeared that there is a reasonable agreement between the two sources and those differences can be explained by the fact that NFCs generally use lower critical loads. As expected, there is a good correspondence between the empirical critical loads assigned by the NFCs and the land cover map.

Recommendations

The first group of recommendations focuses on the availability of information and use of empirical critical loads:

A large number of empirical critical loads are missing or not yet available. The research and derivation of empirical critical loads for the missing ecosystem types should be continued, for instance for forests, heathland and grasslands.

For the differentiation of empirical critical loads across Europe, additional information should be used, especially the ‘base cation availability’ and ‘temperature/frost period’. The NFCs should use additional information (e.g. P-limitation) to diversify their empirical critical loads.

The empirical critical loads are now produced on basis of all ecosystem types, from (semi)natural to agricultural systems (EUNIS class I and E2.6). We recommend that only semi-natural and natural ecosystems should be considered.

A second group of recommendations focus on the production and use of the European land cover map, the SEI-map:

From the SEI-map no distinction can be made between agricultural and (semi)natural grasslands, which is very relevant from the point of view of critical loads. We therefore recommend that at least this distinction could be made in future maps.

Empirical critical loads are often on the third level (or even lower) of EUNIS-classification and the ecosystem information on the land cover map is on the second level. For a better fit of empirical critical loads and map information we recommend that where possible a third level classification of ecosystems is used on the future maps.

We recommend investigating in depth differences in the assignment of ecosystem types and areas and in CLs between NFCs and the SEI-map and how these differences optimal can be analysed, to support the harmonization-process.

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Annex 6-A EUNIS Classes (Up to level 3) present in the land cover map

Numeric code (E3)	EUNIS CODE list	EUNIS description	Numeric code`(E2) combi
1000	A	Marine habitats	100
1100	A1	Littoral rock and other hard substrata	112
1102	A1 or A2 without A2.5	Littoral rock and other hard substrata or Littoral sediment without Coastal saltmarshes and saline reedbeds	112
1200	A2	Littoral sediment	112
1250	A2.5	Coastal saltmarshes and saline reedbeds	112
1300	A3	Infralittoral rock and other hard substrata	134
1304	A3 or A4	Infralittoral rock and other hard substrata or Circalittoral rock and other hard substrata	134
1349	A3 or A4 or A5	Infralittoral rock and other hard substrata or Circalittoral rock and other hard substrata or Sublittoral rock	139
1400	A4	Circalittoral rock and other hard substrata	134
1500	A5	Sublittoral sediment	105
1600	A6	Deep-sea bed	106
1700	A7	Pelagic water column	107
1800	A8	Ice-associated marine habitats	108
2000	B	Coastal habitats	200
2100	B1	Coastal dunes and sandy shores	201
2200	B2	Coastal shingle	202
2300	B3	Rock cliffs, ledges and shores, including the supralittoral	203
3000	C	Inland surface waters	300
3100	C1	Surface standing waters	301
3102	C1 or C2	Surface standing waters and surface running waters	312
3200	C2	Surface running waters	302
3300	C3	Littoral zone of inland surface water bodies	303
4000	D	Mires, bogs and fens	400
4100	D1	Raised and blanket bogs	401
4200	D2	Valley mires, poor fens and transition mires	424
4204	D2 or D4	Valley mires, poor fens and transition mires or Base-rich fens and calcareous spring mires	424
4300	D3	Aapa, palsa and polygon mires	403
4400	D4	Base-rich fens and calcareous spring mires	424
4500	D5	Sedge and reedbeds, normally without free-standing water	405
4600	D6	Inland saline and brackish marshes and reedbeds	406
5000	E	Grasslands and lands dominated by forbs, mosses and lichens	500
5100	E1	Dry grasslands	501
5109	E1 without E1.2, E1.7, E1.8, E1.9, E1.A	Dry grasslands without Perennial grasslands and basic steppes or Non-Mediterranean dry acid and neutral closed grassland or Non-Mediterranean dry acid and neutral closed grassland or Mediterranean dry acid and neutral closed grassland or Mediterranean dry acid and neutral open grassland	501
5120	E1.2	Perennial grasslands and basic steppes	501
5179	E1.7 or E1.9	Non-Mediterranean dry acid and neutral closed grassland or Non-Mediterranean dry acid and neutral closed grassland	501
5189	E1.8 or E1.A	Mediterranean dry acid and neutral closed grassland or Mediterranean dry acid and neutral open grassland	501
5200	E2	Mesic grasslands	502
5209	E2 without 2.3	Mesic grasslands without Mountain hay meadows	502
5230	E2.3	Mountain hay meadows	502
5300	E3	Seasonally wet and wet grasslands	503
5400	E4	Alpine and subalpine grasslands	504
5500	E5	Woodland fringes and clearings and tall forb stands	505
5600	E6	Inland salt steppes	506
5700	E7	Sparsely wooded grasslands	507
6000	F	Heathland, scrub and tundra	600
6001	FA	Hedgerows	610
6002	FB	Shrub plantations	611
6100	F1	Tundra	601
6200	F2	Arctic, alpine and subalpine scrub	602
6300	F3	Temperate and Mediterranean-montane scrub	603
6400	F4	Temperate shrub heathland	604
6500	F5	Maquis, arborescent matorral and thermo-Mediterranean brushes	656
6506	F5 or F6	Maquis, arborescent matorral and thermo-Mediterranean brushes or Garrigue	656
6600	F6	Garrigue	656
6700	F7	Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff	607
6800	F8	Thermo-Atlantic xerophytic scrub	608

Numeric code (E3)	EUNIS CODE list	EUNIS description	Numeric code`(E2) combi
6900	F9	Riverine and fen scrubs	609
7000	G	Woodland, forest and other wooded land	700
7100	G1	Broadleaved deciduous woodland	701
7300	G3	Coniferous woodland	703
7400	G4	Mixed deciduous and coniferous woodland	704
7500	G5	Lines of trees, small anthropogenic woodlands, recently felled woodland, woodland and coppice	705
8000	H	Inland vegetated or sparsely vegetated habitats	800
8100	H1	Terrestrial underground caves, cave systems, passages and water bodies	801
8200	H2	Screes	802
8300	H3	Inland cliffs, rock pavements and outcrops	803
8400	H4	Snow or ice-dominated habitats	804
8500	H5	Miscellaneous inland habitats with very sparse or no vegetation	805
8600	H6	Recent volcanic features	806
9000	I	Regularly or recently cultivated agricultural, horticultural and domestic habitats	900
9100	II	Irrigated arable land	901
9100	I1	Arable land and market gardens	901
9200	IN	Non-irrigated arable land	902
9200	I2	Cultivated areas of gardens and parks	902
10000	J	Constructed, industrial and other artificial habitats	1000
10100	J1	Buildings of cities, towns and villages	1001
10200	J2	Low density buildings	1002
10300	J3	Extractive industrial sites	1003
10400	J4	Transport networks and other constructed hard-surfaced areas	1004
10500	J5	Highly artificial man-made waters and associated structures	1005
10600	J6	Waste deposits	1006
24000	X	Habitat complexes	2400
25000	Y	Unknown	2500

7. Background database for computing critical loads for the EECCA countries, Turkey and Cyprus

Gert Jan Reinds (Alterra, Wageningen University and Research Centre, the Netherlands)

7.1 Introduction

Since many years, the CCE uses a European background database (Posch and Reinds, 2005; Posch et al., 2003) for testing new methods on a European scale and for gap-filling of European wide critical load maps. This background database basically contains data needed for computing critical loads, but can also be used for dynamic simulations to obtain target loads or for scenario analysis with dynamic models.

Until now, the European background databases covered Europe until 42 degrees East and thus covered only the European part of Russia. Furthermore it did not include Turkey and Cyprus (Posch and Reinds, 2005).

Some of the EECCA (Eastern Europe, Caucasian and Central Asian) countries have indicated that they would like to actively participate in the critical load work under the LRTAP Convention. Furthermore, also Cyprus and Turkey participate now (or will in the nearby future) within the LRTAP Convention work. To stimulate and support these countries, the CCE decided to extend the background database with the EECCA countries, Turkey and Cyprus.

This chapter provides an overview of all data and maps used to extend the background database with these additional countries. Basically the database contains data related to soil, vegetation and climate. In the first section an overview is given of the parameters needed for critical loads calculations to be included in the background database. Section 2 provides an overview and comparison of the vegetation maps available. Section 3 does the same for the soil maps. Section 4 describes the available soil databases and how these were used to compile a soil parameter data set, In section 5 and overview is provided of the forest growth data used. In section 6 some statistics are presented derived from the map overlay procedure. In the last section, some discussion is given about the availability and quality of the data used.

7.2 Principles of the background critical load database

Introduction

The background database is primarily used for calculating critical loads. Therefore, the database should contain those variables that directly or indirectly are used in the critical load equations. Critical loads are computed for combinations of soil and forest (receptors); to compute exceedances, receptors are also distinguished on the basis of a grid for which deposition data are available such as the EMEP grid. For the background database, this means that an overlay was made of a soil map and forest map and a grid cell map. The various maps available are discussed in sections 3 to 5. Below, a short overview is provided of the critical load equations, and the various terms are discussed in view of required parameters.

Critical loads for sulphur and nitrogen related to soil acidification

Using the charge balance in soil solution as the basis, one can derive a critical load for sulphur and nitrogen as (UBA, 2004):

$$CL(S) + CL(N) = BC_{dep} - Cl_{dep} + BC_w - Bc_u + N_i + N_u + N_{de} - ANC_{le,crit}$$

with:

BC_{dep} = deposition of base cations
Cl_{dep} = deposition of chloride
BC_w = base cation weathering
Bc_u = net base cation growth uptake
N_u = net nitrogen growth uptake
N_i = long term net immobilisation
N_{de} = denitrification
$ANC_{le,crit}$ = critical leaching of Acid Neutralizing Capacity

Note, that these critical loads of S and N are not unique; every pair of deposition which fulfils the critical load equation shown above are critical loads.

The critical load function is thus determined by the leaching of acidity, the uptake (removal) of base cations and nitrogen, denitrification and by the deposition of base cations and chloride.

Denitrification in soils is strongly influenced by the soil wetness or soil drainage status. In European wide applications the denitrification fraction *fde* is computed as a function of soil wetness (Reinds et al., 2001).

Removal of base cations and nitrogen by growth uptake can be computed by multiplying net forest growth by stemwood contents of Bc and N. Tables of (ranges in) stemwood contents of N and BC for various tree species are given in, e.g., UBA (2004) based on literature data. Net forest growth is a parameter that needs to be included in the database as there are strong regional differences.

Leaching of acidity is computed by multiplying the water flux leaving the root zone by a critical concentration; this concentration is normally derived from a given Al or Al:Bc criterion using a chemical equilibrium between the concentrations of Al and H. The database should thus provide data to compute leaching fluxes. For European-wide computations, simple hydrological models can be applied that normally use texture class dependent hydrological characteristics (Reinds et al., 2001) whereas meteorological data can e.g. be obtained from global meteorological data sets (New et al., 1999). Soil texture is thus an essential parameter for computing leaching fluxes. It is also important to estimate the equilibrium constant in the Al-H equilibrium, as this constant is strongly soil texture dependent. Soil texture is finally used to estimate base cation weathering rates.

Deposition of BC and Cl is not included in the background database, but should be obtained from either interpolated measurements or modelling results.

In recent years, dynamic modelling has become an important issue under the LRTAP convention (Posch et al., 2005). Dynamic models need additional input parameters compared to critical load models. For one of the simplest dynamic model currently available (VSD), additional input consists of soil thickness, bulk density, CEC, carbon pool in the topsoil, C/N ratio of organic matter and base saturation. These parameters were included in background database for the EECCA countries, Turkey and Cyprus to allow dynamic computations with VSD.

7.3 Vegetation Maps

A number of vegetation maps exist that could be used to allocate forest areas in the EECCA territory: The first map only covers the EECCA area whereas the other two maps are global maps that can also be used for Turkey and Cyprus.

(1) RLC Forest Cover Map of the Former Soviet Union, 1990 at scale 1:2.5 M. This map distinguishes 38 forest cover classes. An older version of this map (at scale 1:15 M) from the 1973 exists; some sources note the fact that the new map seems to be based on/derived from the old 1970's map and might thus not really represent the state of the forest areas in 1990.
http://gcmd.nasa.gov/records/GCMD_rlc_forest_map_1990.html

(2) USGS global land cover characterization at 1km resolution, based on AVHRR (Advanced Very High Resolution Radiometer) images from 1992-1993. Several land cover classifications are defined for the map with varying number of classes, but the classification detail is (more than) sufficient. http://edcsns17.cr.usgs.gov/glcc/tablambert_euras_eur.html

(3) Global Land Cover 2000 project (GLC 2000) maps from JRC at 1 km resolution based on high resolution satellite images. Classified in 22 land cover classes of which 9 are forest classes. http://www-gvm.jrc.it/glc2000/ (Bartholome et al., 2002)

Figure 7-1 (a-c) shows the amount of detail of the three maps. To allow comparison of the maps to Corine land use data (that do not cover Russia), an area in western Russia including the Baltic States has been selected. Figure 7-1 (d) shows the land cover maps of Corine (with only forests selected) as the map that is probably the most accurate in delineating land cover. This map is also used as one of the base-maps for the land cover maps being developed within the LRTAP convention (Slootweg et al., 2005).

Comparing the maps leads to the following conclusions:

The RLC Forest Cover Map of the Former Soviet Union has (as to be expected based on scale differences in the 3 compared maps) a much lower resolution than both global land cover maps. The fact that the classification of the forests is very detailed is not of much use in the current critical loads computations, as tree species specific data on nutrient uptake or critical limits are hardly available and neither is growth.

There is quite some difference in the forest areas between the two global land cover maps.

The correlation between the GLC 2000 map and the Corine map is (much) better than between the USGS global land cover map and Corine. Another study also has shown that the USGS map is not very accurate in mapping forests areas in Western Europe (taking the Corine map as a reference) (Vescovi et al.).

Given the above described comparison, the GLC 2000 map was used for delineating the forest areas for the background database.

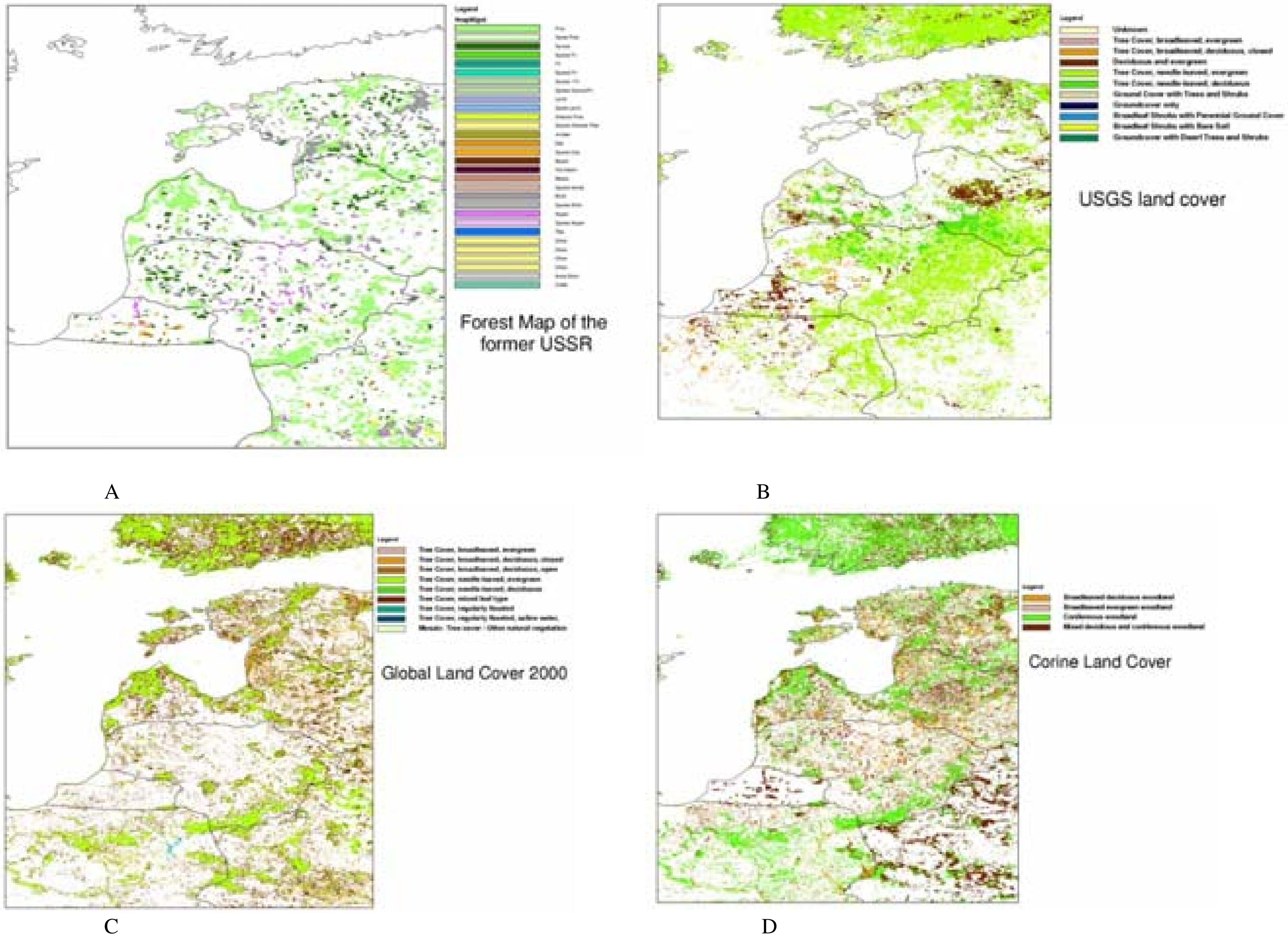

Figure 7-1. *Land cover maps.Soil Maps*

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A number of soil maps exist that cover the EECCA territory:

The FAO soil map of the world and derived soil properties at an original scale of 1:5 million (FAO-UNESCO, 2003) http://www.fao.org/ag/agl/agll/dsmw.htm

The SOTER (Soil and Terrain database) map for Northern and Central Eurasia version 1.0 at scale 1:2.5 M (FAO, 2000) http://www.fao.org/ag/agl/agll/soter.stm

The European Soil Database v2 polygon map (JRC, 2006) at scale 1:1M. http://eusoils.jrc.it/ESDB_Archive/ESDB_Data_Distribution/ESDB_data.html (European Soil Bureau Network, 2004)

For Turkey and Cyprus the only FAO soil map currently available is the FAO 1:5 M soil map of the world (FAO-UNESCO, 2003).

Amount of detail

Figure 2 (a-c) shows the amount of detail in each of the maps.

The maps clearly show that:

- The ESDB map is much more detailed than the other two maps, as was to be expected from the scale differences.
- Although the SOTER maps was produced at scale 1:2.5 M, the amount of detail (at least in this part of the map) does not exceed that of the FAO map at scale 1:5 M
- Delineation of polygons on the three maps is rather different.

Attribute data

Each of the maps has a number of attribute data; for each maps at least soil type, soil texture, slope and soil phase (stony, gravelly etc.) are known. For the SOTER map also terrain information is available such as landform and elevation.

The FAO 1:5M soil map is accompanied by maps with derived soil properties:

- pH
- organic carbon
- nitrogen
- C/N ratio
- CEC soil
- CEC clay
- Base saturation
- Organic carbon pool

Most of these derived properties are divided into four to five classes.

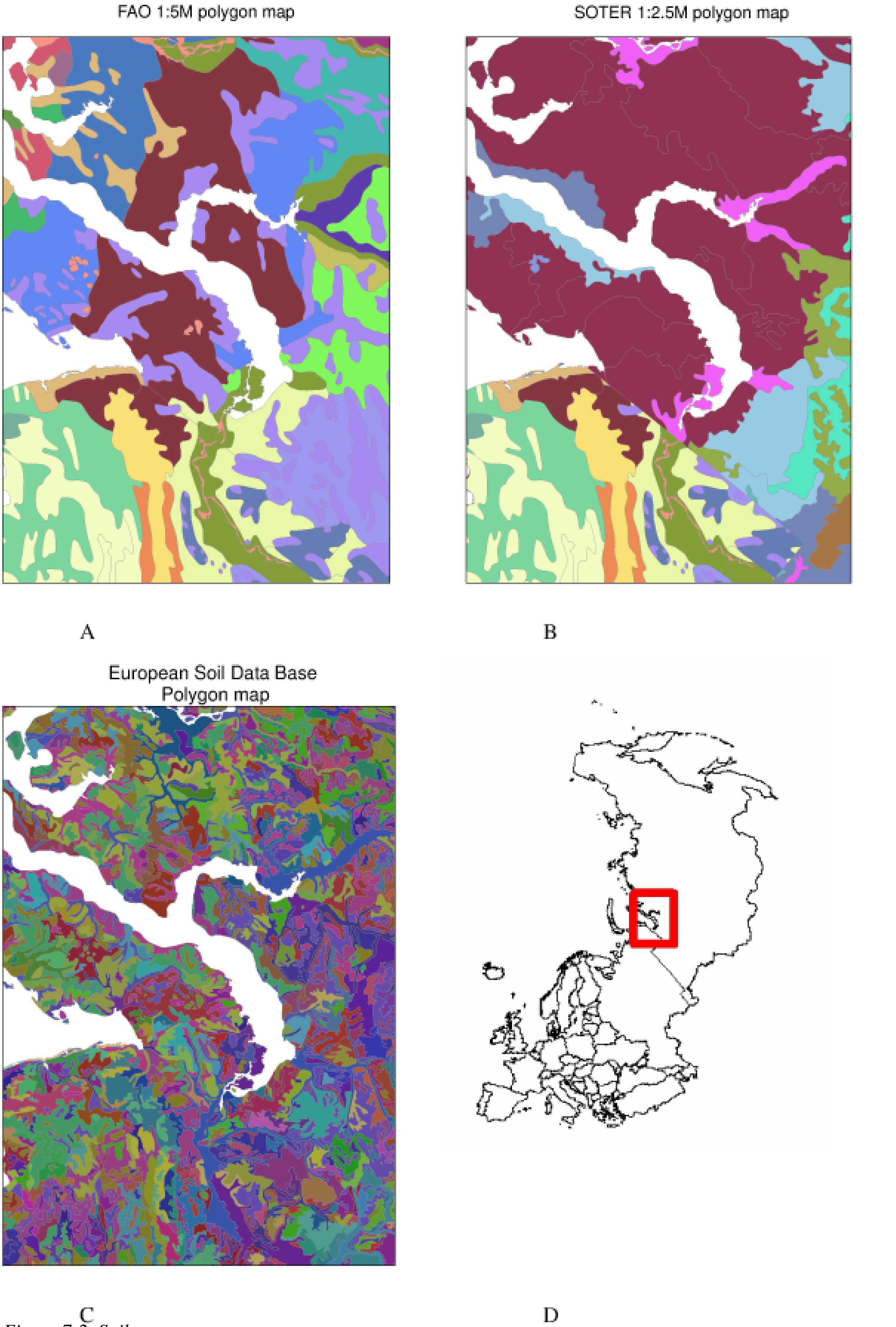

Figure 7-2. Soil maps

The ESDB v2 soil map is accompanied by about 70 derived attributes (including standard attributes such as soil type, soil texture and slope); most relevant for the database are (apart from soil type and soil texture):

- CEC
- Base saturation
- Soil depth
- Available water capacity
- Mineralogy (to be used for weathering rate calculations)

These derived properties are divided into three to six classes each; unfortunately CEC and base saturation are divided in three qualitative classes only (low, medium, high). As a result, the map with derived CEC does not provide the needed amount of resolution, and is inferior to e.g. the FAO 1:5M derived data as e.g. 90 % of the ESDB map consists of two CEC classes only. Therefore, a different approach was used to assign parameters to the map units, as outlined in the next section.

Given the superior amount of detail and the fact that the ESDB v1 map was used as the soil map for the background database of Western Europe (Posch and Reinds, 2005), the ESDB v2 map was selected as the soil map for the background database for the EECCA countries. The FAO 1:5M soil map was used for Turkey, Cyprus and the Commonwealth of Independent States.

7.4 Soil attributes

As describe in the previous chapter, the attribute set supplied with the ESDB soil maps, does not fulfil the requirements for the background database. Some of the needed parameters are only qualitatively described and the number of classes for quantitative parameters is often too limited. As an alternative, external databases can be used that supply quantitative parameters based on measurements in soil profiles.

A homogenized global soil profile database (WISE) exists, that supplies data for 1125 profiles in the world (Batjes, 2002a). Unfortunately, this database contains a very limited number of profiles in the EECCA area. Therefore we have selected the data set by Stolbovoi and Savin (2002) that provides 234 profiles in the EECCA territory. This data set contains all relevant parameters such as CEC, bulk density, base saturation etc. per soil horizon, and thus provides probably the best basis for the background database. From the data set, all profiles that have a natural or semi-natural land use (mostly forest, tundra, bog and meadow) were selected to rule-out influences of soil management such as fertilization or liming on the soil chemical characteristics. Next, the depth-weighted average for 0 - 50 cm depth of all parameters was computed using the horizon thickness as the weighing factor excluding the organic litter layer. In a few cases, organic horizons occurred within the mineral soil, these horizons were left out from the averaging procedure. Also one profile of a mineral soils occurring in a bog area that contained very high organic matter content was not used as it may not be very representative for the soil type. Finally a limited number of profiles of dystric soils that had a base saturation of > 50 % in the upper 50 cm were excluded as these soils should not have been classified as dystric but as eutric. After selection and averaging, 91 soil profiles remain. These profiles form the basis of the soil data set for the EECCA countries. The final soil data set was constructed by grouping the soils according to the FAO 1974 code and texture class, resulting in 45 combinations of soil type and texture class. Results are provided in Annex-7A. The soil types for which data are available cover the majority of the soils occurring on the map, albeit that for a full coverage of all soil types on the map, characteristics have to be assigned from soils grouped at a higher level of classification. Only for a few soil groups no data are available at all in the data set by Stolbovoi and Savin (2002), but these soils occupy less than 0.1 % of the considered area.

To get some first insight in the robustness of the derived soil parameters, a comparison of the parameter values was made with a parameter set based on the WISE data set, in which parameters are assigned to the soil types of the world as a function of soil type, soil depth and soil texture class

(Batjes, 2002b). One should keep in mind that this data set based on the WISE data contains a few profiles from the EECCA territory only and includes all land uses. Figure 7-3 shows that the pH values of both data sets are generally within 1 pH unit; only for a few soil types, the difference is up to 2 units. For CEC, a group of soil-texture combinations exist for which the WISE derived CEC is substantially lower than the EECCA data set. This can be due to effects of land use, as for most of these soils also the organic carbon content in the EECCA data set is higher (which explains the higher CEC). Base saturation from the 2 data sets is generally within about 20 %; only for a few soils large differences exist. Mostly this is explained by the fact that in either of the two data sets the soil contains $CaCO_3$, whereas in the other data set it does not. C:N ratios does not compare so well, but this is probably due to the fact that the EECCA soils are from natural ecosystems only, whereas the WISE derived data set also contains agricultural soils. This explains the relative low C:N ratio's in the latter data set. It also indicates that one has to be careful using data sets with soil properties including all land use classes for natural areas.

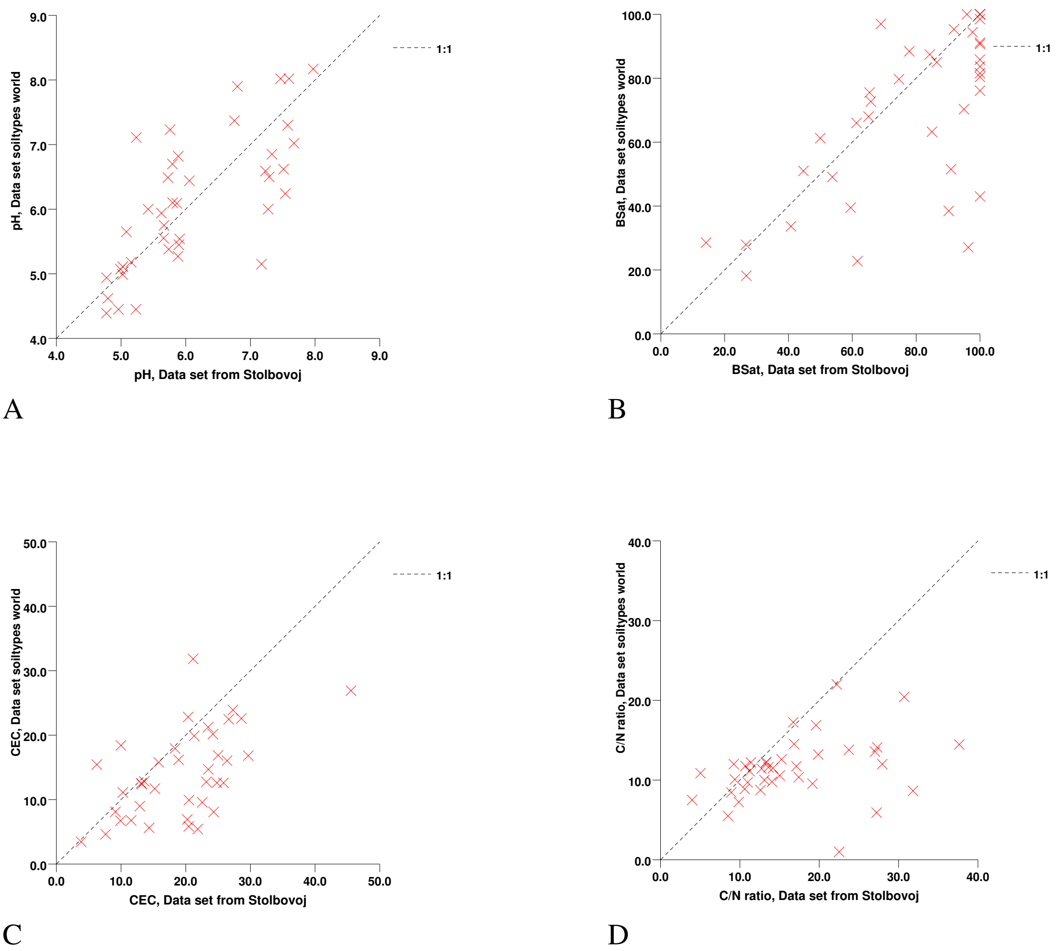

Figure 7-3. *Comparison of soil attributes; pH (A), Base Saturation (B), CEC (C) and C/N ratio in the topsoil (D).*

7.5 Forest growth

To compute uptake of base cations and nitrogen, the net growth rate representative for the ecosystem needs to be known. For the EECCA, Turkey and Cyprus, forest growth rates were estimated from available sources.

For Russia growth rates were derived from (Alexeyev et al., 2004.). These authors have compiled statistical data on growing stock and areas of stocked land from available data sources, tabulated for

74 Republics, Krays and Oblasts within Russia. Although the authors express their concern about the quality of the underlying statistical data, this book still seems currently to be the best possible source of information on forest productivity covering Russia

Productivity as such is not directly provided by (Alexeyev et al., 2004.). Provided are areas per region of conifers forest, deciduous hardwood- and deciduous softwood forests for the age classes young, middle-aged, maturing and mature/over mature forests as well as the standing biomass per region for these species and age classes. For the background database, a rough estimate of net growth was made by computing per age class the standing volume per hectare (using total volumes and stocked areas), assuming ages of 30, 60, 90 and 140 years for the different age classes and fitting through the obtained volumes-age points a logistic function in the form of:

$$GS = \frac{C}{1+\exp^{-b*(age-M)}}$$

with:
GS = growing stock in $m^3\ ha^{-1}$
C,b,M= parameters to be fitted
age = stand age in years

From this constructed growth curve, average growth was computed assuming a rotation period of 90 years, so assuming harvest at the moment the stand becomes mature. Principally, the stand age assumption for the various age classes is of little influence on the results as the average growth rate is computed afterwards over the first 3 age classes.

For the New Independent States, growth rates were obtained from (Prins and Korotkov, 1994), who provide the growing stock per hectare for a.o. the New Independent States. Crudely assuming an average stand age of 60 years provides a first approximation of average forest growth in these regions. Generally growth rates obtained with this method compare well with growth rates obtained from various other sources[4].

For Turkey, growth rates were kindly supplied by the Turkish ICP Forest National Focal Centre as growth rates for 30 species and 2 forest-states (degraded and non-degraded). Furthermore, for a few species growth rates were supplied for coppice and high forest separately. These data were combined with a map showing the distribution of species over Turkey to arrive at growth rates per region per species group (conifers, broadleaves): for each region a visual estimate of the dominant conifers and -broadleaved species (each 1-3 different species) was made and the average of the growth rates of these species was taken as the average growth rate for the region for that species group

For Cyprus a crude approximation of an average growth rate of 0.8 $m^3.ha^{-1}$ was made based on the average standing biomass of 43 $m^3.ha^{-1}$ given by (FAO, 2000) and assuming an average stand age of 60 years.

Growth rates per region obtained by the above described procedure are shown in Figure 7-4 for conifers and broadleaves. Figure 7-4 shows very low growth rates in (< 1 $m^3.ha^{-1}$) in very cold (Kola Peninsula, Eastern Siberia) as well as in very warm and dry regions such as Kazakhstan, Uzbekistan, Turkmenistan and in the degraded forests of south-eastern Turkey. Highest growth rates are found in the European part of Russia, Georgia, Armenia and parts of Turkey were growing conditions are more favourable.

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[4] Other sources are e.g..:
http://enrin.grida.no/htmls/tadjik/soe2/eng/htm/forest/state.htm
http://enrin.grida.no/htmls/georgia/soegeor/english/forest/resource.htm
http://eco.gov.az/v2.1/en/forest

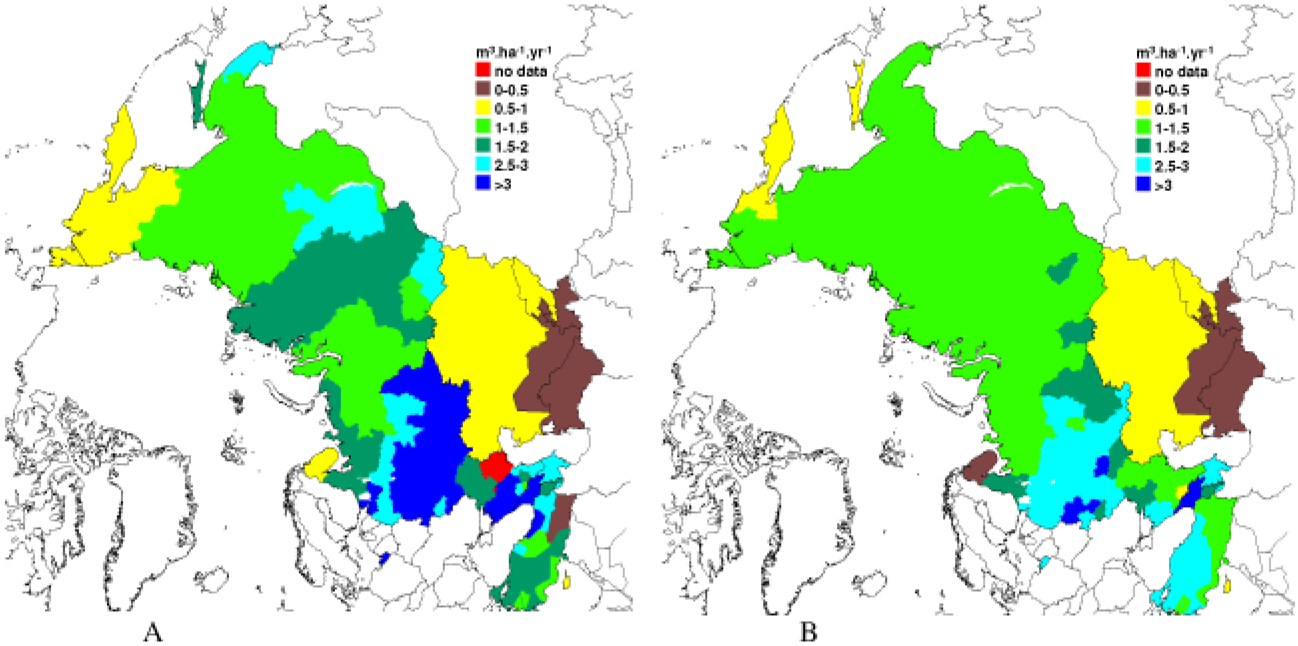

Figure 7-4. *Average forest growth (A=conifers, B=broadleaves).*

7.6 Map overlay

Overlaying the maps with soils, forests and forest growth regions and combining this with the EMEP 50 grid extended over the entire EECCA area, Turkey and Cyprus results in a receptor map with about 125,000 receptors. The total ecosystem area covered is about 8,160,000 km^2.

Table 7-1. *Ecosystem areas per soil group; in total 95 different soil types occur in the data set that can be clustered in 26 soil type groups.*

Soil type group	FAO code	area (km^2)	area (%)	Soil type group	FAO code	area (km^2)	area (%)
Acrisol	(A)	9975	0.12	Histosol	(O)	313535.1	3.84
Cambisol	(B)	1176459	14.42	Podzol	(P)	1871487	22.94
Chernozem	(C)	50001	0.61	Arenosol	(Q)	31397.2	0.38
Podzoluvisol	(D)	1437401	17.62	Regosol	(R)	269889.2	3.31
Rendzina	(E)	639315.3	7.84	Solonetz	(S)	3572	0.04
Ferralsol	(F)	-		Andosol	(T)	64991	0.8
Gleysol	(G)	1518669	18.62	Ranker	(U)	48618	0.6
Phaeozem	(H)	59546.7	0.73	Vertisol	(V)	835.7	0.01
Lithosol	(I)	103186.6	1.26	Planosol	(W)	2942.7	0.04
Fluvisol	(J)	348615.8	4.27	Xerosol	(X)	2470.1	0.03
Kastanozem	(K)	8555.6	0.1	Yermosol	(Y)	170	0
Luvisol	(L)	15606.5	0.19	Solonchak	(Z)	419.4	0.01
Greyzem	(M)	1298.8	0.02	other soils		179224.2	2.2
Nitosol	(N)	-		Total		8158122	100

Table 7-1 shows that Podzols, Gleysols and Podzoluvisols and Cambisols dominate the data set; together these 4 soil groups occupy 74 % of the area. Compared to the background database for Europe (Posch et al., 2003), the share of the dominating Podzols, Podzoluvisols and Cambisols is about the same, but the share of Gleysols is substantially higher in this new data set (18.6 versus 5.7 %).

Figure 7-5 shows the number of receptors per EMEP 50 grid cell. Figure 7-5 shows that large parts of the New Independent States and parts of Northern Siberia are without forests (white areas) and the number of receptors for most grid cells varies between 10 and 30. The number of receptors in Turkey and Cyprus is mostly somewhat lower than in areas in Russia with the same forest coverage due to the fact that the 1:5 M FAO soil map that is used for these countries is less detailed than the 1:1M soil ESDB map.

It should be noted that the critical load models implicitly assume forest with free draining soils. Large areas of Northern Russia, however, have shallow permafrost where the critical load model in its present form cannot be applied. In simulations these areas should be left out.

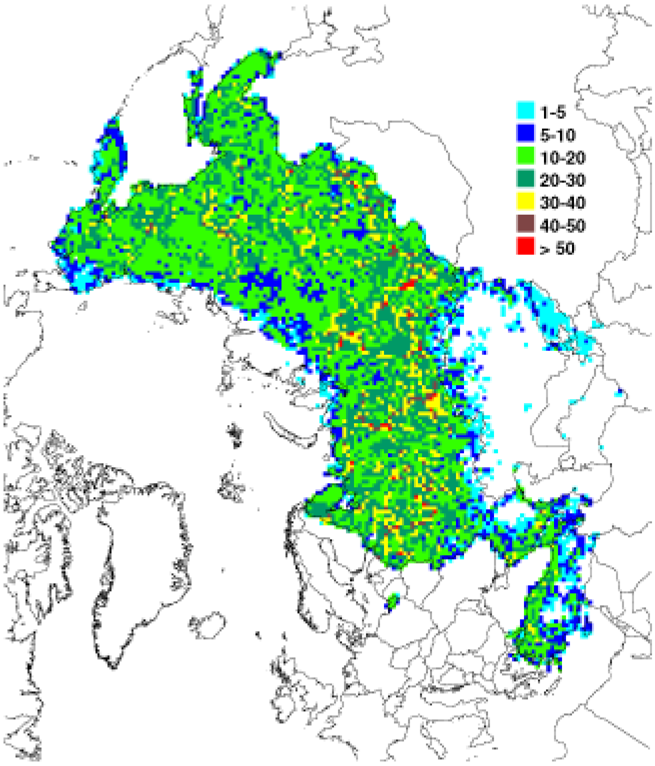

Figure 7-5. *Number of receptors per EMEP grid cell.*

7.7 Conclusions

Based on available materials the background data base was extended with the territory of the EECCA countries, Turkey and Cyprus.

Vegetation cover was obtained from the Global Land Cover 2000 map (Bartholome et al., 2002) as this map, in comparison with other available maps for this region, seems to be the most accurate in delineating forest areas.

Soil types for the EECCA countries were obtained from the European Soil Data Base v2 polygon map (ESDB v2) (European Soil Bureau Network, 2004) that recently became available. This map is superior in the amount of detail compared to other maps available. Furthermore, an older version of the same map will is being used for the background data base for Europe. It is advised to also update the background database of Europe with the new version of the ESDB soil map. If this is accomplished, it is also advisable to merge the two background data bases into one data base covering the whole of Europe (including Turkey and Cyprus) and the EECCA countries.

Soil attribute data were obtained from an external data source (Stolbovoi and Savin 2002), because the attribute data with the ESDB map regarding CEC, base saturation and pH were available with insufficient detail, or only available as qualitative parameters. The profile data by (Stolbovoi and Savin, 2002) were aggregated to arrive at average parameter values per soil type for 0-50 cm, taking into account the soils within natural ecosystems only. Some minor filtering of the data was carried out. Parameter values thus obtained were compared to soil parameter values based on another external database (Batjes, 2002b). Comparison showed that both for pH, CEC and base saturation values are comparable, but that for C:N ratios deviations occur. These devotions may be caused by the fact that the dataset by (Batjes, 2002b) also contains data from agricultural soils. Because the final soil dataset contains only about 100 profiles, it is advised to further investigate if reliable additional data sources exist that could be used to better characterize the soils of the EECCA territory. It is felt that the current data set is too limited to take into account the variation that undoubtedly exists in the vast territory of the EECCA countries.

Growth data for Russia were derived from (Alexeyev et al., 2004). Using the data on standing biomass and stocked areas per age class, a simple growth curve was fitted per region that was used to compute average growth. This simple method gives some first insight in average growth per region, but it should be noted that (Alexeyev et al., 2004.) express their concern about the quality of the underlying data. It is thus worthwhile to investigate if new data sets on forest stocks or forest growth become available to verify and update current results. Forest growth for the New Independent States and Cyprus are based on standing volume (Prins and Korotkov, 1994; FAO, 2000) and crude assumptions on average stand age only, and can thus only be regarded as a first crude approximation of forest growth. Further research and improvement of these data is advised.

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Annex 7-A: Soil type and texture class combinations for EECCA

FAO code	Texture class	PH_H2O	CEC	BS_PERC	CACO3	BULK_DENS	C_PERC	N
B	1	5.86	11.57	74.62	0.00	1.35	0.79	0.06
Bd	1	5.16	21.86	14.17	0.00	1.24	1.05	0.04
Bd	2	4.99	13.21	40.77	0.00	1.42	2.20	0.18
Be	2	5.80	26.39	84.26	0.00	1.29	2.32	0.17
Bg	3	5.08	24.21	84.96	0.00	1.20	1.10	0.23
Bh	2	7.17	26.66	96.34	0.00	1.37	0.78	0.07
Bk	2	7.60	25.01	95.94	3.14	1.36	0.70	0.08
C	2	6.75	20.38	100.00	0.00	1.18	1.78	0.14
Cl	2	7.68	28.61	100.00	8.70	1.35	1.97	0.16
Dd	2	5.02	9.98	44.69	0.00	1.42	0.25	0.01
De	1	5.91	14.35	54.79	0.00	1.30	1.91	0.10
De	2	5.89	22.56	65.09	0.00	1.46	0.79	0.04
Dg	1	5.06	12.39	54.76	0.00	1.32	1.72	0.10
Dg	2	5.74	23.50	61.30	0.00	1.37	0.96	0.06
E	2	7.33	51.63	100.00	6.00	1.37	5.70	0.53
Ec	1	7.85	23.73	100.00	5.86	1.30	2.05	0.11
Ec	3	7.68	25.46	87.59	0.00	1.25	2.20	0.13
G	1	5.80	20.47	65.79	0.00	1.47	2.36	0.17
G	2	5.62	23.19	65.41	0.00	1.45	3.11	0.18
Gh	1	5.88	13.13	100.00	0.00	1.32	1.80	0.07
Gm	1	7.29	24.32	100.00	0.00	1.25	0.30	0.00
Gm	2	7.51	18.35	100.00	10.54	1.21	2.50	0.18
Gm	3	7.28	21.15	100.00	14.37	1.34	2.67	0.20
Hl	2	7.54	21.32	100.00	1.60	1.29	1.36	0.10
I	1	5.24	13.60	90.92	0.00	1.66	0.84	0.04
Je	1	5.88	20.24	86.46	0.00	1.18	2.62	0.17
Je	2	5.76	15.83	77.86	0.00	1.24	1.76	0.20
Je	3	7.23	45.56	100.00	0.00	1.10	2.08	0.15
K	1	6.80	12.90	100.00	0.00	1.15	1.70	0.20
Mo	2	5.73	23.48	91.85	0.00	1.31	1.45	0.14
O	1	4.78	50.49	49.96	0.00	0.38	39.97	2.01
P	1	4.77	9.14	61.60	0.00	1.30	1.16	0.07
Pg	1	4.80	9.91	26.66	0.00	1.25	0.50	0.00
Phf	1	5.11	2.85	21.17	0.00	1.30	0.12	0.00
Pl	1	5.23	7.62	59.47	0.00	1.51	1.47	0.06
Po	1	4.96	10.28	26.79	0.00	1.38	1.24	0.06
Qc	1	6.06	3.83	97.70	0.00	1.54	0.53	0.06
Sg	2	7.58	18.91	100.00	4.94	1.40	1.27	0.09
So	2	7.47	29.68	100.00	3.81	1.37	1.03	0.05
So	3	7.97	27.30	100.00	4.50	1.48	1.32	0.33
T	1	5.67	6.26	90.22	0.00	0.97	0.98	0.01
To	1	5.42	15.22	68.94	0.00	0.72	3.53	0.19
U	2	5.03	20.51	53.76	0.00	1.09	6.28	0.57
W	2	5.66	24.82	94.98	0.00	1.44	1.23	0.13
Zt	2	7.27	25.84	100.00	9.43	1.28	1.27	0.13

Part II. National Focal Centre Reports

This part consists of the reports on national data on critical loads and dynamic modelling calculations submitted to the Coordination Centre for Effects by the National Focal Centres (NFCs). The reports have been edited for format and clarity, but have not been reviewed.

Reports by NFCs which submitted both empirical and modelled critical loads have been merged into a single chapter.

In 2006 no printed report was published by the CCE on the updates provided by NFCs in reponse to the 2005 call for data. Electronic versions of maps, figures and national reports were made available on www.mnp.nl/cce. For completeness, this part also includes the reports of the NFCs that submitted data in 2006 (but not this year): Cyprus, Latvia and the Russian Federation.

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Modelled critical loads and dynamic data

Status

In response to the call for data of November 2006 a new dataset of critical loads and dynamic modelling is provided. In contrast to previous data calls two different approaches for the calculation of critical loads are applied. CL of acidity and dynamic modelling output are calculated using the VSD model and soil data from about 500 soil monitoring sites as used for previous reports. The calculation of CL of nutrient nitrogen is also using the mass balance approach, but now based on Corine Land cover 2000 datasets instead of soil monitoring sites. This is possible because of the reduced data requirements of *CLnutN* and this approach better fits to the empirical critical loads, which are also based on CLC 2000 datasets.

Critical loads of acidity

Data Sources

Changes to the 2005 dataset are:
- New deposition time series for sulphur and nitrogen provided by the CCE 2006
- New precipitation surplus data from the Hydrological Atlas of Austria
- New mean temperature data from the Hydrological Atlas of Austria
- *lgKAlox* is calculated for each sample point individually as a function of soil organic matter content

Table AT-1 lists the origin of all of the submitted variables.

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

Variable	Explanation and Unit	Description
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	calculated from Austrian forest inventory data
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
CLnutN	Critical load of nutrient nitrogen (eq $ha^{-1}a^{-1}$)	- not calculated within the VSD approach -
nANCcrit	The quantity –ANCle(crit) (eq $ha^{-1}a^{-1}$)	calculated by VSD

Variable	Explanation and Unit	Description
cNacc	Acceptable (critical) N concentration (meq m^{-3})	- not calculated within the VSD approach -
crittype	Chemical criterion used	used: molar Al:Bc ratio (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) (zero 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 (log_{10})	[9.8602 - 1.6755 * log(*OM*) for 1.25 < *OM* < 100; 9.7 for *OM* < 1.25]; SAEFL 2005 (*OM* = Organic Matter [%])
expel	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 CO2 pressure = 0.00037 atm; equation recommended by CCE
cOrgacids	Total concentration of organic acids (m*DOC) (eq m^{-3})	used: 0.01 (recommended by M. Posch)
Nimacc	Acceptable amount of nitrogen immobilised in the soil (eq $ha^{-1}a^{-1}$)	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 (log_{10})	calibrated by VSD; initial value 0
lgKHBc	Exchange constant for H vs Bc (log_{10})	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)
EUNIScode	EUNIScode of ecosystem	G1, G3, G4, G3.1B (unmanaged protection forests)

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 on a 8.7×8.7 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 that runs 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 et al., 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: Four forest ecosystem types have been investigated according to EUNIS classification: G1 (Fagus sylvatica, Quercus robur), G3 (Picea abies, Pinus sylvestris, Larix decidua), G4 and G3.1B, which is used to indicate unmanaged protection forests. The ecosystem area was identified by dividing the known ecosystem area per grid cell (from forest inventory) by the number of soil inventory points located in this ecosystem type.

Depositions: Sulphur and Nitrogen deposition time series provided by the CCE 2006 (included with the database-file); Base cation depositions: Van Loon et al. (2005)

Calculation Method

The calculations and assumptions are generally in accordance with the Mapping Manual (ICP M&M, 2004) and the CCE Status Reports.

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 and 40, resp. Oliver constants for the organic acid dissociation were set to be 4.5, 0, 0.

Base cations were included lumped 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 based on about 18,000 forest patches of the Austrian Corine Land cover dataset. Generally data sources and calculation method are comparable to the *CL of acidity method*, although some changes were necessary due to the different spatial approach and the data availability.

Denitrification: The denitrification fraction is based on the soil type units of the soil map 1:1M 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.

Table AT-2. *Assignment of f_{de}-values to soil type units.*

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

Leaching: As the acceptable leaching is not depending on the precipitation surplus and the critical nitrogen concentration but depending on the altitude (see Swiss NFC Report in Posch et al. 2001), the *cNacc* is back-calculated from the acceptable leaching and *Qle* leading to very high (at low *Q* values) and very low (at high *Qle* values) acceptable nitrogen concentrations.

Ecosystem: EUNIS type G3.1B, which is used to indicate unmanaged protection forests, cannot be identified within the Corine Land cover dataset. On the other hand, the area per EMEP grid cell is known from the forest inventory. As protection forests are mostly located at higher altitudes, the assumption is made, that those G3-patches (deciduous forests) covering the highest parts of the EMEP grid cell are assigned to G3.1B until the known protection forest-area is reached.

A description of the parameters and the data and methods used for their derivation is given in Table AT-3.

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

Variable	Explanation and Unit	Description
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	Corine Land cover 2000 patch size
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 $ha^{-1}a^{-1}$)	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 ($0 \leq fde < 1$) (-)	from 0.1 (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
EUNIS code	EUNIS code of ecosystem	Corine Land cover 2000; G1, G3, G4, G3.1B (unmanaged protection forests; information from Austrian forest inventory)

Tentative assessment of the application potential of dynamic models in Austria (T. Dirnböck)

The coupled approach with BERN and a dynamic soil model (e.g. SMART2 or any biogeochemical model like BGC) is preferable to the other model combinations. BERN calculates potential natural vegetation with given site conditions and predicted changes. Latter can come from dynamic soil and climate models and allows thus for the derivation of scenarios. Habitat specific critical loads can be calculated as well as qualitative estimates of the ecosystem condition (‘reversibility’, ‘reduction of vitality’, ‘extinction of species’, etc.). The main advantage is that the model was calibrated with Central European data which makes it much more applicable to the situation in Austria than models such as MOVE, GBMOVE or NTM.

Advantages of BERN

An application of the plant species/community response models in MOVE, GBMOVE or NTM for Austria is critical due to the calibration of qualitative Ellenberg indication values with measured soil factors based on a limited Northern European data set. This is, most probably, not representative for a range of habitats which occur in Austria, such as dry habitats of the Pannonian region, montane forests, or alpine habitats. This is particularly critical with regard to biodiversity since these areas harbour habitats and species with a high conservation value. The limitation could be overcome by an appropriate training data set. Though vegetation data exist in Austria only few also include soil data and they are only partly available within reasonable time.

The baseline plant communities (‘basic site types’) of BERN can be directly used for policies based on important habitats for biodiversity such as the Flora-Fauna-Habitat Directive. With some exceptions (Pannonian region) habitats which occur in Austria are implemented in BERN.

Limitations of BERN

BERN was not validated with data from other countries than Germany. A validation should thus be carried out before applying the model in Austria based on Intensive Monitoring sites (e.g. UNECE-ICP Integrated Monitoring and ICP Forest).

It should be mentioned that dynamic vegetation models were developed for forests (see e.g. Lexer et al., 2001, as an example of climate change assessment in Austria), which can be coupled to biogeochemistry models. Owing to its mechanistic nature these models are preferred to BERN, but are limited to forests and are very data demanding (Lexer et al. 2001). In addition, they were not developed for the calculation of Critical Loads thus could be implemented only with considerable effort.

The approach views plant communities as the static outcome (‘climax’) of site characteristics and does not include dynamic processes and time lags. Though BERN can be applied with a dynamic soil model, the vegetation model itself remains static. Nevertheless, the implementation of Target Load functions is under development.

Potential applications in Austria

- Calculation of Critical Loads for eutrophication and acidification: since CL are only available for a limited range or a limited resolution of habitats more reliable CL could be calculated particularly for habitats with high conservation values in Austria.
- Time series and scenarios with dynamic models for soil changes.
- Comparison of actual and potential habitat conditions.
- Determination of a habitat specific recovery target and its regeneration potential.

Data demand and availability

BERN has interfaces for dynamic soil models (VSD) and mass balance models (SMB). The interface parameters and other necessary parameters are (potential availability in Austria is given in parentheses):

Static variables

- Climate region -> can be derived from standard meteorological data
- Relief type -> field data; can be derived from a digital elevation model
- Exposition type -> field data; can be derived from a digital elevation model
- Soil type/parent material -> field data; can probably be derived from geological and soil maps (only coarse resolution)
- Dynamic variables
- degree of moisture -> can probably be modelled or estimation
- humus form -> field data; can probably be estimated from surrogates (climate, forest type, etc.)
- land cover type -> CORINE
- C:N ratio -> SMB
- base saturation -> analysed soil data; estimation?
- Climate variables
- Duration of vegetation period -> can be derived from standard meteorological data
- Continentality index -> can be derived from standard meteorological data

Empirical critical loads of nutrient nitrogen

Data sources and methods

The Austrian Corine Land cover 2000 dataset is the main data source for this study. Additionally the Austrian mire conservation database is used to update the small-scale CLC2000 data with mire, bog and fen habitats.

EUNIS-codes are applied and *CLempN* values are assigned to the habitats according to the recommendations made in the Mapping Manual. The mean value of the recommended range is used as CL (Table AT-4), no further adaptation to abiotic factors according to Table 5.2 of the Mapping Manual is done due to the restricted data availability and the poor knowledge of the quantitative influence of these factors.

The code-number '3' in the column 'Protection' is used for sites being SPA *and* SAC.

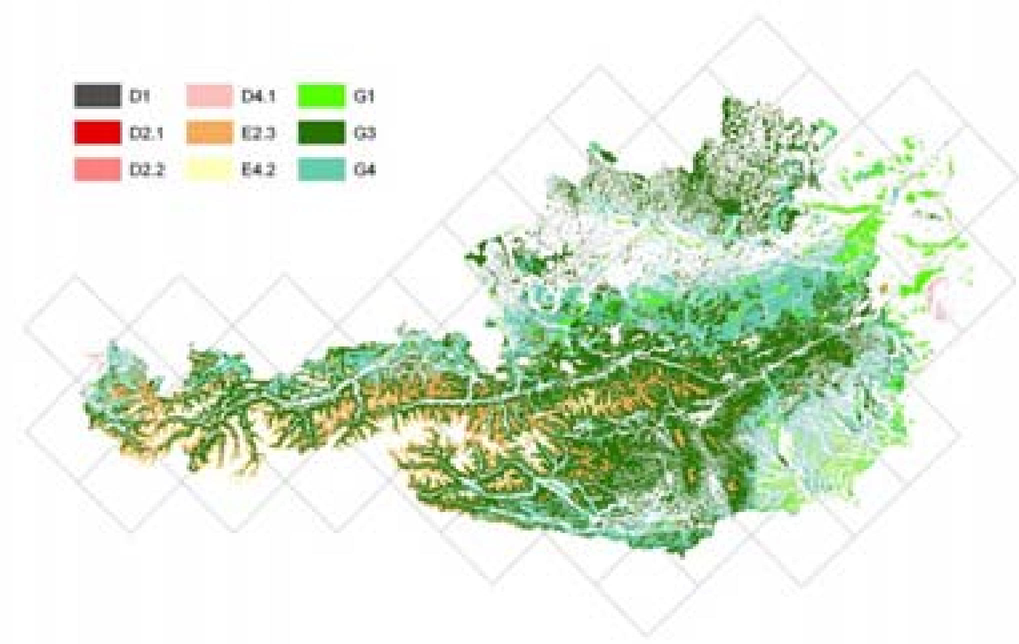

Figure AT-1. *Natural and semi-natural habitats in Austria (Corine Land Cover 2000).*

Table AT-4. *Ecosystem, Corine2000 code, EUNIS code, recommended CL range and applied CLempN value.*

Ecosystem	CLC2000code	EUNIScode	CLNrange	*CLempN*
Raised and blanket bogs	a)	D1	5-10	7.5
Oligotrophic fens	a)	D2.1	10-15	12.5
Mesotrophic fens	a)	D2.2	15-20	17.5
Eutrophic fens	a)	D4.1	15-25	20
Mountain hay meadows	321	E2.3	10-20	15
Moss and lichen dominated mountain summits	333	E4.2	5-10	7.5
Broadleaved deciduous woodland	311	G1	10-20	15
Coniferous woodland	312, 322	G3	10-20	15
Mixed deciduous and coniferous woodland	313, 324	G4	10-20	15

a) Ecosystem information from Austrian mire conservation database

Table AT-5. *Applied empirical CL values, affected ecosystem area and percentage of the total area.*

CLempN	*EcoArea*	Percentage
<= 12,5 kg	2907 km²	5,9 %
12,5 - 15 kg	45 742 km²	93,5 %
> 15 kg	295 km²	0,6 %

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Mapping procedure Wallonia

Digitized maps with a total of 1900 ecosystems were overlaid by a 5×5 km^2 grid to produce the resulting maps for coniferous, deciduous and mixed forests in Wallonia.

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 and results Wallonia

Forest soils

Calculation methods

Critical loads for forest soils were calculated according to the method as described in UBA (1996) and Manual for Dynamic Modelling of Soil Response to Atmospheric Deposition (2003):

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

where:

$[Al^{3+}] = 0.2$ eq/m^3
$[H^+]$ = concentration of $[H^+]$ at critical pH (see Table BE-2).
$[RCOO^-]$= 0.044 mol$_c$/molC × $DOC_{measured}$ (see Table BE-2)

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-3) 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.

The Tables BE-1 and BE-2 summarise the values given to some of the parameters.

Table BE-1. *Aluminium equilibrium and weathering rates calculated for Walloon soils.*

Sites	Soil types	K	BCwe eq ha^{-1} a^{-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 or (2) coniferous forest

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

Parameter	Value
N_i	5.6 kg N ha^{-1} a^{-1} coniferous forest
	7.7 kg N ha^{-1} a^{-1} deciduous forest
	6.65 kg N ha^{-1} a^{-1} mixed forest
$N_{le\ (acc)}$	4 mg N L^{-1} for coniferous forest
	6,5 mg N L^{-1} for deciduous forest
	5,25 mg N L^{-1} for mixed forest
N_{de}	Fraction of $(N_{dep} – N_i – N_u)$

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 rate

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}, an acid input was fixed at 900 eqH$^+$ ha^{-1} a^{-1} in order to keep a long term balance of base content in soils.

$N_{le} = Q_{le} \cdot cN_{(acc)}$

The flux of drainage water leaching, Q_{le}, from the soil layer (entire rooting depth) was estimated from lysimetric measurement on 10 different representative soil types (Table BE-3) (Catholic University of Louvain, 2005).

Table BE-3. *Flux of drainage water through entire root layer Qle, concentration of organic acids ($RCOO^-$) and pH critique in Walloon soils.*

Sites	**Soil types**	**$RCOO^-$** eq/m^3	**pH crit**	**Q_{le}** m a^{-1} (at 0.5m)
Bande (1-2)	Podzol	0.103	3.95	0.138
Chimay (1)	Cambisol	0.038	4.10	0.046
Eupen (1)	Cambisol	0.105	4.36	0.045
Eupen (2)	Cambisol	0.094	3.70	0.045
Hotton (1)	Cambisol	0.031	4.38	0.108
Louvain-la-Neuve (1)	Luvisol	0.099	4.17	0.039
Meix-dvt-Virton (1)	Cambisol	0.037	4.35	0.049
Ruette (1)	Cambisol	0.007	4.47	0.045
Transinne (1)	Cambisol	0.078	4.41	0.053
Willerzie (2)	Cambisol	0.038	4.37	0.044

(1) deciduous; (2) coniferous forest

Precipitation surplus

The actual methodology can not be compared with the previous methodology because the definition of the precipitation surplus is modified. In the previous methodology the surplus was defined as the total amount of water leaving the root zone (total run off). In the present methodology the precipitation surplus doesn't take into account of the horizontal flux but considers only the amount of water percolating through the root zone (mm a^{-1}). In forest growing on abrupt locations, a non negligible fraction of the precipitation runs off on the top soil.

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; Bosman et al., 2001; Unité des Eaux et Forêts, May 2001).

The net growth uptake of nitrogen ranges between 266 and 822 eq ha^{-1} a^{-1}, while base cations uptake values vary between 545 and 1224 eq ha^{-1} a^{-1} depending on trees species and location in Belgium.

Base cations 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.

Results

In Wallonia, The highest CL values were found in 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.

More sensitive forest ecosystems are met on sandy-loamy or loamy gravelly soils. The lowest *CLnutN* values were found in Ardennes. In this zone, *Picea abies L.Karts.* frequently show magnesium deficiency symptoms, which have been exacerbated by atmospheric pollution (Weissen et al., 1990).

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Modelled critical loads and dynamic data

Data sources

This report presents recent results of the team-work of the Bulgarian experts of Executive Environmental Agency and the Bulgarian scientific team as parts of the ICP Modelling and Mapping on the dynamic assessment of exceedances of critical loads for acidifying pollutants in Europe. Current critical loads data for acidification and eutrophication are described as well justifying methods and data applied.

Critical loads of acidifying sulphur and nitrogen are calculated for main forest tree species using the Steady State Mass Balance method in accordance with the latest recommendations provided in the last version of the Mapping Manual (UBA, 2004). The database involve maximum critical loads of sulphur (Manual, equation 5.22), maximum critical loads of nitrogen (Manual, equation 5.26), minimum critical loads of nitrogen (Manual, equation 5.25), nutrient nitrogen (Manual, equation 5.5) and all related data.

Critical loads are calculated using soil data base of the content of the organic mater (%), the clay content for the fraction 0,01 mm in the soil (%), soil bulk density, cation exchange capacity *CEC*, Base saturation, C:N ratio and the pH of the soil. in grid cells of 16 km×16 km (Ignatova et al., 2001). Data of base saturation have been obtained by means of 0.1 M $BaCl_2$ (ISO 11260 and ISO 14254). Runoff of water under root zone has been measured in grid cells of 10×10 km^2 for the entire country.

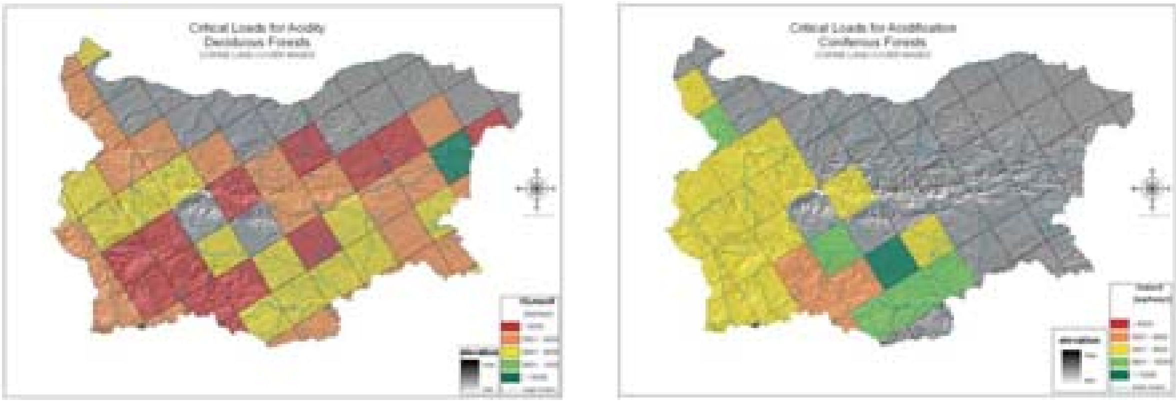

Figure BG-1. *CLmaxS for broadleaved (left) and coniferous (right) forests in Bulgaria.*

A network of 66 permanently opened collectors for atmospheric deposition by precipitation have been used for base cations, sulphur and nitrogen depositions.

Nitrogen and base cations net uptake rates are obtained by multiplying the element contents of the stems (N, Ca, K, Mg and Na) with annual harvesting rates. Data on biomass removal for forests have been derived from the National Forests Survey Agency. The content of base cations and nitrogen in the biomass has been taken from the literature for different harvested parts of the plants (stem and bark of forest trees) (Ignatova et al., 2000).

In the absence of more specific data on the production of basic cations through mineral weathering for most of 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).

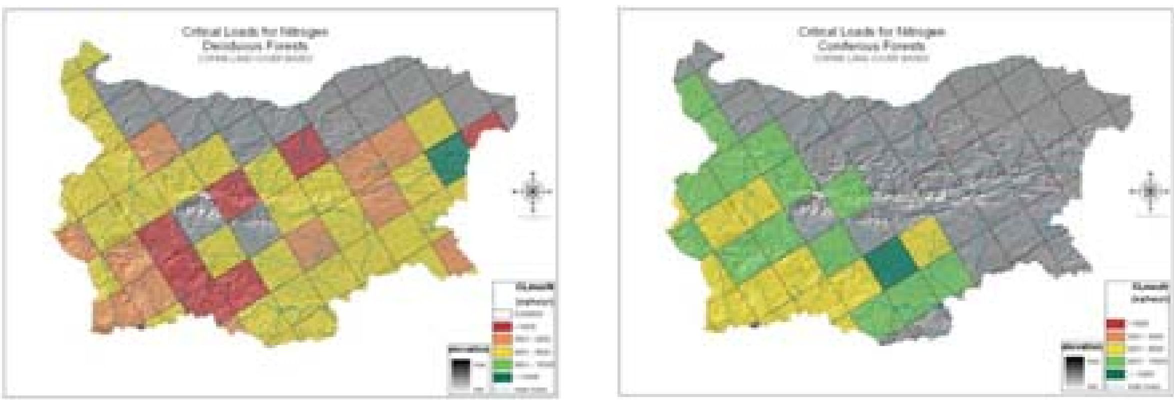

Figure BG-2. *$CL_{max}N$ for broadleaved (left) and coniferous (right) forests in Bulgaria.*

Chemical criterion used is a molar ratio [Al]:[Bc]=1 (Manual, equation 5.31). Identifiers of the site for critical loads calculation of acidifying nitrogen and sulphur, and the integers in the submission of the empirical critical loads of nitrogen are not identical because of different number of sites under consideration in two submissions but they correlate each to other by the EMEP-grid cells indices and geographical coordinates.

Calculated values for *CLmaxS* vary between 5234 and 10044 eq ha^{-1} a^{-1} for coniferous, and between 3266 and 10774 eq $ha^{-1}a^{-1}$ for broadleaved forests (Figure BG-1). *CLmaxN* are similar but a little higher than *CLmaxS* (Figure BG-2). On the contrary, critical load values for nutrient nitrogen are lower and ranged between 584 and 950 eq $ha^{-1}a^{-1}$ for coniferous, and between 400 and 781 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 394 and 768 eq ha^{-1} a^{-1} for deciduous forests).

In general, all calculated critical loads values for all over the country are higher for coniferous forests than for brood leaved ones, due to the lower mean values of critical loads parameters used for the computing (base cations weathering, deposition and uptake).

Table BG-1. *Average, maximum and minimum values of critical loads of sulphur, nitrogen as well as alkalinity for broadleaved and coniferous forests in Bulgaria (in eq ha^{-1} a^{-1}).*

	Coniferous			*Broadleaved*		
	Min	*Max*	*Average*	*Min*	*Max*	*Average*
CLmaxS	*5234*	*10044*	*7273*	*3266*	*10774*	*5560*
CLminN	*573*	*926*	*789*	*394*	*768*	*534*
CLmaxN	*5985*	*10621*	*8062*	*3778*	*11230*	*6094*
CLnutN	*584*	*950*	*801*	*400*	*781*	*550*
nANCcrit	*3154*	*6060*	*4384*	*1989*	*6473*	*3353*

For the minimum critical loads of nitrogen as well as the critical loads of nutrient nitrogen the variability of computed individual data is much smaller, which reflects on the average values (789 eq $ha^{-1}a^{-1}$ for coniferous ecosystems for minimum critical loads of nitrogen with 534 eq ha^{-1} a^{-1} for broadleaved ones, and 801 eq $ha^{-1}a^{-1}$ for coniferous for nutrient nitrogen against 550 eq $ha^{-1}a^{-1}$ for broad leaved forests) (Table BG-1).

Empirical critical loads of nutrient nitrogen

Data sources

The empirical critical loads of nitrogen for habitats groups treated have been determined in accordance with the Mapping Manual chapter 5.2.1 (UBA, 2004) using suggested empirical critical loads for nitrogen deposition as follow (Bobbink et al., 2003):

Forest habitats (G): 10-15 kg N $ha^{-1}a^{-1}$;

Heathland, scrub and tundra habitats (F): 5-15 kg N $ha^{-1}a^{-1}$ for alpine and subalpine scrub habitats (F2) and 10-20 kg N $ha^{-1}a^{-1}$ for dry heaths (F4.2)

Grasslands and tall forb habitats (E): 10-20 kg N $ha^{-1}a^{-1}$ for Inland dune pioneer grassland (E1.94), inland dune siliceous grasslands (E1.95) and mountain hay meadows,

10-15 kg N $ha^{-1}a^{-1}$ for alpine and subalpine grassland (E4), 20-30 kg N $ha^{-1}a^{-1}$ for low and medium altitude hay meadows (E2.2);

Mire, bog and fen habitats (D): 5-10 kg N $ha^{-1}a^{-1}$ for raised and blanket bogs (D1);

Inland surface water habitats (C): 10-20 kg N $ha^{-1}a^{-1}$ for dune slack pools (C1.16);

Coastal habitats (B)- 10-20 kg N ha^{-1} a^{-1} for shifting coastal dunes (B1.3), coastal stable dune grasslands (B1.4) and coastal dune heaths (B1.5);

Because of insufficient national data of empirically derived Nitrogen critical loads for ecosystems of concern, the lower, middle or upper part of the Ranges of the Nitrogen critical loads for natural and (semi-)natural ecosystem groups have been used according to the general relationships between abiotic factors like mean annual temperature, soil wetness, base cation availability, management intensity etc. on the one hand and critical loads for Nitrogen, on the other, as given in Table BG-2 (UBA, 2004). The empirical critical loads of nitrogen in eq $ha^{-1}a^{-1}$ have been derived by multiplying the values in kg N $ha^{-1}a^{-1}$ with 71.4286 (1000/14).

Table BG-2. *Suggested values for using lower, middle or upper part of the set critical loads of nitrogen for the selected habitats groups (in eq* $ha^{-1}a^{-1}$*).*

Habitats group	Temperature	Soil wetness	Base cation availability	Management intensity	Empirical N CLs
	Cold	Dry	Low	Low	357.14
D1	Intermediate	Normal	Intermediate	Usual	535.71
	Hot	Wet	High	High	714.28
	Cold	Dry	Low	Low	357.14
F2	Intermediate	Normal	Intermediate	Usual	714.28
	Hot	Wet	High	High	1071.42
	Cold	Dry	Low	Low	714.28
G1, G3, E4	Intermediate	Normal	Intermediate	Usual	892.81
	Hot	Wet	High	High	1071.42
F4.2, E1.94,	Cold	Dry	Low	Low	714.28
E1.95, C1.16,	Intermediate	Normal	Intermediate	Usual	1071.42
B1.3,B1.4, B1.5	Hot	Wet	High	High	1428.56
	Cold	Dry	Low	Low	1428.56
E2.2	Intermediate	Normal	Intermediate	Usual	1785.70
	Hot	Wet	High	High	2142.84
	Cold	Dry	Low	Low	2142.84
A2	Intermediate	Normal	Intermediate	Usual	2499.98
	Hot	Wet	High	High	2857.12

To facilitate and harmonize the mapping procedure with respect to empirical nitrogen critical loads, the receptor groups were classified according to the EUNIS habitats classification for Europe (Davies and Moss, 2002; Hall et al., 2003). Woodland and forests habitats (G code in accordance with the EUNIS system), heathland, scrub and tundra habitats (F), grasslands and tall forb habitats (E), mire, bog and fen habitats (D), Inland surface water habitats (C), Costal habitats (B) and Marine habitats (A) have been selected as receptors.

Concerning the type of management of the studied areas the proposed classification in the instructions for submitting empirical critical loads of nitrogen has been applied as follow:

0: No specific nature protection applies
1: Special Protection Area (SPA), Birds Directive applies
2: Special Area of Conservation (SAC), Habitats Directive applies
9: A national nature protection program applies

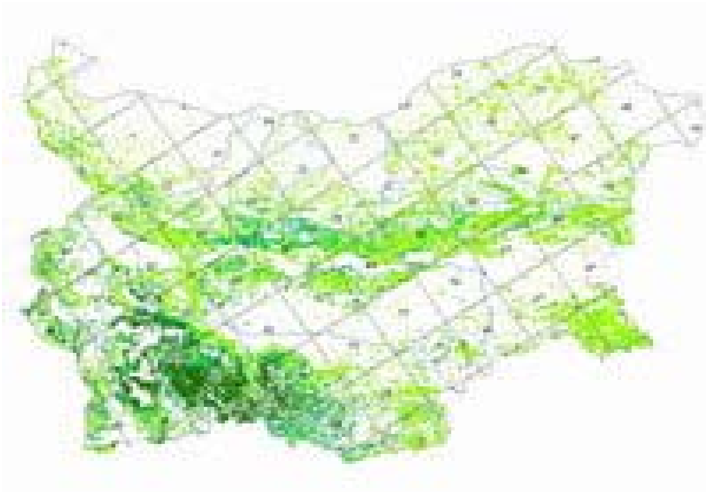

Figure BG-3. Distribution of forested areas in Bulgarian part of the 50 km×50 km EMEP grid cells.

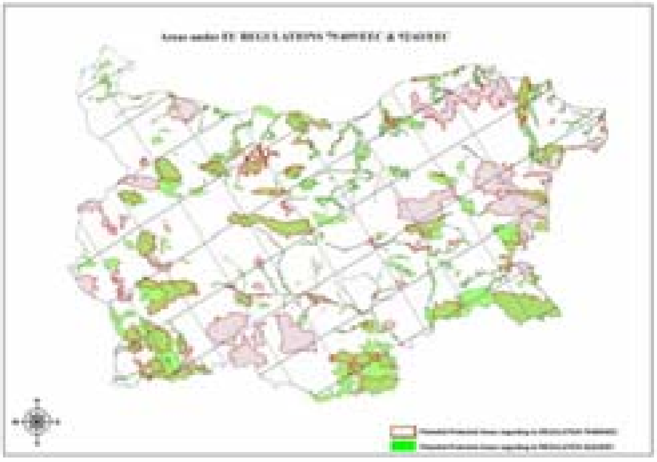

Figure BG-4. Distribution of areas under EU Regulations 79/409/EEC and 92/43/EEC in Bulgarian part of the 50 km×50 km EMEP grid cells.

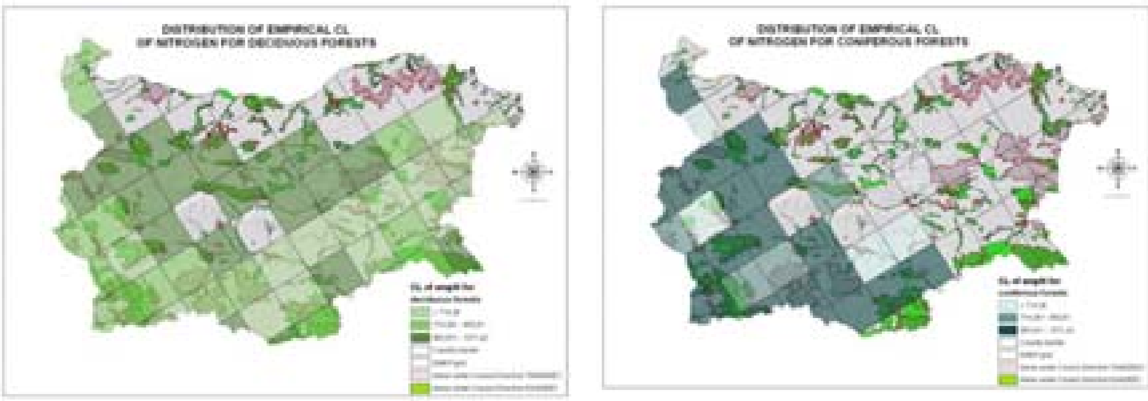

Figure BG-5. Distribution of the empirical critical loads of Nitrogen for broad leaved (left) and coniferous (right) forests in Bulgaria, eq ha^{-1} a^{-1}.

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Data sources

In response to the 2007 call for voluntary contributions, the Canadian National Focal Centre (NFC) submitted data on critical loads of nitrogen (N) and sulphur (S) and dynamic modelling. The primary focus of the data submission was to provide values of chemical variables from dynamic model runs (historic and future years) under different deposition scenarios. The submission provided dynamic modelling scenario output for 496 lakes in eastern Canada (Figure CA-1); the lakes and application of a dynamic soil-chemical model (MAGIC; Cosby et al., 2001) have been previously described in the 2005 CCE Status Report (Posch et al., 2005; Aherne et al., 2005). The voluntary contribution represents the first data submission from Canada to the CCE.

Critical load determination and dynamic modelling methodology followed the general approach and guidelines in UBA (2004). The data submission was in accordance with the instructions laid out by the CCE (November 2006) with some minor exceptions. The determination of critical loads was based on the Steady-State Water Chemistry (SSWC) model and not the Freshwater Acidity Balance (FAB) model; as such, several nitrogen specific parameters were not included in the data submission. Secondly, the future deposition scenarios provided by the CCE (i.e., ‘Current LEgislation’ (CLE), which assumes implementation of current legislation (Gothenburg Protocol, NEC directive, etc.) by 2010 and ‘Maximum Feasible Reductions’ (MFR), which assumes the implementation of maximum technically feasible reductions) obviously do not exist for Canada. Instead, current and proposed control scenarios (CCUSA1, CCUSA2, NOX3P and 75CAP) generated by the Acid Deposition and Oxidant Model (ADOM) were combined to make ‘equivalent’ CLE and MFR scenarios (see Figure CA-1). In total seven scenario regions were defined and scenario simulations were approximately in accordance with the CCE instructions, i.e., historic deposition was constant until 1997 (for sulphate; 2010 for nitrate), with linear transitions (see Figure CA-1) to 2030 and constant thereafter until 2100 under 27 scenarios for each region. Ammonium deposition was constant under all scenarios. Further details on the ADOM scenarios are given by Environment Canada (2004) and WxPrime (2004).

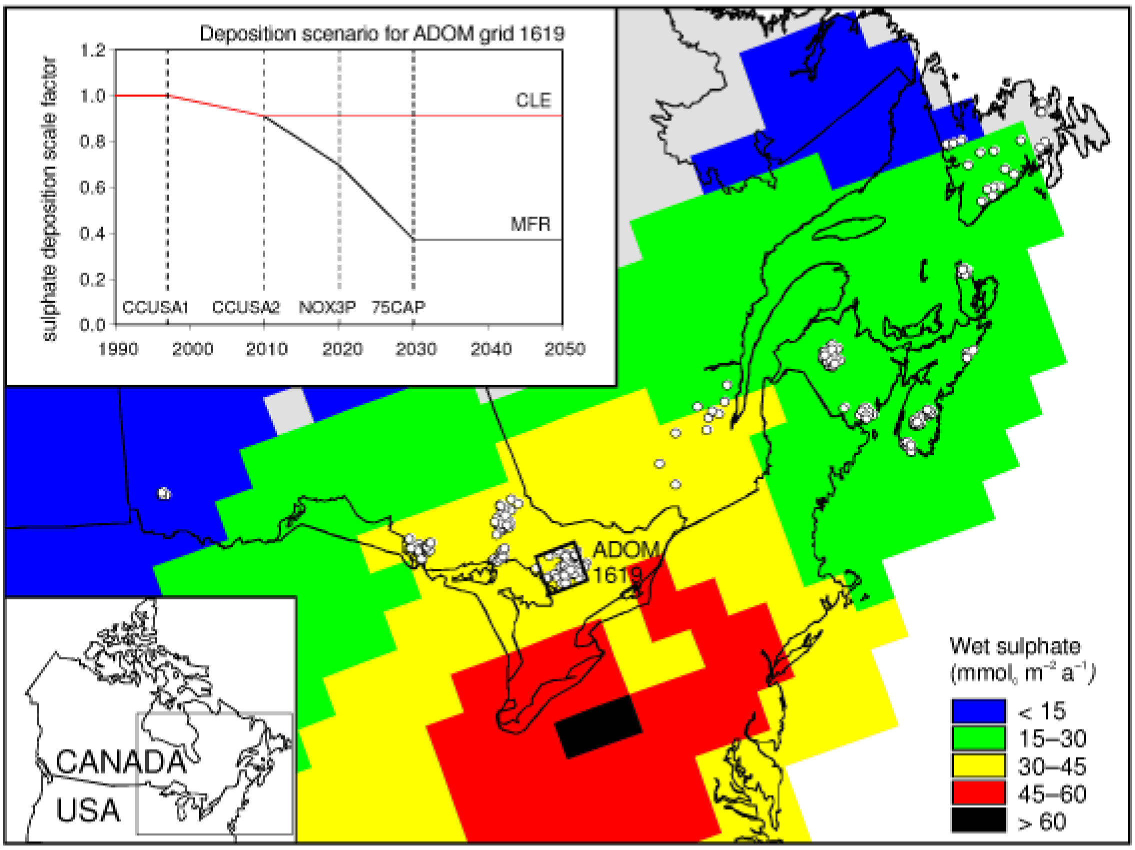

Figure CA-1. *Wet deposition of sulphate in eastern North America as estimated using the Acid Deposition and Oxidant Model (ADOM). The ADOM is a comprehensive eulerian acid deposition model with a grid spacing of 127 km × 127 km (ADOM grid 1619 in south-central Ontario in shown). The location of the study lakes is also shown (white dots). The inset depicts the Current LEgislation (CLE) and Maximum Feasible Reductions (MFR) deposition scenarios for ADOM grid 1619 derived from several current and proposed control scenario (CCUSA1, CCUSA2, NOX3P and 75CAP).*

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CYPRUS (report submitted in 2006)

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Calculation methods for critical loads of acidity and nutrient nitrogen and for dynamic modelling

Cyprus provides an update of the national critical load data (steady-state mass balance approach), input data for the application of the dynamic model VSD, and resulting target load functions. Critical loads are calculated in accordance to the methods described in the Mapping Manual (UBA, 2004).

About 40 % of the area of Cyprus is covered by forests and other (semi-)natural vegetation for which critical loads of acidity and nutrient nitrogen are computed (see Table CY-1).

Table CY-1. *Ecosystem types used as receptors for the critical loads approach.*

CORINE LAND COVER type	Precipi-tation (mm/a)	Geological zone	Preferred soil groups/ parent materials	Dominant species	EUNIS-Code	
323	>850	Troodos Terrane	Eutric Cambisols from tectonized Harzburgites	Juniperus foetidissima	F7.4G	Cyprian hedgehog-heaths
312	>850	Troodos Terrane	Eutric Cambisols from Serpentinites	Pinus nigra	G3.5	[Pinus nigra] woodland
312	<850	Troodos Terrane, Kyrenia Terrane	Eutric lithic Leptosols from Gabbro, Calcaric lithic Leptosols from Dolomitic limestone	Pinus brutia	G3.75	[Pinus brutia] forests
323, 324,333	700-850	Troodos Terrane,	Eutric lithic Leptosols from sheeted dykes (diabase)	Cedrus brevifolia	G3.9C	[Cedrus] woodland
311, 313	400-800	Troodos and Mamonia Terranes	Eutric lithic Leptosols from diabase dykes	Quercus ilex (ssp. alnifolia)	G2.136	Cyprian [Quercus alnifolia] forests
323, 324,333	700-850	Kyrenia Terrane	Calcaric lithic Leptosols from Dolomitic limestone	Cupressus sempervirens	G3.91	Western Palaearctic [Cupressus] forests
323, 324,333	550-700	Troodos Terrane Kyrenia Terrane	Eutric lithic Leptosols from sheeted dykes (diabase), Calcaric lithic Leptosols from Dolomitic limestone	Cupressus sempervirens	G3.91	Western Palaearctic [Cupressus] forests
323, 324, 333, 334	0-550	Kyrenia Terrane	Calcaric leptic Regosols from greywacke	Juniperus phoenicea	F5.132	[Juniperus phoenicea] arborescent matorral
323, 324, 331 333, 334	400-550	Circum Troodos sedimentary succession and	Skeletic calcaric Regosols from Chalks, marls	Cistus creticus/ Genista fasselata	F5.24	Low [Cistus] maquis

CORINE LAND COVER type	Precipi-tation (mm/a)	Geological zone	Preferred soil groups/ parent materials	Dominant species	EUNIS-Code	
323, 324, 331, 332, 333, 334	0-400	Mamonia Terrane Circum Troodos sedimentary succession and Mamonia Terrane	Calcic Luvisols from alluvial sands, silts, gravels and clays	Thymus capitatus/ Sarcopoterium spinosum	F7.341	Cyprian phrygana
311,313	0-950	Riverine	Calcaric fluvic Cambisols from alluvial sands, silts, gravels and clays	Alnus orientalis	G1.385	Cyprian plane forests
311,313	0-950	Riverine	Gleyic Solonchaks	Platanus orientalis	G1.385	Cyprian plane forests
323, 324, 333	400-450	Troodos Terrane Mamonia Terrane	Eutric lithic Leptosols from sheeted dykes (diabase), Skeletic calcaric Regosols from Chalks, marls	Olea europaea	G2.41	Wild Olea europaea woodland
321	0-950	everywhere	all dry soils	Bromus spec	E1.332	Helleno-Balkanic short grass and therophyte communities
323, 324, 333, 332, 334, 421, 512, 523	-	azonal	Gleyic Solonchalks	Juncus acutus/Salicornia europaea	A2.652	Mediterranean coastal halo-nitrophilous pioneer communities

The Cyprus critical load database consists of 16 247 records. A detailed description of the data and the methods for derivation is given in Table CY-2.

The calculation of acceptable leaching of nitrogen based on values given in Table CY-3 to avoid nutrient imbalances or vegetation changes.

Critical loads of acidity, *CLmaxS*

The highest critical loads of acidity with values 8-15 keq $ha^{-1}a^{-1}$ are observed in the Troodos Mountains. Less sensitive soils (eutric leptosols from diabase) are combined with medium high weathering rates of base cations and relatively high precipitation surplus. Also high critical loads (about 7–10 keq $ha^{-1}a^{-1}$) are located in the Pentadactylos mountains, including the Karpasia region. The lowest critical loads (<4-5 keq $ha^{-1}a^{-1}$) have to be allocated to the lowlands between Pentadactylos and Troodos from Morfou to Ammochostos (including the Mesaoria region), the lowlands around Larnaca Bay.

Table CY-2. *National critical load database and calculation methods / approaches.*

Parameter	Term	Unit	Description
Critical load of acidity	*CLmaxS*	eq ha^{-1} a^{-1}	Manual, equation 5.22
	CLminN	eq ha^{-1} a^{-1}	Manual, equation 5.25
	CLmaxN	eq ha^{-1} a^{-1}	Manual, equation 5.26
Critical load of nutrient nitrogen	*CLnutN*	eq ha^{-1} a^{-1}	Manual, equation 5.5 including nitrogen loss by fire (Nfire) (see CCE Progress Report 2004, p. 62)
Acid neutralisation capacity leaching	*nANCcrit*	eq ha^{-1} a^{-1}	Manual; the minimum value of the following approaches using different chemical criteria was taken for the calculation (crittype)

			1 [Al]:[Bc] equation 5.31 2 [Al] derived from $Al_{le(crit)}$ in equation 5.32-5.34 by Al_{le}/Q_{le} 4 pH equation 5.35 (see CCE Progress Report 2004, p. 62: Table CY-3)
Acceptable nitrogen leaching	*Nleacc*	eq ha^{-1} a^{-1}	Manual, equation 5.6; $[N]_{crit}$ see Table CY-3
Thickness of the soil layer	*thick*	m	reference profile for soil type unit (regarding actually rooted zone, depending on vegetation) (Soil Geographical Database of Euro-Mediterranean Countries /Soil map of Cyprus 1999/Corine Land Cover 2005)
Bulk density of the soil	*bulkdens*	g cm^{-3}	reference profile for soil type unit (Soil Geographical Database of Euro-Mediterranean Countries /Soil map of Cyprus 1999)
Bc and Cl deposition	*Cadep, Mgdep, Kdep, Nadep, Cldep*	eq ha^{-1} a^{-1}	wet and dry deposition data for the year 2003-2005 at Level-II-sites (Cyprus Department of Forest 2006)
Weathering of base cations	*Cawe; Mgwe* and *Kwe* = 0	eq ha^{-1} a^{-1}	Manual, equation 5.39, Manual, Table 5.12-5.14 weighted mean for actually rooted zone
Gibbsite equilibrium constant	*Kalox*	m^6 eq^{-2}	300
Nitrogen immobilisation	*Nimm*	eq ha^{-1} a^{-1}	temperature dependent, CCE-Status Report 2001, p. 142, Table DE-7
Denitrification	*Nde*	eq ha^{-1} a^{-1}	Manual, equation 5.4 site specific according to dead pore content
Weathering of Na	*Nawe*	eq ha^{-1} a^{-1}	Manual chapter 5.3 p. 23
Nitrogen uptake by vegetation	*Nupt*	eq ha^{-1} a^{-1}	Manual, equation 5.7, 5.8 (stem and bark) Manual, Table 5.8 (element contents), Jacobsen et al., 2002
Uptake of base cations by vegetation	*Caupt*; *Mgupt* and *Kupt* = 0	eq ha^{-1} a^{-1}	Manual, equation 5.7, 5.8 (stem and bark) Manual, Table 5.8 (element contents), Jacobsen et al., 2002
Amount of water percolating through the root zone	*Qle*	mm a^{-1}	Meteorological survey of Cyprus 1991-2003 Manual chapter 5.5: equation 5.91b

Table CY-3. *$[N]_{crit}$ values (according to Mapping Manual Table 5.7).*

vegetation type	$[N]_{crit}$
deciduous forest	0.02760
coniferous forest	0.01430
mixed forest	0.02142
natural and semi-natural vegetation outside forest	0.02142

Pliocene biocalcarenites and alluvial sands, silts and gravels have a medium potential weathering rate of base cations. But garique vegetation growing there does not take advantage of cycling this supply in the soil because of the small rooting zone. Simultaneously the annual precipitation surplus is near zero, therefore the leaching of ANC is very low. In the Mammonia Terrain (from Lemesos to Pafos, including the Akamas region) medium critical loads are obtained (5-8 keq $ha^{-1}a^{-1}$), because of the medium precipitation surplus. The regional distribution of critical loads of acidity is shown in Figure CY-1 and the statistical classification of sensitivity is given by Table CY-4.

Table CY-4. *Statistical classification of receptor sensitivity for critical loads of acidity, CLmaxS.*

CLmaxS sensitivity classes (eq ha^{-1} a^{-1})	Percentage of the sensitivity classes to total receptor area (%)	Percentage of the sensitivity classes to the total area of Cyprus (%)
< 4000	0.64	0.27
4000-5000	12.72	5.38
5000-6000	18.91	8.00
6000-7000	29.80	12.61
7000-8000	21.60	9.14
8000-9000	8.40	3.56
9000-10000	4.60	1.95
>10 000	3.33	1.41
	100.00	42.32

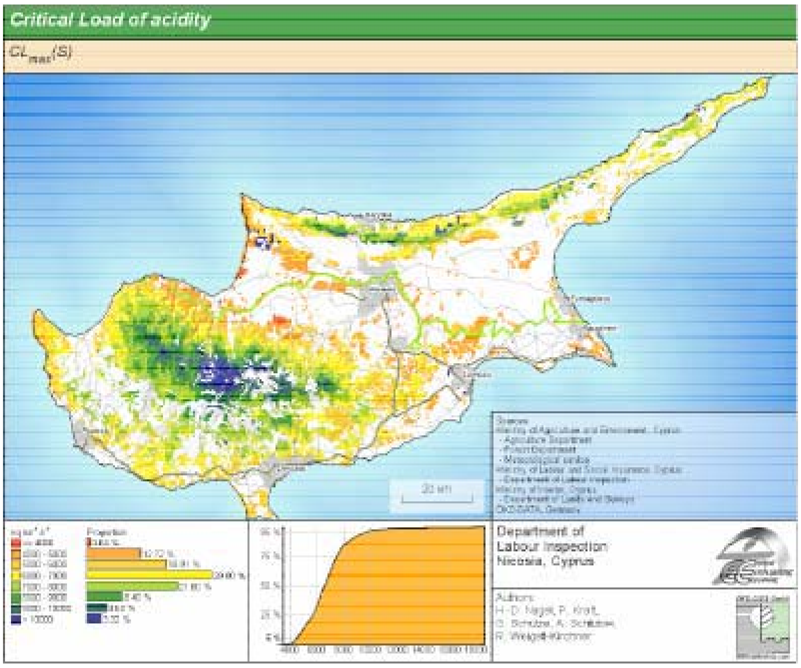

Figure CY-1. *Regional distribution of critical loads of acidity, CLmaxS, in Cyprus.*

Critical loads of nutrient nitrogen, *CLnutN*

In contrast to the insensitivity concerning acid inputs the critical loads of nutrient nitrogen underline the necessity to protect ecosystems in Cyprus from anthropogenic nitrogen inputs. Similar to the critical loads of acidity the Troodos mountains have also high critical loads of nutrient nitrogen (about 7-10 kg N $ha^{-1}a^{-1}$). A significant uptake by harvesting of the Calabrian pine is accompanied by relatively high precipitation surplus. Medium high critical loads (6-9 kg $ha^{-1}a^{-1}$) are located in the Pentadactylos mountains, including the Karpasia region. Calcareous soils from limestone could cause a high growth rate, but trees are not harvested in this region. The lowest critical loads values (1.5-3 kg $ha^{-1}a^{-1}$) are observed in the Kommandaria region, in the lowlands between Pentadactylos and Troodos and from Morfou to Ammochostos (including the Mesaoria and Solea region), in the lowlands around Lanarca Bay and from Lemosos to Pafos (including Akamas region). Pliocene biocalcarenites and alluvial sands, silts and gravels have a medium high nutrient supply, but maquis and garique vegetation are not able to use this because of missing precipitation in the lowlands. The regional distribution of critical loads of nutrient nitrogen is shown in Figure CY-2 and the statistical classification of sensitivity is given by Table CY-5.

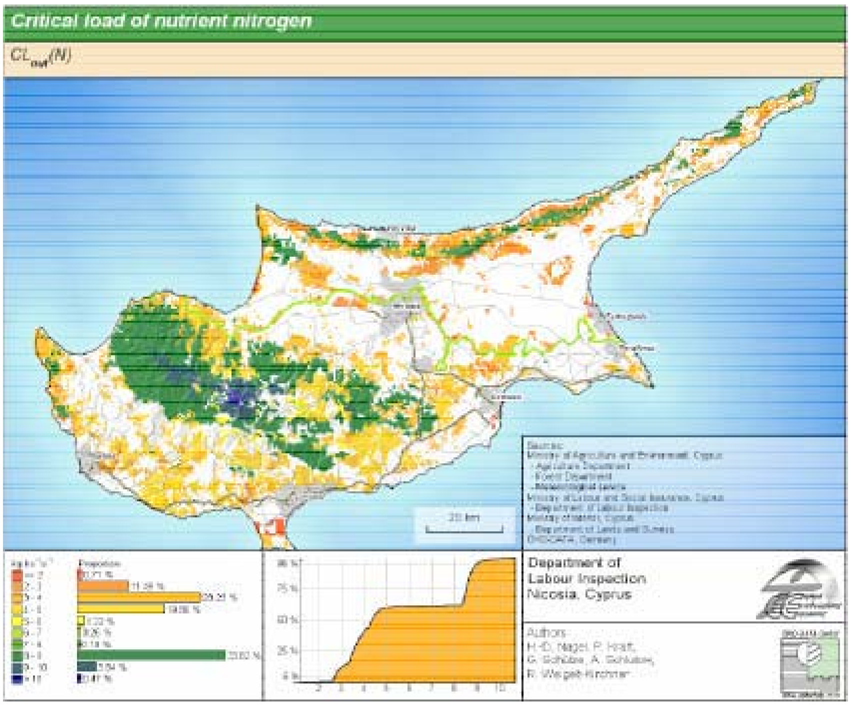

Figure CY-2. *Regional distribution of critical loads of nutrient nitrogen, CLnutN, in Cyprus.*

Table CY-5. *Statistical classification of sensitivity for critical loads of nutrient nitrogen, CLnutN.*

CLnutN sensitivity classes (kg ha^{-1} a^{-1})	Percentage of the sensitivity classes to total receptor area (%)	Percentage of the sensitivity classes to the total area of Cyprus (%)
< 2	0.71	0.30
2-3	11.49	4.87
3-4	28.23	11.94
4-5	19.86	8.41
5-6	1.22	0.52
6-7	0.26	0.11
7-8	0.10	0.04
8-9	33.82	14.31
9-10	3.84	1.62
>10	0.47	0.20
	100.00	42.32

Status of dynamic modelling and target load calculation in Cyprus

The model VSD was used to calculate the geochemical dynamic and, in case of violation of critical limits, to calculate target loads. All receptor sites used in the Critical Load approach with SMB, were calculated with VSD. Since no site is affected by acidic deposition, because every site is in a ‘safe’ basic state now and in future, there is no target load to calculate.

	No. of Sites
Sites calculated with SMB:	16 247
Sites calculated with VSD	16 247

Results for all sites:

Sites safe and non-exceedance at present:	16 247
Target loads values present in table ‘targetloads’	0

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Christou A (Ministry of Agriculture natural Resources and Environment of Republic of Cyprus, Department of Forests) (2004) Information on Level I and Level II plots established in Cyprus

Cyprus contribution to the Soil Geographical Database of Euro-Mediterranean countries at scale 1:1,000,000, version 4.0.

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Markides L (Ministry of Agriculture natural Resources and Environment of Republic of Cyprus, A. O. of Land and Water Use Section) (1999a) Soil Map of Cyprus 1:250,000

Meteorological Services of Cyprus (2005) Meteorological Survey at 220 meteorological stations (temperature and precipitation) 1991-2003

UBA (2004) Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads & Levels and Air Pollution Effects, Risks and Trends, Federal Environmental Agency (Umweltbundesamt) Berlin, UBA-Texte 52/04 www.icpmapping.org

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The national database of nutrient nitrogen critical loads

The evaluation of critical loads of nitrogen was carried out for forest ecosystems. Three forest ecosystem types have been investigated (prevailing tree types):

- broadleaved deciduous forest ecosystems: G1 (*Fagus sylvatica, Quercus robur, Quercus petraea, Carpinus betulis*),
- coniferous forest ecosystems: G3 (*Picea abies, Pinus sylvestris, Larix decidua*),
- mixed forest ecosystems: G4.

This database involves critical loads of nutrient nitrogen and empirical critical loads of nitrogen together. 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 and related soil data. The methodology of the calculation of critical loads presented in this report has been changed from the previous database evaluation (in 2005). Firstly, a new critical limit for nitrogen in the soil solution resulting from the conclusion of the 16th CCE workshop and the 22nd Task Force meeting of the ICP M&M (Bled, 2006) has been used. Secondly, denitrification factors have been derived from the ability of soil types to bound water (hydromorphism of soils).

Calculations of nutrient nitrogen critical loads and empirical critical loads

Land cover map CORINE has been used for describing three main types of forest ecosystems (broadleaved, coniferous and mixed). 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 (UBA, 2004, section 5.5). The uptake of nitrogen, *Nupt*, represents average annual wood increments (in 2004, data from the Forest Management Institute, Brandys nad Labem, www.uhul.cz). The immobilisation rates of nitrogen have been derived from long-term annual temperatures. These values were presented for the first time in Skorepova et al. (2001). Denitrification factors for forest soils derived from the type of soils and the classification of their ability to bound water (Nemecek et al., 1996) occur in the range of 0 and 0.8. Spatial distribution of denitrification factors for all soil types in the Czech Republic is shown schematically in Figure CZ-1. Spatial data for calculations are summarised in the Table CZ-1.

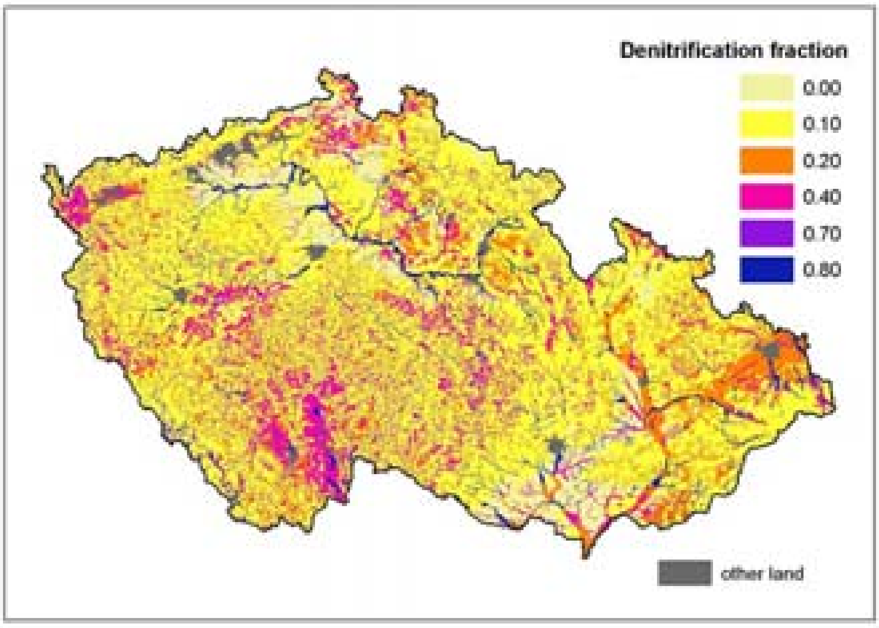

Figure CZ-1. *Spatial distribution of denitrification factors for soil types of the Czech Republic.*

The following equations have been used in the calculation of nutrient nitrogen critical loads for forest ecosystems:

$CL_{nut}(N) = N_{upt} + N_{imm} + N_{leacc}/(1-f_{de})$
$CL_{min}(N) = N_{upt} + N_{imm}$
$N_{leacc} = Q_{le} * [N]_{crit}$

N_{upt} = uptake of nitrogen
N_{imm} = immobilisation rate of nitrogen
N_{leacc} = acceptable leaching of nitrogen
f_{de} = denitrification factors
Q_{le} = water runoff
$[N]_{crit} = 2.5$ mg l^{-1}

A half of the territory of forest ecosystems approximately yields values of nutrient nitrogen critical loads higher than mean empirical critical loads proposed for forests, cca 15 kg N ha^{-1} a^{-1} (Achermann and Bobbink, 2003). These values occur in the localities of relatively high denitrification factors and/or high amounts of precipitation. Therefore these localities have been supplied by the empirical critical load (15 kg N $ha^{-1}a^{-1}$ or 1071.43 eq $ha^{-1}a^{-1}$). A schematic map in the Figure CZ-2 represents the result of the combination of nutrient critical loads and empirical critical loads for forest ecosystems.

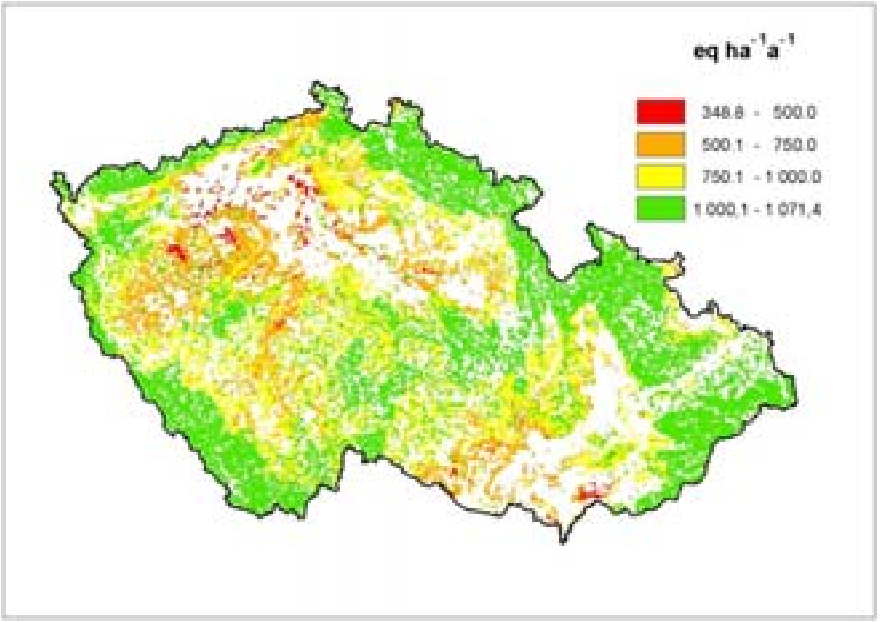

Figure CZ-2. *Critical loads of nutrient nitrogen and empirical critical loads for forest ecosystems.*

Data sources

Table CZ-1. *Spatial data used in the calculation of nutrient nitrogen critical loads.*

Map	Scale	Source
CORINE map (2000)		Ministry for the Environment of the Czech Republic
Annual mean temperature (1960-1990)	1 : 500 000	Czech Hydrometeorological Institute, Prague
Annual mean precipitation (1960-1990)	1 : 500 000	Czech Hydrometeorological Institute, Prague
Annual mean atmospheric deposition of N (2001)	2x2 km^2	Czech Hydrometeorological Institute, Prague
Soil map of the Czech Republic	1 : 200 000	Czech Agricultural University, Soil and Geology Dept., Prague (Němeček et al., 1996)

Comments and conclusions

In comparison to the previous critical loads of nutrient nitrogen the present updated values using new nitrogen critical limits of soil solution have changed substantially. Precipitation amounts exhibit the main impact on these values. Critical loads of nutrient nitrogen exceed the value given by empirical critical loads for forest ecosystems nearly in a half of the territory of the Czech Republic. For this reason the mean empirical critical load value for forest ecosystems showing the higher values of nutrient critical loads has been supplied. From the point of view of the atmospheric deposition stagnant in the last some years (Fottová et al., 2006) about two thirds of the area of forest ecosystems in the Czech Republic show exceedances of critical loads (Figure CZ-3).

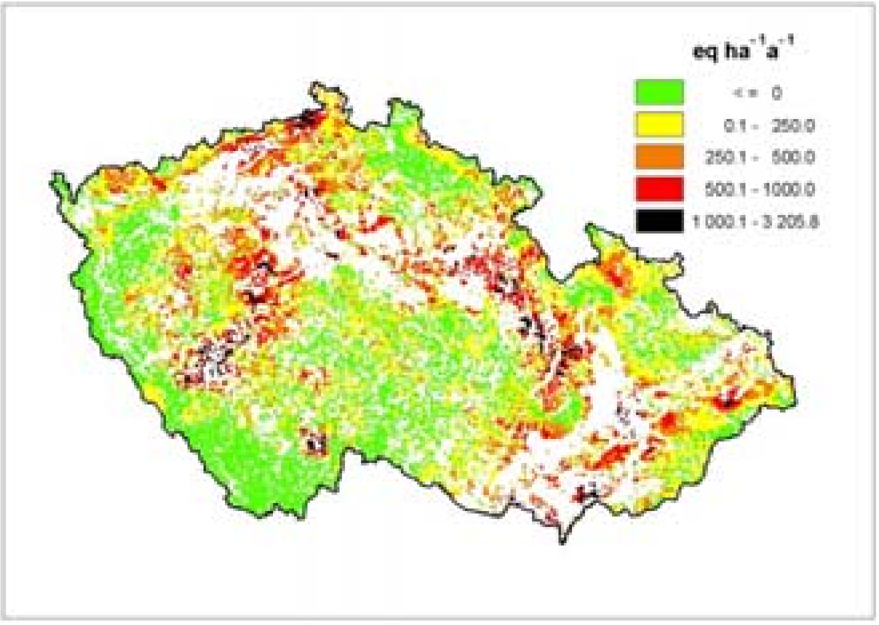

Figure CZ-3. *Critical load exceedances for nutrient nitrogen.*

References

Acherrmann B, Bobbink R (2003) Empirical Critical Loads for Nitrogen. Proceedings of the Expert Workshop, Berne, 11-13 November 2002. Environmental Documentation No. 164 – Air, Swiss Agency for the Environment, Forests and Landscape SAEFL, Berne, 327 pp

Fottová D, Krám P, Navrátil T, Skořepa J, Skořepová I (2006) Twelve years of hydrochemical monitoring of the GEOMON network, Czech Republic, BIOGEOMON - 5th International Symposium on Ecosystem Behaviour, Conference Program and Abstract, June 25–30, 2006, Santa Cruz, CA, USA, p. 84

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Calculation of critical loads of acidity and nutrient nitrogen and dynamic modelling data

The German NFC provides an update of the national critical load data of sulphur and nitrogen (steady-state mass balance approach) and results of the dynamic model application (VSD).

Critical loads are calculated in accordance to the methods described in the Mapping Manual (UBA, 2004) and following the instructions of the CCE for data submission (CCE, 2006). The German critical load database consists of 101,098 records.

In comparison with the data submission of 2005 only very small changes are to be observed concerning the critical loads of sulphur, *CLmaxS*, mostly due to some new deposition values of base cations (Figure DE-1). More important changes results for nitrogen critical loads (Figure DE-2). Applying the suggested update of critical concentrations in soil solution (CCE, 2006) a national approach was derived using the vegetation period for assignment of different concentration values in Northern and Western Europe (Fig. DE-3). As result in Figure DE-4 is shown a box plot of submitted nitrogen critical load data, the calculation of 2005 using the original critical N concentrations given by the Mapping Manual, the empirical critical load values and *CLnutN* with the suggested (national modified) update of the 2007 call for data.

The dynamic model VSD was successful implemented. For the three given scenarios 'Current LEgislation' (CLE), 'Maximum Feasible Reduction' (MFR) and a deposition scenario based on EMEP-MSC-W calculated background values (bkg) results are shown in Figures DE-5 to DE-7. As one of the most sensitive indicators the pH value was selected and the distribution trend over time was demonstrated in a box plot.

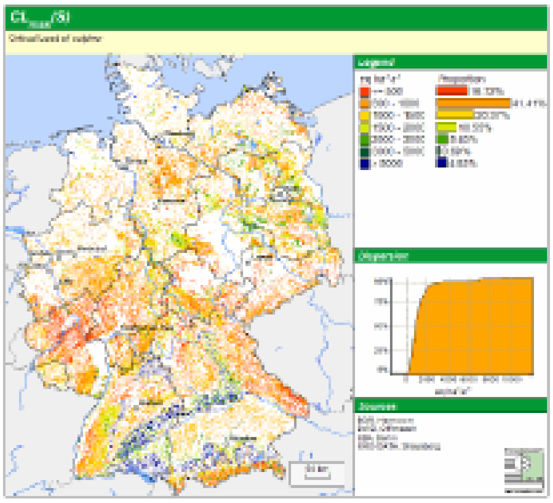

Figure DE-1. *Critical load of sulphur, CLmaxS.*

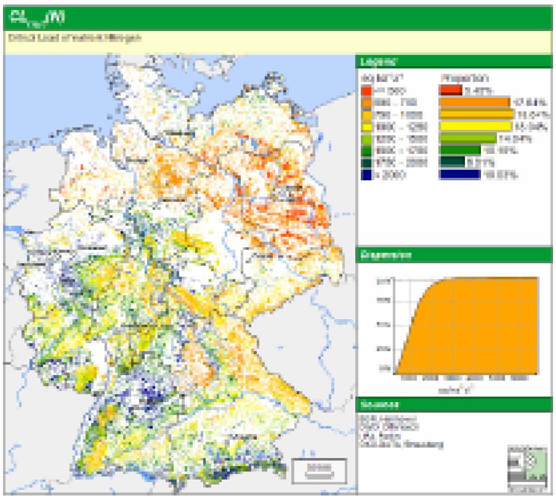

Figure DE-2. *Critical load of nutrient nitrogen, CLnutN.*

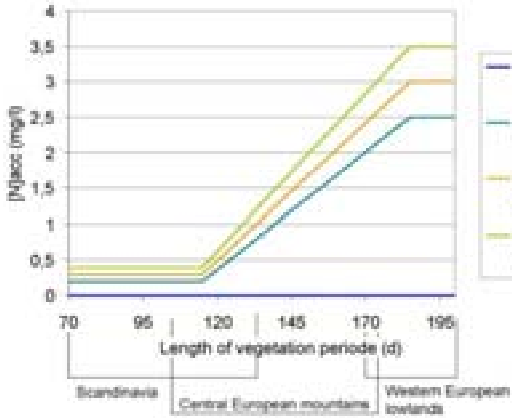

Figure DE-3. *Critical (acceptable) N concentrations in soil solution for calculating CLnutN.*

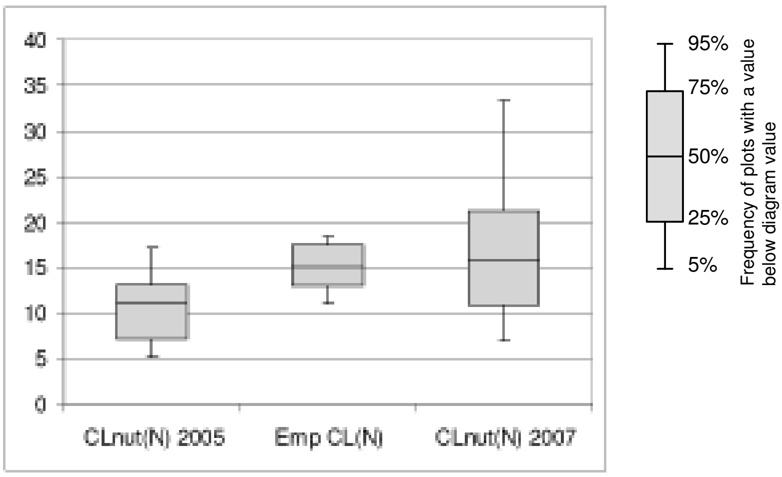

Figure DE-4. *Comparison of Nitrogen Critical Load values, data calculation 2005, empirical Critical Loads and data calculation of 2007.*

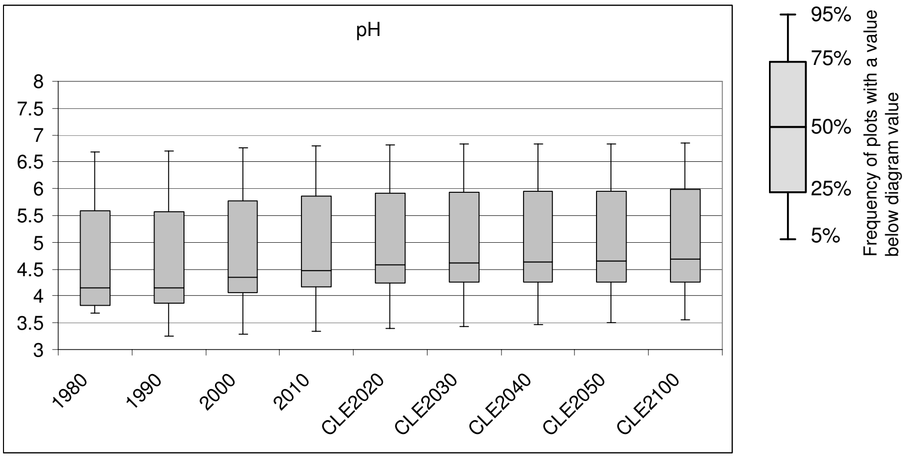

Figure DE-5. *Trend of the distribution of pH values in Germany following the 'current legislation' deposition scenario (101098 Plots calculated).*

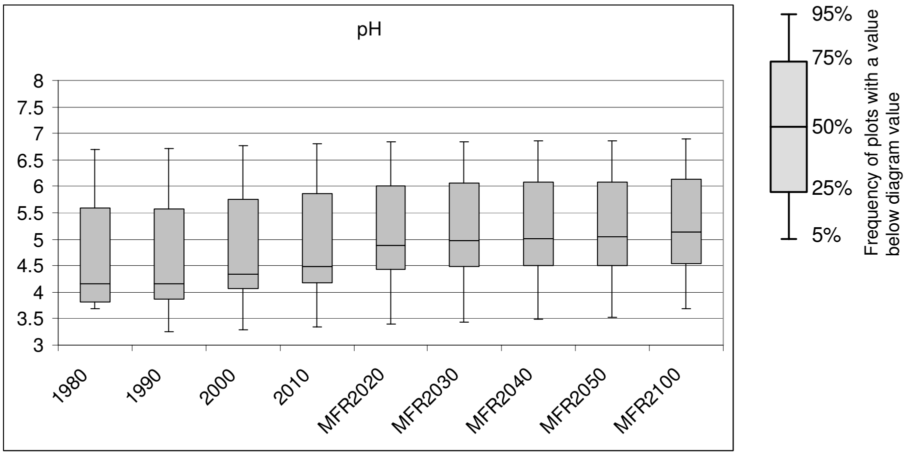

Figure DE-6. *Trend of the distribution of pH values in Germany following the 'maximal feasible reduction' deposition scenario (101098 plots calculated).*

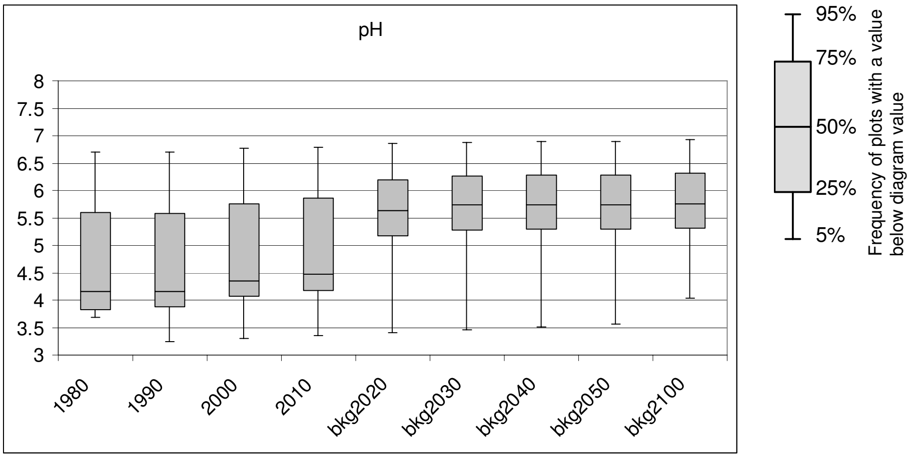

Figure DE-7. *Trend of the distribution of pH values in Germany following the 'background' deposition scenario (only natural sources from 2020) (101098 plots calculated).*

Data sources

CORINE Land Cover, Federal Environmental Agency (DLR-DFD 2004)

Data on soil properties described for the reference profiles of the units of the General Soil Map of Germany (BUEK 1000; Hartwig et al., 1995).

German Weather Services (DWD), 30 year means (1971–2000) of precipitation and temperature.

Empirical critical loads of nitrogen for terrestrial ecosystems

In addition to the calculation of critical loads with the steady-state mass balance approach and the application of the dynamic model VSD, empirical critical loads of nitrogen were assessed for the complete national dataset and submitted by the German NFC.

Empirical critical loads were derived in accordance to the methods described in the Chapter 5.2 of the Mapping Manual (UBA, 2004) and following the recommendations of the workshop ‘Empirical Critical Loads for Nitrogen’ (Achermann and Bobbink, 2003). The German empirical critical load database consists of 102,561 records of 1×1 km^2 grids. A regional distribution of this dataset is shown in Figure DE-8.

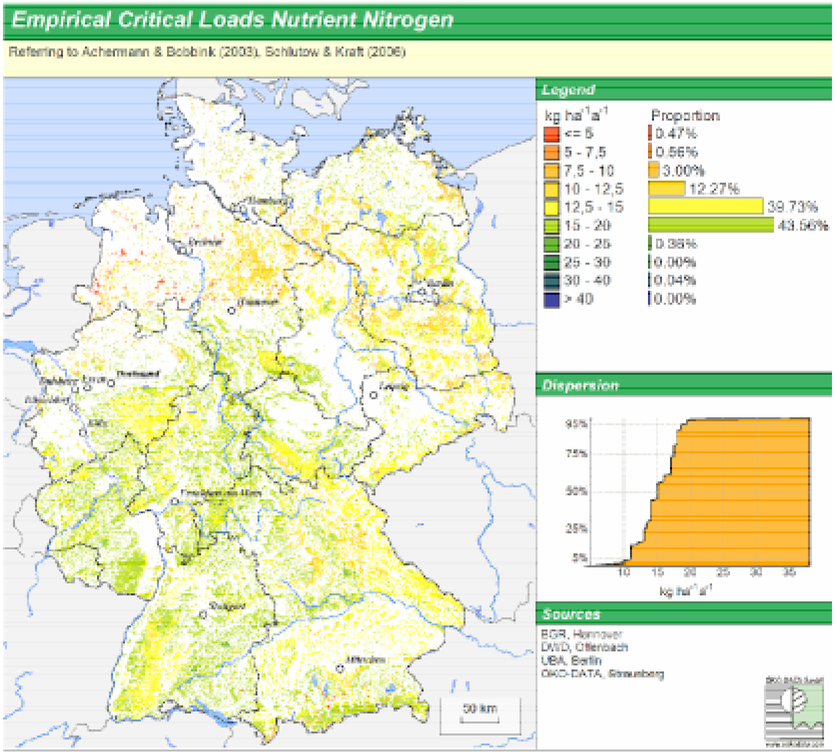

Figure DE-8. *Regional distribution of empirical critical loads of nitrogen for terrestrial ecosystems in Germany.*

Critical load ranges given by Table 5.1 of the Mapping Manual were specified by applying the BERN model (Schlutow and Kraft 2006). A typical plant community with a unique empirical critical load value could be defined for each EUNIS code (Table DE-1).

Table DE-1. *EUNIS code, typical plant community and empirical critical load values.*

EUNIS Code	BERN plant community	CL kg/(ha y)
A2.5423	Salicornietum strictae	35
A2.537	Eleocharetum uniglumis	32
A2.5422	Puccinellietum maritimae	38
A2.5425	Spergulario-Puccinellietum distantis	38
B1.321	Elymo-Ammophiletum arenariae	18
D1.1111	Eriophoro-Sphagnetum recurvi	5
D2.2222	Juncetum acutiflori	23
D2.31	Sphagno-Caricetum lasiocarpae	10
D2.32	Caricetum diandrae	18
D4.1H	Crepido-Juncetum subnodulosi	38
D5.21	Caricetum elatae (Comaro-Subass.)	20
D5.21	Caricetum gracilis	25
D5.216	Caricetum paniculatae	25
E1.26	Onobrychido-Brometum erecti	24
E1.2726	Helianthemo-Xerobrometum	22.5
E1.29	Armerio-Festucetum trachyphyllae	18
E1.29	Diantho gratianopolitani-Festucetum pallentis	22
E1.71	Polygalo-Nardetum strictae	15
E1.72	Airo-Agrostidetum tenuis	18
E1.72	Festuco-Koelerietum glaucae	25
E1.72	Polygalacto-Festucetum rubrae	12
E1.72	Pulsatillo-Phleetum phleoides	14
E1.72	Thymo-Festucetum ovinae	17
E1.93	Ornithopodo-Corynephoretum canescentis	11
E1.94	Teesdalio-Sperguletum vernalis	11
E2.11	Lolio-Cynosuretum cristati (Ranunculus bulbosus-Subass.)	24
E2.111	Alchemillo-Cynosuretum	20
E2.22	Alchemillo-Arrhenatheretum (Salvia pratensis-Subass.)	26
E2.22	Angelico-Cirsietum oleracei	25
E2.22	Heracleo-Arrhenatheretum elatioris (Alopecurus-Subass.)	30
E2.22	Heracleo-Arrhenatheretum elatioris (typ. Subass.)	27
E2.22	Lolio-Brometum racemosae	27
E2.23	Dauco-Arrhenatheretum (Salvia pratensis-Subass.)	26
E2.23	Pastinaco-Arrhenatheretum elatioris (typ. Subass.)	26
E2.236	Poo-Trisetetum flavescentis	12
E2.236	Trifolio-Festucetum rubrae	12
E2.31	Astrantio-Trisetetum flavescentis	16
E2.31	Geranio-Trisetetum flavescentis	16
E2.31	Meo-Festucetum rubrae	15
E2.31	Poo alpinae-Prunelletum vulgaris	9
E3.41	Galio-Alopecuretum pratensis	35
E3.411	Polygonetum bistortae	35
E3.44	Phalaridetum arundinaceae	45
E3.51	Junco-Molinietum	23
E3.52	Nardo-Juncetum squarrosi	18
E4.414	Trifolio-Festucetum violaceae	15
E4.4311	Seslerio-Caricetum sempervirentis	6
F2.41	Vaccinio-Rhododendretum ferruginei	15
F4.262	Cladonio-Callunetum vulgaris	10
G1.111	Salicetum albo-fragilis	12.5
G1.213	Carici remotae-Fraxinetum	14.6
G1.213	Filipendulo-Alnetum	14.7
G1.213	Pruno-Fraxinetum	20
G1.213	Ribeso sylvestris-Fraxinetum	14
G1.221	Fraxino-Ulmetum	14.5
G1.42	Lysimachio-Quercetum roboris (Anemone-Subass.)	19.2
G1.42	Molinio-Quercetum roboris	16
G1.42	Vaccinio vitis-idaeae-Quercetum petraeae	14
G1.51	Eriophoro-Betuletum pubescentis (Sphagnum recurvum-Subass.)	6
G1.52	Carici elongatae-Alnetum betulosum	13
G1.52	Stellario-Alnetum (typ. Subass.)	14
G1.61	Dicrano-Fagetum (Leucobryum-Subass.)	15
G1.61	Luzulo-Fagetum (Carex brizoides-Subass.)	16
G1.61	Luzulo-Fagetum (typ. Subass.)	15
G1.61	Molinio-Fagetum	16.5
G1.61	Myrtillo-Fagetum (typ. Subass.)	16
G1.61	Pteridieae-Fagetum (Agrostis-Subass.)	15.8
G1.63	Asperulo odorati-Fagetum sylvaticae (typ. Subass.)	17.5
G1.63	Cephalanthero-Fagetum (Carex-Subass.)	18.5
G1.63	Lathyro-Fagetum (typ. Subass.)	16
G1.63	Majanthemo-Fagetum (Poa nemoralis-Subass.)	18.5
G1.63	Majanthemo-Fagetum (typ. Subass.)	17
G1.65	Calamagrostio-Abieto-Fagetum (Dryopteris-Subass.)	17.5
G1.65	Dentario bulbiferae-Abieto-Fagetum	16
G1.65	Luzulo-Abieto-Fagetum (typ. Subass.)	17
G1.66	Cephalanthero-Fagetum (Lithospermum-Subass.)	18.5
G1.7C3	Adoxo-Aceretum pseudoplatani	13.8
G1.922	Agrostio-Populetum tremulae	12
G1.A14	Aceri monspessulani-Quercetum petraeae (typ. Subass)	15
G1.A16	Bromo-Carpinetum (typ. Subass.)	16.5
G1.A16	Galio-Carpinetum (typ. Subass.)	17
G1.A16	Mercuriali-Carpinetum (Primula-Subass.)	19.5
G1.A16	Polygonato-Carpinetum (typ. Subass.)	16
G1.A16	Stachyo-Carpinetum	18.5
G1.A16	Stellario-Carpinetum	19
G3.13	Vaccinio-Abietetum (typ. Subass.)	15.2
G3.1321	Luzulo-Abietetum (typ. Subass.)	15
G3.1B1	Asplenio-Piceetum	13.5
G3.1C	Bazzanio-Piceetum	13.5
G3.1C	Calamagrostio villosae-Piceetum (typ. Subass.)	13.3
G3.1C3	Adenostylo glabrae-Abietetum	18
G3.1C3	Galio rotundifolii-Abietetum	19
G3.1C3	Pyrolo-Abietetum	17
G3.1D2	Galio harcynici-Cultopiceetum (typ. Subass.)	13.5
G3.1J	Brachypodio sylvaticae-Cultopiceetum	14
G3.1J	Epilobio angustifoliae-Cultopiceetum	14
G3.1J	Equiseto-Cultopiceetum	13
G3.1J	Pteridio-Cultopiceetum	14
G3.1J	Urtico-Cultopiceetum	15
G3.22	Larici-Pinetum cembrae	16
G3.421	Empetro nigri-Pinetum sylvestris	10
G3.4211	Avenello-Cultopinetum	13
G3.4211	Brachypodio sylvaticae-Cultopinetum	13
G3.4211	Dicrano-Cultopinetum	10
G3.4211	Milio-Cultopinetum	12
G3.4211	Molinio-Cultopinetum	12
G3.4211	Myrtillo-Cultopinetum	11
G3.4211	Pruno spinosae-Cultopinetum	11
G3.4211	Pteridio-Cultopinetum	13.3
G3.4211	Rhamno frangulae-Cultopinetum	13
G3.4211	Rubo-Avenello-Cultopinetum	13
G3.4211	Urtico-Cultopinetum	13.3
G3.4211	Vicio cassubicae-Cultopinetum	13
G3.4A1	Pyrolo-Pinetum sylvestris	13
G3.E2	Eriophoro-Pinetum sylvestris	7
G3.E2	Leucobryo-Pinetum sylvestris (Molinia-Subass.)	10
G4.31	Cladonio-Pinetum sylvestris (Pleurozium-Subass.)	10.2
G4.31	Leucobryo-Pinetum sylvestris (typ. Subass.)	10.5
G4.31	Vaccinio myrtilli-Pinetum sylvatrae	11
G4.71	Dictamno-Quercetum	17.5

Empirical critical loads of nitrogen for terrestrial ecosystems in Germany range between 5 and 38 kg N $ha^{-1}a^{-1}$ with a mean of 15 kg N $ha^{-1}a^{-1}$; the statistical distribution is given in Table DE-2.

Table DE-2. *Statistics of empirical critical loads of nitrogen for terrestrial ecosystems in Germany in kg N* $ha^{-1}a^{-1}$

Minimum	5
5 percentile	11
25 percentile	13
Mean	15
75 percentile	17.5
95 percentile	18.5
Maximum	38

As additional information the protection status of all grid cells with empirical critical loads of nitrogen was checked. The European Habitats Directive (FFH) applies at nearly 28 percent (28,806) of mapped grids, 10,532 of them are also Special Protection Areas (SPA) for which the Birds Directive applies. About 5% of the grid cells are SPA areas only (Table DE-3).

Table DE-3. *Protection status of grid cells with empirical critical loads of nitrogen.*

Protection	Area (km^2)	Percent
No specific nature protection applies	68,348	66.6
Special Protection Area (SPA), Birds Directive applies	5,407	5.3
Special Area of Conservation (SAC), Habitats Directive applies (FFH)	28,806 (10,532 SPA + FFH)	28.1 (10.3)
A national protection program applies	no information	

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Modelled critical loads and dynamic modelling data

The objectives of this call for data were to submit updated critical loads and to provide time series of modelled chemical variables for different deposition scenarios, i.e. dynamic modelling results. In 2005, the French National Focal Centre (NFC) provided updated critical load values for nitrogen (acid and nutrient) and sulphur as well as dynamic modelling results (Probst et al., 2005). In 2007, the French NFC: (1) tested the updated critical concentrations for the calculation of critical loads of nutrient nitrogen proposed by the Coordination Centre for Effects (CCE) and, (2) sent data for dynamic modelling. In comparison with 2005, the only major change is the removal of costal ecosystems (EUNIS code B1.4) from the dynamic modelling database as, for those ecosystems, critical loads were determined empirically (Probst et al., 2005).

Calculation method

The data were computed following the method used in 2005 by the French NFC (Probst et al., 2005) which is in accordance with the Mapping Manual (UBA, 2004). For steady state critical loads, the Steady State Mass Balance (SSMB) model was applied on the soil top-layer (0–20 cm). VSD (Posch et al., 2003) was used for dynamic modelling. The results obtained with VSD for soils with high buffering capacity show significant differences with more complex models (Probst et al., 2003; Probst et al., 2005). However VSD allows better consistency for impact assessment within Europe (Probst et al., 2005). Due to software inconsistencies, the French NFC could not run VSD in 2007. In consequence, the modelling was performed by the CCE with the data provided by the French NFC.

Data sources

Table FR-1. *Critical loads and dynamic modelling parameters.*

Parameter	Unit	Description
Chemical criterions used and critical values		See Table FR-3
Acceptable critical nitrogen concentration	meq m^{-3}	Derived from the acceptable nitrogen leaching (0 for plain deciduous forest; 50 for plain coniferous forest; 100 for mountain forest ecosystems — Party and Thomas, 2000) and the amount of water percolating through the root zone.
BCdep	eq $ha^{-1}a^{-1}$	RENECOFOR network measurements extrapolated at the national scale (Ulrich et al., 1998; Croisé et al., 2002)
BCweath	eq $ha^{-1}a^{-1}$	PROFILE simulations (Party, 1999)
BCuptake	eq $ha^{-1}a^{-1}$	Calculated from [BC] in vegetation (Party, 1999) and net uptake of biomass by harvesting (IFN, 2002)
Nuptake	eq $ha^{-1}a^{-1}$	Calculated from [N] in vegetation (Party and Thomas, 2000) and net uptake of biomass by harvesting (IFN, 2002)
fde	eq $ha^{-1}a^{-1}$	Extrapolated from Guidance manual data (UBA, 2004) to French soil conditions (see Table FR-2)
All soil parameters		From RENECOFOR network data (Brêthes et al., 1997) and CCE network data (Badeau and Peiffer, 2001). See Table FR-4.

Table FR-2. *Denitrification factor values (adapted from UBA, 2004).*

Soil type	*fde*
Non hydromorphic soil	0.05 to 0.2
Hydromorphic silt or sandy soil	0.3
Hydromorphic clay	0.4
Peat soil and marshes	0.5

Table FR-3. *Critical limit values.*

Soil and bedrock type	**ANC criteria**	**Critical limit value**
Soft calcareous sediments	Al:BC	1.2
Hard calcareous sediments	Al:BC	1.2
Soft acid sediments		
Sands	pH	4.6
Sandy silex formations	pH	4.6
Others	Al:BC	1.2
Hard acid sediments		
Schists	pH	4.6
Sandstones	pH	4.6
Others	Al:BC	1.2
Metamorphic rocks		
Acid granite	pH	4.6
Others	Al:BC	1.2
Volcanic rocks	Al:BC	1.2

Table FR-4. *Soil parameters (from Brêthes and Ulrich, 1998).*

	Units	Min	Max	Median
Bulk density	g cm^{-3}	0.732	1.4	0.915
Conc. Org. Acids	eq m^{-3}	0	0.02436	3.5×10^{-5}
CEC	meq kg^{-1}	1	38	20
Base saturation	-	0.12	1	0.78
Carbon	g m^{-2}	3920	14000	9878
C:N ratio		12	28	15

The total concentration of organic acids in soil solution is calculated from *DOC* (Dissolved Organic Carbon) which is estimated from pH and clay content in soil layer. Due to the lack of data on *pCO2*, only one value (5 atm) was considered for *pCO2* in the topsoil.

Results

As no major changes were made between 2005 and 2007, please refer to the 2005 national report (Probst et al., 2005) for results and comments.

Empirical critical loads of nutrient nitrogen

Method

The determination of empirical critical loads of nitrogen for French ecosystems was based on the method described in chapter 5.2 of the Mapping Manual (UBA, 2004). The values given in table 5.1 of the Mapping Manual, were adapted to the French terrestrial ecosystems (Party et al., 2001) based on: (1) the information available on the potential vegetation and the land use for each ecosystem and, (2) the adaptation rules given in table 5.2 of UBA (2004) using temperature, frost period and base cation availability estimated by expert judgement. The subsequent empirical critical loads are given in Table FR-5.

Table FR-5. *Empirical critical loads, in eq $ha^{-1}a^{-1}$, derived for the French ecosystems (adapted from Party et al., 2001). K: calcareous ecosystem; A: acidic ecosystem; Out Cors.: outside Corsica; Per.+Bord.: Perigord and Bordeaux regions;SW+Nantes: South-West and Nantes regions.*

Potential vegetation	Land use			
	Coastal dune	Grassland	Upland meadow	Forest
Coastal dunes and heathlands	1786			
Swamps, bogs and wet heathlands	1786	714		714
Quercus robur dominated woodlands		1214		714
Quercus-*Carpinus* or *Ulmus* woodlands with *Quercus petraea*	1214	1214	500	857
Quercus petraea and *Q. pubescens* woodlands	1429	1429		1214
Quercus petraea, *Q. robur* or *pubescens* and *Q. pyrenaica* woodlands		1214		Per. + Bord.: 1214 SW + Nantes: 714
Mixed *Fagus*-*Quercus* and *Fagus* woodlands	1214	1214	500	1071
Quercus pubescens woodlands		K: 1789 A: 714		Corsica: 1071 Out Cors.: 1429
Quercus ilex woodlands	K: 1789 A: 714	K: 1789 A: 714		Corsica: 1071 Out Cors.: 1429
Quercus suber woodlands		714		Corsica: 1071 Out Cors.: 1429
Pinus halepensis and *P. nigra laricio corsicana* Mediterranean woodlands		857		1071

Potential vegetation	Land use			
	Coastal dune	Grassland	Upland meadow	Forest
Pinus pinaster woodlands		714		500
Abies and mixed *Abies-Fagus* woodlands		714	714	857
Picea woodlands		714		714
Pinus sylvestris woodlands		714		500
Pinus uncinata and *P. cembra* woodlands		500		500
Larix woodlands		714		714
Alpine and subalpine grasslands			500	

Data Sources

The French ecosystem classification and map was updated in 2003 for calculation and mapping of the critical loads of acidity and nutrient nitrogen (Probst *et al*., 2003; Moncoulon et al., 2004). The map of potential vegetation was synthesised for the French territory by Party (1999) from various vegetation maps (Dupias and Rey, 1985; Houzard, 1986; Ozenda and Lucas, 1987). Land use was derived from the map of forested and grassland areas in de Monza (1989) as well as the Digital Elevation Model GTOPO30 (USGS, 1996).

Results

The most sensitive areas to nitrogen deposition are located in the Landes (SW), the eastern part of the Paris basin, the eastern part of the Massif Central as well as in the Alps. Empirical critical loads of nitrogen are higher than critical loads for nutrient nitrogen determined with the Steady State Mass Balance (SSMB) model (Probst et al., 2005). Consequently, the sensitivity of the ecosystems is lower when derived from the empirical method. Comparatively to the SSMB model, most of the ecosystems shifted to a higher critical load class with the empirical method (+ 1 class for 49 % of the ecosystems and + 2 classes for 35 % of the ecosystems).

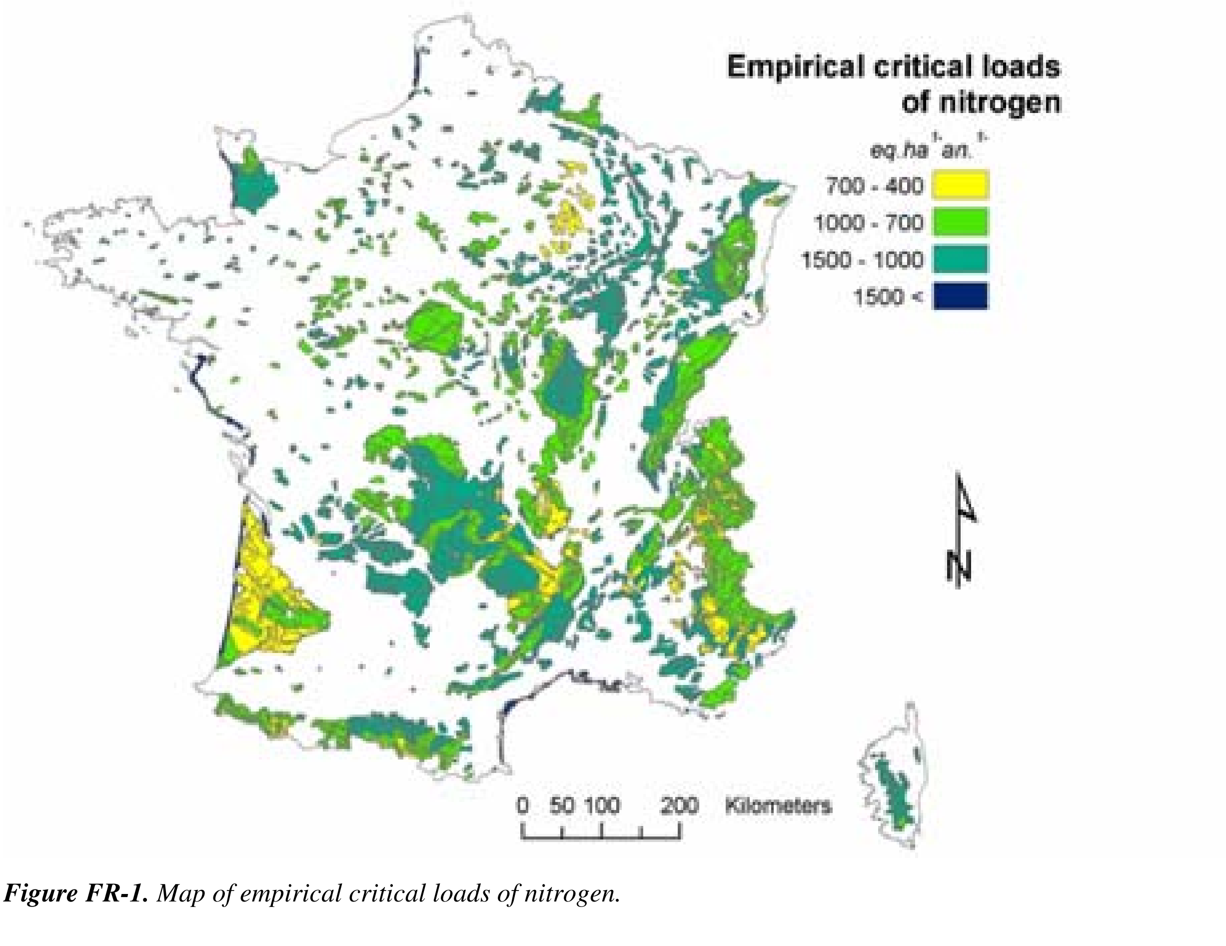

Figure FR-1. *Map of empirical critical loads of nitrogen.*

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Data sources

In response to the 2007 call for voluntary contributions, the Irish National Focal Centre (NFC) submitted data on empirical critical loads, and data on critical loads of nitrogen (N) and sulphur (S) and dynamic modelling. However, the intent of the Irish NFC contribution was not to meet the objective of the call but rather to correct an error in the 2005 data submission. A mass balance approach for nutrient nitrogen (*CLnutN*) was applied to all ecosystems under the 2005 call, whereas, an empirical approach should have been applied to all ecosystems other than coniferous forests. This resulted in low *CLnutN* values for Ireland (see Figure IE-1; Posch et al., 2005).

The 2007 contribution only provided corrected data for CLnutN; all other data have not been revised or updated since the 2005 contribution (Posch et al., 2005). As such, the contribution was primarily composed of a reformatted 2005 database; new dynamic modelling data were not provided. In response to the 'call for contributions on critical loads of N and S and dynamic modelling', CLnutN based on the mass balance approach were provided for coniferous forests (EUNIS code: G3); the data have not been revised since Posch et al. (2005) and the methodology followed the approach in the UBA (2004).

In response to the 'call for contributions on empirical critical loads', empirical CLnutN data were provided for deciduous (G4), natural grasslands (E3) and heathlands (F4). Empirical CLnutN were set for different ecosystem types based on observed changes in the ecosystem structure or function as reported in the refereed literature (Achermann and Bobbink, 2003). The CLnutN for deciduous forests was set to the mid-point of the range 10–15 kg N ha^{-1} a^{-1}; natural grasslands, and heathlands, were set to the mid-point of the range 10–20 kg N ha^{-1} a^{-1} (Achermann and Bobbink, 2003). The corrected *CLnutN* data are significantly different to the 2005 contribution and are more consistent with the *CLnutN* data for Northern Ireland (see Figure IE-1). The average 5^{th} percentile for *CLnutN* for Irish ecosystems was 557 eq ha^{-1} a^{-1} under the 2007 call, compared to 230 eq ha^{-1} a^{-1} under the 2005 call.

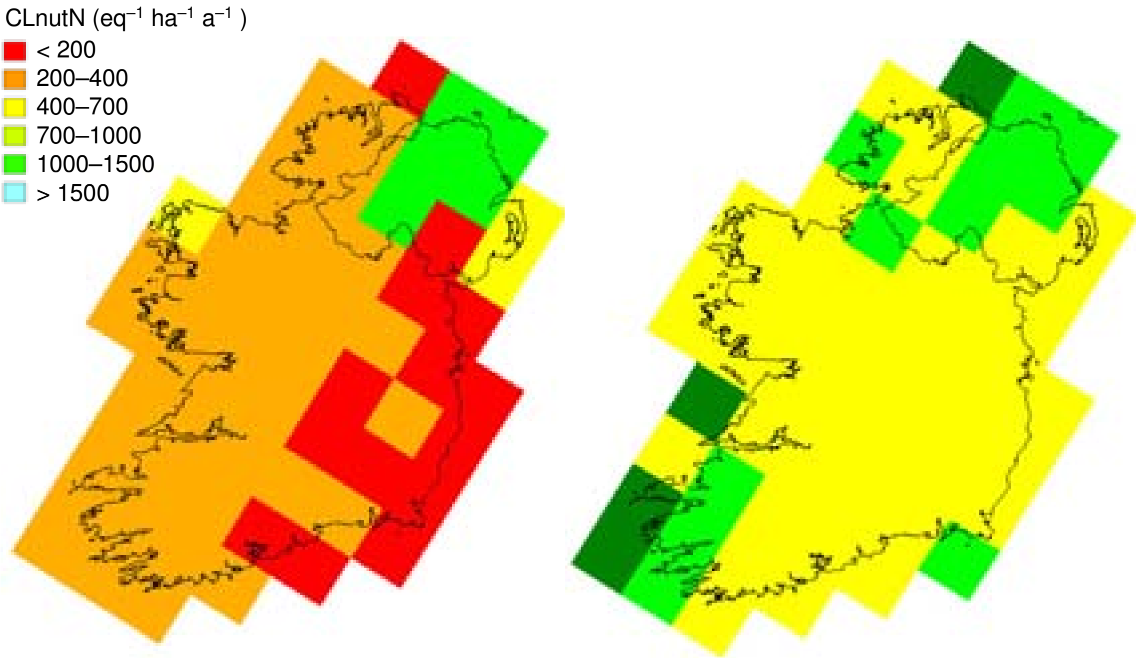

Figure IE-1. *Critical loads of nutrient nitrogen (CLnutN) under the 2005 data call (left) and the 2007 voluntary data call (right). Northern Ireland is shown for completeness (2005 data); ecosystems are similar across both regions indicating that critical loads should be consistent. The CLnutN data submitted to the 2007 voluntary call (right) are consistent with the United Kingdom (i.e. Northern Ireland) data.*

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Data sources

In the Call for Data 2007, critical load of nutrient nitrogen was updated. Old values of critical (acceptable) nitrogen concentrations were replaced with new ones, according to tab. 4 (see CCE Call 2007 instructions). Now these data are more consistent with the different EUNIS habitats. Others followed methodologies have not been changed; they are described in detail in the previous CCE Status Report.

Mostly, critical loads were calculated according to the SMB methodology, as suggested in the Mapping Manual 2004 (UBA, 2004).

Receptors mapped: CORINE Land use database has been adopted. Receptors are defined geometrically by the CORINE database, while vegetation characteristics were defined by intersection with a vegetation map provided by the Ministry for Environment.

Meteorology: datasets regarding the annual mean temperature and precipitation were updated by means of data provided by Climate Research Unit of the University of East Anglia.

Soil parameters: soil parameters were derived from the European database EUsoils

In order to simplify consistency checks and statistical analysis, EUNIS level 2 ecosystems considered in critical load calculation, were reduced to the first level as shown in Table IT-1 (Bonanni et al., 2006).

Table IT-1. *Considered ecosystem types at EUNIS level 1 and 2.*

Level 1	Level 2	Habitat
A4	A4.5	Shallow sublittoral sediments dominated by angiosperms
B1	B1.4	Coastal stable dune grassland
B3	B3.3	Rock cliffs, ledges and shores, with halophytic angiosperms
C1	C1.2	Permanent mesotrophic lakes, ponds and pools
C3	C3.2	Water-fringing reedbeds and tall helophytes other than canes
E2	E2.3	Mountain hay meadows
E1	E1.2	Perennial calcareous grassland and basic steppes
	E1.3	Mediterranean xeric grassland
	E1.5	Mediterranean-montane grassland
	E1.8	Mediterranean dry acid and neutral closed grassland
E4	E4.3	Acid alpine and subalpine grassland
	E4.4	Calciphilous alpine and subalpine grassland
F2	F2.3	Subalpine and oroboreal bush communities
F3	F3.1	Temperate thickets and scrub
	F3.2	Mediterraneo-montane broadleaved deciduous thickets
F5	F5.2	Maquis
F7	F7.4	Hedgehog-heaths
G1	G1.1	Riparian [Salix], [Alnus] and [Betula] woodland
	G1.5	Broadleaved swamp woodland on acid peat
	G1.6	[Fagus] woodland
	G1.7	Thermophilous deciduous woodland
	G1.8	Acidophilous [Quercus]-dominated woodland
G2	G2.1	Mediterranean evergreen [Quercus] woodland
G3	G3.1	[Abies] and [Picea] woodland
	G3.2	Alpine [Larix] - [Pinus cembra] woodland
	G3.4	[Pinus sylvestris] woodland south of the taiga
	G3.5	[Pinus nigra] woodland
	G3.7	Lowland to montane Mediterranean [Pinus] woodland (excluding [Pinus nigra])
G4	G4.6	Mixed [Abies] - [Picea] - [Fagus] woodland

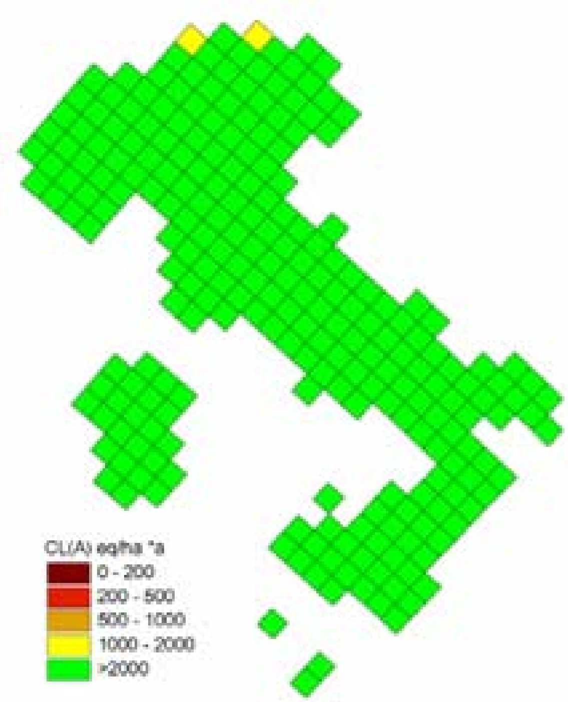

Figure IT-1. *Critical load of acidity.*

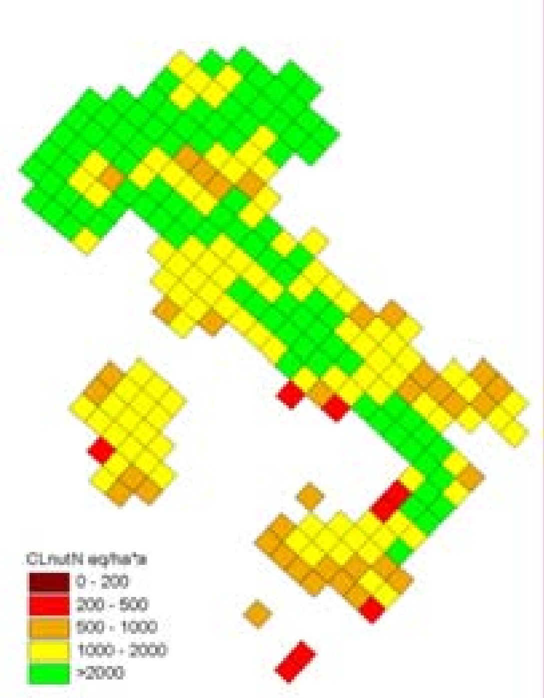

Figure IT-2. *Critical load of nutrient nitrogen.*

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LATVIA (report submitted in 2006)

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Introduction

Forests cover 2.7 million ha or 42% of the total Latvia area (Figure LV-1). During the last 70 years this percentage has had a stable trend of growth. Increase was from 24.7% in the year 1923 to 41% in 1991. The territorial distribution of woodlands in Latvia is not even. Areas with higher forest coverage are the central part (Riga region), the southeast area (Cesis and Madona regions) as well as the western parts (Ventspils, Liepaja, Talsi regions). The highest forest coverage is - 60 percent; the lowest - 28.8 percent.

Latvia's forests are regenerated either naturally or artificially. Natural regeneration of pine, spruce and deciduous species take place according to the site conditions on wet mineral and wet peat soils. Artificial rejuvenation involves the use of genetically improved seed and planting stock; forest seed orchards cover a total area of 965 ha. The main forest tree species are: pine (697 ha), spruce (170 ha), larch (57 ha), birch (10 ha), aspen (11 ha), and others (11 ha).

According to land use data, forest ecosystems has been set as an indicator interested for acidification and eutrophication effects description.

Figure LV-1. *Forest distribution map.*

Calculation methods

The Very Simple Dynamic (VSD) model has been used for dynamic modeling, consisting of a set of mass balance equations describing the soil input and output data relationships and fluxes, and soil properties. In the short and long-term, dynamic modeling can contribute to a better understanding of time delays of recovery in regions where critical loads are no longer exceeded and time delays of damage in regions where critical loads continue to be exceeded.

The mapping of critical loads of acidity, sulphur and nitrogen is based on 25564 deciduous, coniferous and mixed forest soil receptor polygons (area >0.01 km^2). The results have been mapped in the EMEP 50×50 km^2 grid.

Most of data needed for VSD running was computed and prepared regarding to Mapping Manual (UBA, 2004).

Data sources

National monitoring data

Soil data
Critical loads have been calculated for all major tree species using a soil database with observed parameters (soil inventory): soil pH, soil parent material, soil type and grading composition of soil. The soil inventory was performed from 1997 until 2003, totally were measured 2548 soil samples. A total of 942 values from measured forest soil profiles have been included in the calculations.

Forest data
Data on volume of fellings were taken from State Forest Service annual reports – Forest statistic data from 2001 until 2004, averaged for 4-year period.

Meteorological data
Meteorological data as temperature (long term observations from 1961 until 1990), precipitation (long term observations) and evapotranspiration were observed by the Latvian Environment, Geology and Meteorology Agency.

Calculation data

Soil data
The parameters as organic matter content (%), clay content in the soil (%), soil bulk density, cation exchange capacity (CEC), base saturation, C:N ratio were calculated using soil data information according to equations in the Mapping Manual (UBA, 2004).

Forest data
Volumes of fellings data were used for nitrogen uptake calculation (Mapping Manual, 2004 and Jacobsen et al., 2002).

Nitrogen and base cations net uptake rates were calculated by multiplying the element contents of the stems (N, Ca, K, Mg and Na) with annual harvesting rates (Mapping Manual, 2004; Jacobsen et al., 2002).

Maps
Forest map of Latvia from Corine Land Cover (CLC) was used to obtain information about forest types and density.

Results and conclusions

All data necessary to run the VSD model and to evaluate critical loads of acidity, sulphur and nitrogen have been prepared in Access database files and mapped for the EMEP 50×50 km^2 grid and forest polygons using ArcView software.

Calculated values for *CLmaxS* vary between 326 and 9021 eq $ha^{-1}a^{-1}$ for forest ecosystems. Calculated values of critical loads are given in Table LV-1 and distributions of critical load values are shown in figures LV-2 to LV-5.

***Table LV-1**. Extremes of critical load values in Latvia.*

Parameter eq $ha^{-1}a^{-1}$	Minimum value	Maximum value
CLmaxS	2889	5631
CLmaxN	8955	16242
ClminN	107	677
CLnutN		

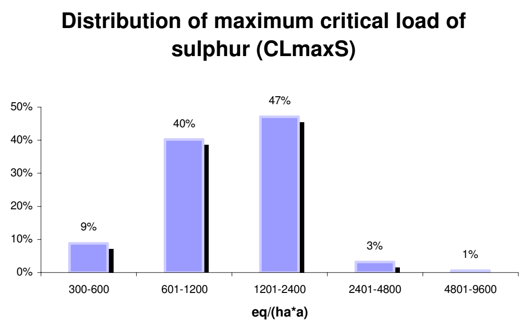

***Figure LV-2**. Distribution of CLmaxS concentrations.*

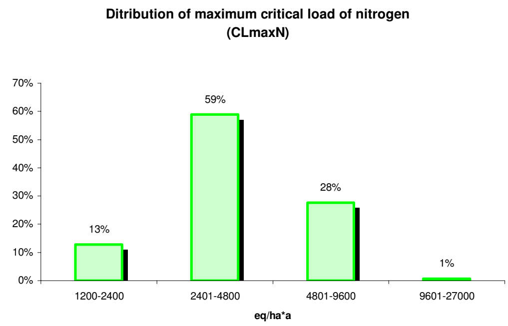

***Figure LV-3**. Distribution of CLmaxN concentrations.*

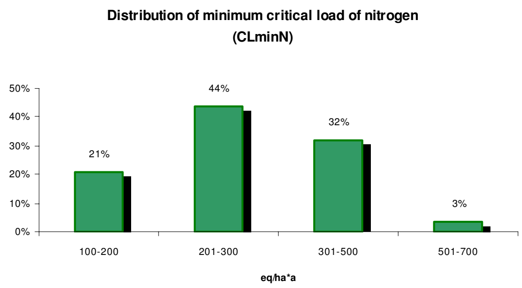

***Figure LV-4**. Distribution of CLminN.*

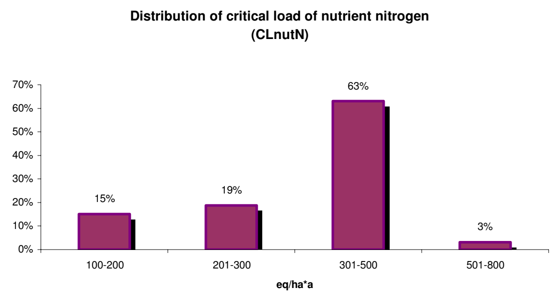

***Figure LV-5**. Distribution of CLnutN.*

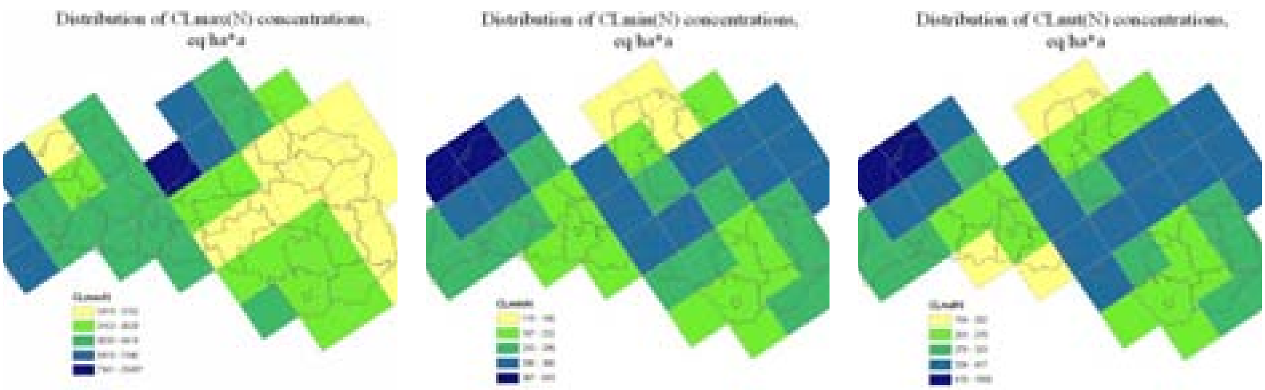

***Figure LV- 6**. Average ClmaxN, CLminN and CLnutN in EMEP grid cells.*

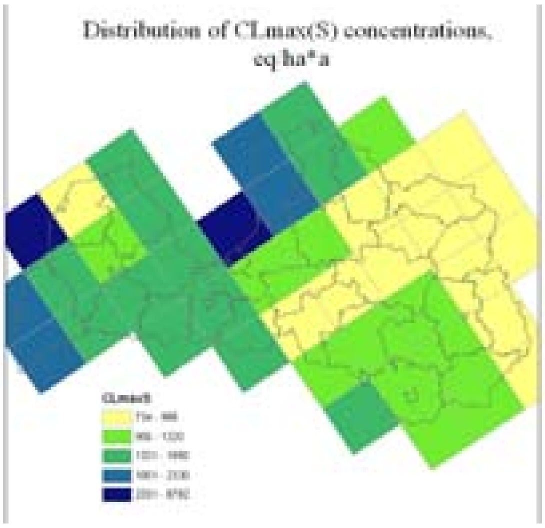

Figure LV-7. *Average CLmaxS in EMEP grid cells.*

According to the data, calculations and simulations, **critical loads for acidification** in Latvia are high. The Critical Loads for acidification are not exceeded in any Latvian area. Therefore acidification does not seem to be a problem in the future.

The situation is different for **eutrophication**. The calculated Critical loads for eutrophication in forested ecosystems are much lower.

Future tasks

Since the negative influence of nitrogen in all ecosystems will become worse (loss of biodiversity), it is recommended from experts to calculate critical loads also for nitrogen sensitive non-forest ecosystem such as raised bogs in Latvia; also to protect and monitor this very sensitive ecosystem in the future.

Calculation of critical loads of heavy metals (mercury, cadmium, lead) also has high priority, especially mercury. The accumulation of mercury especially in the ecosystems of Nordic countries is becoming a serious problem. It can be expected that the critical loads of mercury in Latvia are exceeding due to the hydro biological and geological circumstances (wet lands, high organic carbon content in sediments).

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National critical load maps

The Dutch data set on critical loads of acidity and nutrient nitrogen contains information for 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 vegetations) against eutrophication and acidification;
– plant species composition in small heathland lakes against eutrophication.

The methods to calculate critical loads for these targets have been described in Albers et al., 2001 and in various CCE reports since 2001. Critical acid loads for the protection of forest soils were calculated with SMB (CCE, 2003). 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 vegetations were calculated with a steady-state version of SMART2-MOVE/NTM (Posch et al., 2005).

In 2007, the critical loads for plant species composition in terrestrial ecosystems were updated. Critical loads for forests, as calculated with SMB, and critical loads for plant species composition in small heathland lakes remained unchanged. In response to the (voluntary) call for data, empirical critical loads were mapped and dynamic scenario analyses were carried out.

Updated critical loads

For the critical loads calculated with the static version of SMART2-MOVE/NTM, a minor update of the database was made. The focus has been to improve the calculations for those sites were the method did not yield realistic critical loads (>100 eq $ha^{-1}a^{-1}$) for either nitrogen or acidity (Posch et al., 2005). Moreover, for one nature target type (species rich grassland on clay) better critical limits for pH and N availability were used. These critical limits better suit the conditions of the soil types. Furthermore, some inconsistencies were removed in the software related to the assignment of incorrect values for pH to some nature target types that, in turn, lead to low, incorrect, critical loads of S.

Due to the changes the 5th percentile of *CLmaxS* increased from 266 to 344 eq $ha^{-1}a^{-1}$. The change in the average value of *CLmaxS* over all ecosystems is much larger (increased from

4600 to 5900 eq $ha^{-1}a^{-1}$). Changes in *ClnutN* were smaller (the average value decreased from 1332 to 1235 eq $ha^{-1}a^{-1}$, the 5th percentile from 573 to 563 eq $ha^{-1}a^{-1}$).

Empirical critical loads

Ranges of empirical critical loads (Achermann and Bobbink, 2003) were assigned to the different nature targets types. Critical loads computed with SMART2-MOVE/NTM or AquAcid were used to assign one value to each target type, when calculated critical loads were inside of the ranges of empirical critical loads. When calculated critical loads were outside of the empirical ranges the nearest limit was used to set the empirical critical load. No critical loads were set for those nature target types for which no empirical ranges are available (i.e. fluvial, riparian or swamp woodlands and reedlands).

Dynamic modelling

Based on the software and data provided by CCE, 27 scenarios of combined N and S deposition were derived for the Netherlands. For forests, the VSD model was applied to evaluate these scenarios, for plant species composition the dynamic version of SMART2-MOVE/NTM was used.

Both models were calibrated on spatial patterns of base saturation, Cpools and C/N ratio's; for each grid cell the model was calibrated such that is fits the measurements in the year of observation.

For the calibration, an improved map of base saturation was constructed in the following way. First a regression analysis was carried relating measured base saturation with environmental factors such as soil type, soil texture, drainage class and, seepage (quality and quantity). In a next step the regression equation (r^2=0.32) was used to map base saturation based on maps of the above mentioned explanatory variables. The former map of base saturation was calculated in a similar way, but than only 2 types of sandy soils were distinguished (calcareous and non-calcareous soils). In new the regression analyses 5 types of sandy soils were distinguished.

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Procedures

Dynamic modelling

Due to resource limitation a limited part of the country (counties Østfold and Hedmark) was selected for calculations of scenarios for this call for data. The MAGIC model was used (Cosby et al., 1985; Cosby et al., 2001). Calibrated lakes were those from the statistically selected lakes (1007 nationwide) in the 1995 National lake survey (Skjelkvåle et al., 1996). The survey had 62 lakes in the two counties. Two of the lakes were disregarded due to very high phosphorus concentrations (and ANC) from local pollution. The model was calibrated to observed water chemistry for each of the lakes and to estimated soil base saturation in 1995. In the automatic calibration routine of MAGIC the following switches were set: BC optimizer: on, SO4 adsorption optimizer: off, soil pH optimizer: off, N dynamics optimizer: off.

Atmospheric deposition history was provided by CCE for EMEP grid cells. These were grouped into 6 groups (the squares in each group had similar history). Each lake was placed into one of the six groups by location. The 27 scenarios were calculated for each of the 6 groups (162 scenarios in total).

After calibration, all 27 scenarios were run for all 60 lakes. In order to get a reasonable coverage within each EMEP grid cell, the calibrated lakes were then used to assign scenarios to all grid cells (1/4*1/8 degree) in the Norwegian critical loads database in the two counties (217 cells) using a matching routine called ‘MAGIC library’ (IVL, 2007) (see also country report for Sweden). The ‘MAGIC library’ is operated and developed by IVL, and includes data for several hundred lakes calibrated with MAGIC in both Sweden and Norway. The 60 lakes here, was added to the database, then the 217 grid cells lakes were matched according to a Euclidian distance routine based on water chemistry and location. Each of the 217 grid cell lakes was thus assigned a MAGIC modelled lake in the library. Sweden used the same approach to calculate the MAGIC predicted water chemistry for the 27 scenarios. Norwegian grid cell lakes may be matched to a Swedish lake (and vice versa). The data reported is then MAGIC calculated water chemistry for each of the 27 scenarios.

Empirical critical loads for nutrient nitrogen

The empirical critical loads for nutrient nitrogen were updated using the harmonised land use map by SEI provided by the CCE and the lower limits of the critical load values given in the Mapping Manual (UBA, 2004).

***Table NO-1**. Critical Loads for the submitted ecosystem types.*

Map code category	EUNIS code	Critical limit (mg m^{-2} a^{-1})	Map code category	EUNIS code	Critical limit (mg m^{-2} a^{-1})
301	C1	500	701	G1	1000
302	C2	500	703	G3	1000
401	D1	500	704	G4	1000
501	E1	1000	804	H4	500
502	E2	1000	805	H5	500
503	E3	1000	901	I1	2000
504	E4	500	1000	J	
601	F1	500			
602	F2	500			
603	F3	500			
604	F4	1000			

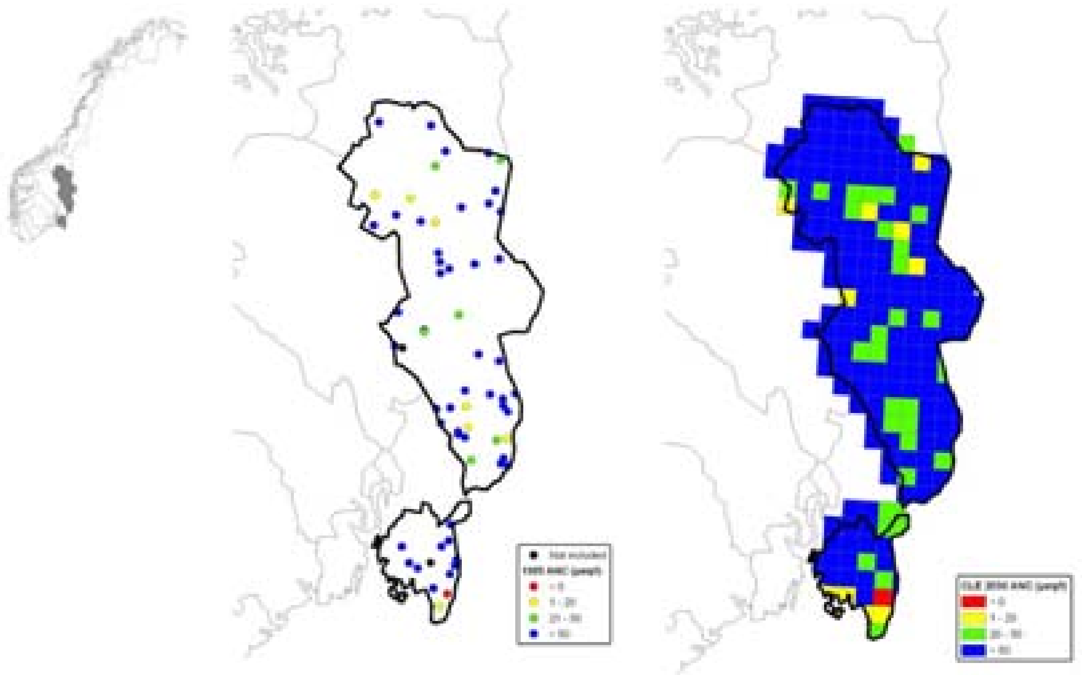

***Figure NO-1**. Left map: Observed ANC in 1995 for each calibrated lake. Right map: Modelled ANC in 2030 according to the CLE scenario for each 'grid cell lake'. Open circle on the left map show: disregarded lake due to very high phosphorus concentrations (and ANC) from local pollution: Stomperudtjern (128-1-4) and Kinnlitjernet (412-1-20).*

Data sources

Ranges of model inputs and parameters and comments on their sources and justifications are listed in Table NO-2.

***Table NO-2.** Sources of the submitted data.*

Var	Unit	Min	Max	Assumptions, data sources and justifications
EcoArea	km^2	3.2	204.6	We consider 100% of the land area to contain watersheds for lakes and rivers. We have not calculated the area of the EMEP grid cells, which should be given

Var	Unit	Min	Max	Assumptions, data sources and justifications
				here (minus the part of the cell covering ocean).
CLmaxS	eq $ha^{-1}a^{-1}$	50.9	20800	Calculated with FAB model (according to Mapping Manual, except BC^*_0 taken from MAGIC calibrations (1860))
CLminN	eq $ha^{-1}a^{-1}$	32.0	504	
CLmaxN	eq $ha^{-1}a^{-1}$	103	25354	
CLnutN	mgN m^{-2} a^{-1}	500	2000	Empirical values taken as minimum of range suggested in mapping manual
crittype		6	6	ANC is used as criterion for all lakes
critvalue	µeq L^{-1}	1.2	50	Variable ANC_{limit}
SoilYear		1985	2000	Lake catchment split into 4 categories: i) Forest area, taken from nearest relevant soil sampling locations (National Forest Inventory) for the percent forest in the lake catchment. ii) Peat area, taken from Langtjern soil pits no. 2 and 3 (1991 and 2000 average). iii) Non-forested upland, all from one project (Rondane National Park (Skjelkvåle et al., 1997)); arithmetic average from six sampling points. iv) Open water, including lake itself.
ExCa	%	2.2	42.4	
ExMg	%	0.8	22.2	
ExNa	%	0.3	4.9	
ExK	%	0.6	6.1	
thick	m	0.20	1.4	
BulkDens	g cm^{-3}	0.32	1.28	
CEC	meq kg^{-1}	18.0	430	
Porosity	%	50	50	Assumption. Constant value used for all sites.
DOCsoil	µmol L^{-1}	100	100	Assumption. Constant value used for all sites.
UptCa	meq $m^{-2}a^{-1}$	0.00	34.5	Based National Forest Inventory. Same as in critical loads database: value for the 12x12 km^2 grid cell in which the lake was located.
UptMg	meq $m^{-2}a^{-1}$	0.00	8.5	
UptK	meq $m^{-2}a^{-1}$	0.00	10.0	
UptNa	meq $m^{-2}a^{-1}$	0.00	1.7	
UptSO4	meq $m^{-2}a^{-1}$	0.00	0.00	
HlfSat	µeq L^{-1}	100	100	Assumption. Constant value used for all sites.
Emx	meq kg^{-1}	0.10	0.10	Assumption. Constant value used for all sites.
Nitrif	%	100	100	Assumption based on the fact that ammonium concentrations are very low.
Denitrf	%	0.00	0.00	
DepYear		1985	2000	
Cldep	eq $ha^{-1}a^{-1}$	17.5	1755	Deposition flux of chloride, sat equal to catchment output flux
Cadep	eq $ha^{-1}a^{-1}$	0.7	175	Calculated from $[Cl^-]$ using standard sea salt ratios and assuming no non-sea salt deposition. When Na deposition was calculated to be higher than base cation flux out, the base cation deposition was reduced such that net flux is 0 (2 cases of the 60).
Mgdep	eq $ha^{-1}a^{-1}$	3.4	350	
Nadep	eq $ha^{-1}a^{-1}$	15	1506	
Kdep	eq $ha^{-1}a^{-1}$	0.3	74.3	

Var	Unit	Min	Max	Assumptions, data sources and justifications
NH4dep	eq $ha^{-1}a^{-1}$	22.0	596	Calculated from observed ratios in deposition to SO_4. NO_3 deposition was increased to make net flux always negative or 0 (1 case of the 60). SO4 deposition was calculated from runoff flux assuming geological contribution (calculated as 0.17*([Ca]+[Mg]-0.234*[Cl])*Qs) and background deposition from CCE scenarios. If excess deposition was less than 5 meq/m2/a, the weathering was reduced to give excess deposition that was the same as others in the EMEP grid (10 cases).
NO3dep	eq $ha^{-1}a^{-1}$	48.0	593	
LakeYear		1985	2000	Lake chemistry taken from the statistically selected lakes (1007 nationwide) in the 1995 National lake survey.
Calake	µmol L^{-1}	8.2	835	
Mglake	µmol L^{-1}	2.0	206	
Nalake	µmol L^{-1}	13.9	463	
Klake	µmol L^{-1}	1.1	35.3	
NH4lake	µmol L^{-1}	0	7.1	

Var	Unit	Min	Max	Assumptions, data sources and justifications
SO4lake	µmol L^{-1}	11.1	259	
Cllake	µmol L^{-1}	5.6	363	
NO3lake	µmol L^{-1}	0.1	363	
DOC	µmol L^{-1}	1.7	765	Calculated from pH and charge balance
pKAl		7.5	11.4	Calculated from pH and Al-tot
RelArea	%	0.01	30.0	Data for each catchment
RelForArea	%	3.0	100	Data for each catchment
RetTime	a	0.20	5.30	Assumption. 3 classes, by lake size.
Qs	m	0.3	1.2	Runoff taken from digital 30-year normal runoff database.
expAllake		3.00	3.00	Assumption. Constant value used for all sites.
pCO2	%	0.05	0.06	Assumption. Constant value used for all sites. (0.06 used for the matched Swedish sites)
Cased	m a^{-1}	0.00	0.00	Assumption. Constant value used for all sites.
Mgsed	m a^{-1}	0.00	0.00	
Nased	m a^{-1}	0.00	0.00	
Ksed	m a^{-1}	0.00	0.00	
SO4sed	m a^{-1}	0.00	0.00	
Clsed	m a^{-1}	0.00	0.00	
NH4sed	m a^{-1}	0.00	0.00	
NO3sed	m a^{-1}	0.00	0.00	
UptNH4lake	%	0.00	0.00	Assumption. Constant value used for all sites.
UptNO3lake	%	0.00	0.00	Assumption. Constant value used for all sites.
DMstatus		-1	1	1 for all data from Østfold and Hedmark counties, -1 for all others in this submission (although target loads have been submitted previously, but included in the scenario assessment)

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Extension of the ecosystems types considered

The coniferous and deciduous forest ecosystems considered so far in the Polish mapping program have been supplemented with the following other ecosystems: mixed forests; natural grasslands; moors and heathlands; mire, bog and fen habitats. This resulted in an increase of the total ecosystem coverage from 88,383 km^2 to 128,398 km^2. The spatial resolution remained unchanged and is based on a 1×1 km grid cell. Details are given in Table PL-1.

Data sources

The CORINE land cover database (version 12/2000) was used to construct an extended database containing the new ecosystem types considered for mapping the empirical critical loads of nitrogen.

The values of empirical critical loads of nitrogen presented in Table PL-1 were adopted from the Mapping Manual (UBA, 2004 - Table 5.1). The ecosystems protection statistics is given in Table PL-2

Table PL-1. *Ecosystem types subject to mapping empirical critical loads of nitrogen.*

Ecosystem	EUNIS code	Area km^2	Percentage of receptor area	EmpCLnutN eq/ha/year
Broad-leaved forest	G1	19070	15	893
Coniferous forest	G3	77115	60	893
Mixed forest	G4	30214	24	893
Natural grasslands	E	576	~ 0	1071
Moors and heathland	F	38	1	857
Mire, bog and fen habitats	D	1385	~ 0	714

***Table PL-2**. Ecosystem protection status.*

Protection program	Area km^2	Percentage of receptor area	Percentage of country area
0 - no specific protection	49747	38.7	15.9
1 – SPA – Birds Directive	12231	9.5	3.9
2 – SAC – Habitats Directive	6432	5.1	2.1
12 – SPA & SAC Directives	5012	3.9	1.6
9 – National protection programs	54976	42.8	17.6

The spatial distribution of the estimated empirical critical loads of nitrogen for Polish ecosystems is presented in Figure PL-1.

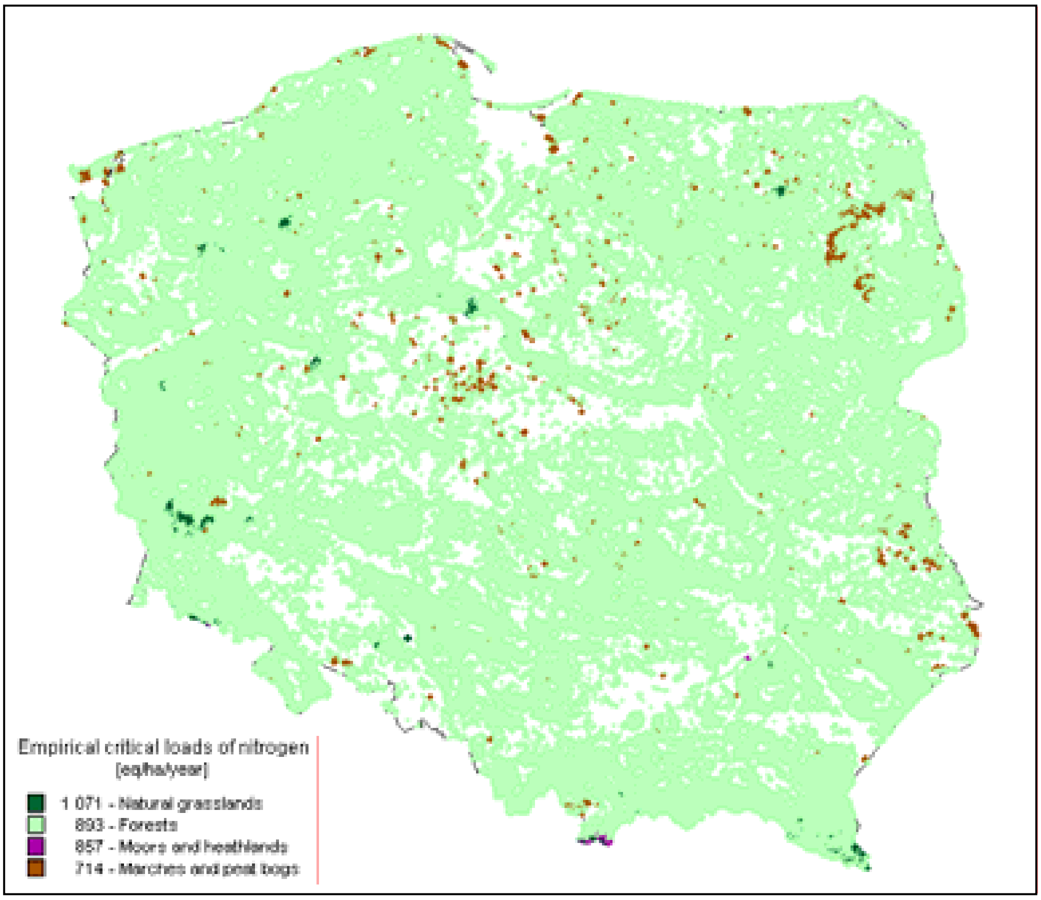

Figure PL-1. *Spatial distribution of empirical critical loads of nitrogen.*

References

UBA (2004) Manual on methodologies and criteria for modelling and mapping critical loads & levels and air pollution effects, risks and trends. Umweltbundesamt Texte 52/04, Berlin. www.icpmapping.org

RUSSIA (report submitted in 2006)

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National maps produced

In response to the call for data of October 2005, a new data set of critical loads for acidity and eutrophication was provided. The critical loads (CLs) were updated for forested lands of European Russia on a 5x5 km^2 grid. Data processing included combining soil and land use data with GIS layers such as temperature, precipitation amounts, base cations depositions and others. The following maps were produced:

- *maximum critical loads of sulphur,*
- *maximum critical loads of nitrogen,*
- *minimum critical loads of nitrogen,*
- *critical loads of nutrient nitrogen.*

Calculation methods

In the previous submissions, critical loads of S and N for terrestrial ecosystems of European Russia have been calculated using modified steady-state mass balance equations (Bashkin et al., 1995, 1999). A percentage of coniferous/deciduous forests and arable lands were used to describe a spatial distribution of main input data and to calculate CLs in 50×50 km^2 grids.

The Russian NFC now updated both the database and calculation methods. In general, critical loads were computed in accordance with the methods summarized in the Mapping Manual (UBA, 2004). The basic ecosystem map for calculating and mapping was produced by overlaying several maps; it consists of 31,043 units. A summary of the variables used and methods/approaches applied is given in Table RU-1.

Table RU-1. *National critical loads database and references.*

Parameter	Variable	Unit	Description
Critical load of acidity	*CLmaxS* *CLminN* *ClmaxN*	eq $ha^{-1}a^{-1}$	Mapping Manual, eq.5.22 Mapping Manual, eq.5.25 Mapping Manual, eq.5.26
Critical load of nutrient nitrogen	*CLnutN*	eq $ha^{-1}a^{-1}$	Mapping Manual, eq.5.25
BC and Cl deposition	*Cadep,Mgdep, Kdep,Nadep, Cldep*	eq $ha^{-1}a^{-1}$	Received from MSC-West database
Base cations weathering	*BCwe*	eq $ha^{-1}a^{-1}$	Calculations based on De Vries et al., 1993
Uptake of base cations (Ca, Mg, K) by vegetation	*Bcupt*	eq $ha^{-1}a^{-1}$	Mapping Manual, eq. 5.8; calculated for stem wood biomass
Acid neutralization capacity leaching	*nANCcrit*	eq $ha^{-1}a^{-1}$	Chemical criterion used is pH; Mapping Manual, eq.5.35
Nitrogen uptake by vegetation	*Nupt*	eq $ha^{-1}a^{-1}$	Mapping Manual, eq. 5.8; calculated for stem wood biomass
Nitrogen immobilization	*Nimm*	eq $ha^{-1}a^{-1}$	Upper limit suggested in Mapping Manual
Acceptable nitrogen leaching	*Nleacc*	eq $ha^{-1}a^{-1}$	Mapping Manual, eq. 5.6; [N]crit = 0.0143-0.02 eq m^{-3}
Denitrification factor	*Fde*	-	Rates depending on soil type
Water percolation flux through the root zone	*Qle*	m^3 $ha^{-1}a^{-1}$	Calculations based on precipitation and temperature data according to Michalzik et al. (2001)
Gibbsite equilibrium constant	*lgKAlox*	m^6eq^{-2}	Mapping Manual, Table 5.11

Data sources

Soil related data

Data on soil types and soil texture classes were taken from FAO UNESCO (1981) Soil Map of the World (1:5,000,000) after its revising based on general soil map of Russian Federation (National Atlas, 2003) and map of soil parent materials (GUGK, 1976).

Total values of the weathering rate of base cations (Ca, Mg, K, Na) depending on temperature zone were calculated for five soil texture classes according to De Vries et al. (1993). All estimations were carried out for the layer 0-50 cm. The value of *BCwe* in the peat soils is assumed to be equal zero.

Data on nitrogen immobilization are highly uncertain. The differences in the values presented in the CCE Status Report 2005 for cold temperature zone (< 5°C) are by 3-5 times. Based on literature data (Hornung et al., 1995; Hall et al., 2003) and CCE recommendation as well as on national expert estimations, rates of *Nimm* in the forest soils of the European Russia were assumed to be equal 1-2 kg N $ha^{-1}a^{-1}$ depending on warm-cold climate and soil types.

Forest related data

Data on spatial distribution of forested lands in European Russia were received from Land use, IGBP Map of EDC DAAC (1997); specification of forest types was realized using the map of forest tree dominants (National Atlas, 2003).

Nitrogen and base cations uptake by main forest tree species (pine, spruce, birch and oak) was calculated using national data on N and Bc concentrations in the stem wood biomass (Remezov et al., 1959; Bazilevich and Rodin, 1971; Fedoretc and Bakhmet, 2003). The average values of stem wood yield (harvested part) were accounted on the base of NPP data that were computed in accordance with Leith (1975) and taking into account national monitoring and inventory data on stem/branches/leaves ratio in different forest types (Isaev, 1992; Bazilevich, 1993). The ranges of N and base cations uptake values for coniferous, deciduous and mixed forests are given in Table RU-2.

Table RU-2. *Ranges of N and Bc uptake with stem yields for forest ecosystems of European Russia depending on tree dominant and temperature zone.*

Forest tree (dominant)	*Uptake* (min-max), eq $ha^{-1}a^{-1}$			
	N	***Ca***	***Mg***	***K***
Pine	10-250	6-139	2-50	2-49
Spruce	9-379	4-157	1-57	1-55
Birch	18-357	6-118	4-43	2-42
Oak	268-429	74-118	27-40	26-39
Mixed forests	12-341	5-128	2-46	2-46

- *Acceptable nitrogen leaching* was computed using data on water percolation flux (*Qle*) and critical nitrogen concentration in the soil solution ($[N]_{crit}$) that was equal 0.0143-0.02 eq m^{-3} depending on tree dominant species (UBA, 2004).

Climate related data

- Data on average values of *temperature* and *precipitation* obtained from IWMI World Water and Climate Atlas (2002) were particularly processed and recalculated.
- Data on *water percolation flux* through the root zone in the forest ecosystems were accounted in accordance with Michalzik (2001) and taking into account runoff fraction (National Atlas, 2003).

Results and comments

The results of critical load calculating structured in accordance with EUNUS classification for coniferous (G4) and mixed (G3) forest ecosystems are given in Table RU-3. Figure RU-1 provides a spatial distribution of critical loads for acidification, *CLmaxS*, and eutrophication, *CLnutN*, in the forest ecosystems of European Russia.

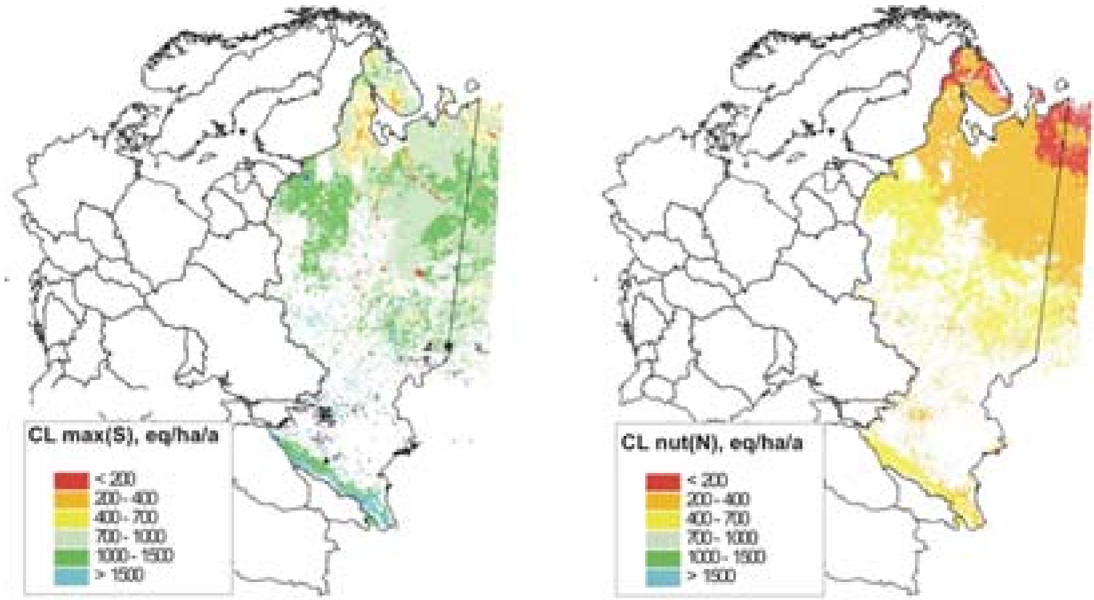

Figure RU-1. *Critical loads for acidity (left) and nutrient nitrogen (right) for forest ecosystems of European Russia.*

Table RU-3. *Summary of Russian critical load data.*

		G3: mixed forests			G4: coniferous forests		
Term	*Unit*	*Min value*	*Mean value*	*Max value*	*Min value*	*Mean value*	*Max value*
CLmaxS	$eq\ ha^{-1}a^{-1}$	10	1024	10386	30	778	4096
CLminN	$eq\ ha^{-1}a^{-1}$	80	317	450	81	367	428
CLmaxN	$eq\ ha^{-1}a^{-1}$	305	1706	13321	448	1391	5605
CLnurN	$eq\ ha^{-1}a^{-1}$	117	339	535	83	380	531
Cadep	$eq\ ha^{-1}a^{-1}$	20	70	9163	20	125	3004
Mgdep	$eq\ ha^{-1}a^{-1}$	17	55	3357	17	56	2531
Kdep	$eq\ ha^{-1}a^{-1}$	3	8	317	3	11	241
Nadep	$eq\ ha^{-1}a^{-1}$	35	150	14653	35	110	10981
Cldep	$eq\ ha^{-1}a^{-1}$	40	175	17085	40	128	12804
BCwe	$eq\ ha^{-1}a^{-1}$	10	611	1336	0	670	1453
Bcupt	$eq\ ha^{-1}a^{-1}$	6	193	269	0	161	219
nANCcrit	$eq\ ha^{-1}a^{-1}$	0	415	824	0	110	245
Nupt	$eq\ ha^{-1}a^{-1}$	9	246	379	10	296	357
Nimm	$eq\ ha^{-1}a^{-1}$	71	105	143	71	105	143
Nleacc	$eq\ ha^{-1}a^{-1}$	0	43	85	0	54	119
fde	-	0.1	0.2	0.4	0.1	0.2	0.4
Qle	$m^3\ ha^{-1}a^{-1}$	0	3010	597	0	2740	5970

Critical points in the modern calculations

Weathering was calculated for the layer of 0-50 cm as a typical root layer for the forest soils in the area of the European part of Russian Federation ANC leaching was calculated using the unique value of *KAlox* = 300 $m^6\ eq^{-2}$ without differentiating for organic and mineral layers owing to the characteristic morphological features of the studied soils. Nitrogen immobilization values seem to be a bit lower than actual values however the CCE recommendations were applied as a basic level with further differentiation according spatial variability of Russian soils and ecosystems. Critical concentration of nitrogen in soil solution was applied as 0.2-0.4 ppm; however, these values should be higher for some ecosystems in the south taiga and forest steppe zones. Nitrogen uptake was calculated for only 50% trunk wood yearly increase and some of these data are still very uncertain, especially for the Caucasian ecosystems. Values of water percolation flux were also very uncertain for the Caucasian ecosystems due to high spatial heterogeneity of local ecosystems and relief.

Acknowledgements

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Transformation of forest plant communities from the digital vegetation map of forest communities of Slovenia in a scale of 1:100.000 into the 34 EUNIS (European Nature Information System) forest habitat types were done (Table SI-1).

Table SI-1. *Transformation of forest plant communities of forest communities of Slovenia into the 34 EUNIS (European Nature Information System) forest habitat types.*

Code	Forest Plant Communities	EUNIS code	Habitat Classification Categories
AcF	dinarski gozd javorja in bukve	G1.6C22	Illyrian montane fir-beech forests
AgF2	dinarski visokogorski bukov gozd	G1.6C223	Illyrian high montane fir-beech forests
AdF3	predalpski visokogorski bukov gozd	G1.6C223	Illyrian high montane fir-beech forests
AF	dinarski gorski gozd jelke in bukve	G1.6C22	Illyrian montane fir-beech forests
AFp	predalpski gozd jelke in bukve	G1.6C223	Illyrian high montane fir-beech forests
Ag	logi crne jelse	G1.2111	Sedge ash-alder woods
Ain	logi sive jelse	G1.1211	Alpine grey alder galleries
AnF1	primorski visokogorski bukov gozd	G1.6334	Southeastern Alpine bittercress beech forests
AnF3	alpski bukov gozd	G1.6334	Southeastern Alpine bittercress beech forests
APs	alpski smrekov gozd	G3.1B21	Adenostyles glabra subalpine spruce forests
ArF	bukov gozd s kresnicevjem	G1.6C21	Illyrian collinar neutrophile beech forests
AsP	predalpski gozd smreke v skalovju	G3.1C2	Calciphile montane inner Alpine spruce forests
BA	gozd jelke in smreke z vilicastim mahom	G3.135	Bazzania fir forests
BF	acidofilni bukov gozd z rebrenjaco	G1.6C1	Illyrian woodrush-beech forests
BP	smrekov gozd z vilicastim mahom	G3.1F3	Peri-Alpine bazzania spruce forests
CaF	bukov gozd s sasulico	G1.676	Pre-Alpine hop-hornbeam beech forests
CF	predalpski termofilni bukov gozd	G1.676	Pre-Alpine hop-hornbeam beech forests
CO	termofilna zdruzba gabrovca in omelike	G1.7C14	Illyrian hop-hornbeam woods
CP	predalpski gozd smreke na moreni	G3.1F42	Illyrio-Alpine montane beech spruce forests
DA	jelov gozd s praprotmi	G3.11221	Illyrian neutrophile spruce fir forests
DF	acidofilni bukov gozd z vijugasto masnico	G1.6C1	Illyrian woodrush-beech forests
EF3	predalpski bukov gozd s trilistno vetrnico	G1.6C22	Illyrian montane fir-beech forests
EF4	preddinarski gorski bukov gozd	G1.6C22	Illyrian montane fir-beech forests
F	ilirski gozd gorskega javorja in velikega jesena	G1.A463	Illyrian ravine forests
FdF	predalpski bukov gozd z gorsko bilnico	G1.6351	Sub-Pannonic beech forests
Fs	subalpsko bukovje	G1.6C4	Illyrian subalpine beech forests
GP	ilirski bazofilni borov gozd	G3.4C52	Dinaric dolomite Scots pine forests
HF2	dinarski predgorski bukov gozd	G1.6C21	Illyrian collinar neutrophile beech forests
HF3	predalpski predgorski bukov gozd s trilistno vetrnico	G1.6C21	Illyrian collinar neutrophile beech forests
HF4	preddinarski predgorski bukov gozd z lobodiko	G1.6C21	Illyrian collinar neutrophile beech forests
IF	preddinarski gozd bukve z javorjem in polzarko	G1.6C223	Illyrian high montane fir-beech forests
LA	jelov gozd z belkasto bekico	G3.1322	Illyrian acidophile fir forests
LF1	primorski bukov gozd z belkasto bekico	G1.6C1	Illyrian woodrush-beech forests
LF3	predalpski bukov gozd z belkasto bekico	G1.6C1	Illyrian woodrush-beech forests
LF4	ilirski bukov gozd z belkasto bekico	G1.6C1	Illyrian woodrush-beech forests
LQ	preddinarski bazofilni gradnov gozd	G1.7432	Illyrian black pea sessile oak woods
MP	acidofilni borov gozd	G3.425	Eastern Alpine acidophilous Scots pine woods
NA	dinarski gozd jelke v skalovju	G3.124	Dinaric calcareous block fir forests

Code	Forest Plant Communities	EUNIS code	Habitat Classification Categories
ng	ostalo	ng	ng
OA	primorski gozd gorskega javorja in bresta	G1.A463	Illyrian ravine forests
OF	predalpski grmicav gozd gabrovca in kraskega jesena	G1.676	Pre-Alpine hop-hornbeam beech forests
OP	primorski borovi gozdovi	G3.5215	Illyrian sub-Mediterranean Pinus nigra forests
OrF	primorski gorski bukov gozd	G1.6C31	Illyrian coastal beech forests
OS	visokogorska sotna barja	G3.E	Nemoral bog conifer woodland
Pm	dinarsko rusje	F2.47	Pelago dinaride Pinus mugo scrub
Psi	predalpski bazofilni borov gozd	G3.441	Alpine spring heath Scots pine forests
QC1	primorski nizinski gozd gradna in belegagabra	G1.A1A1	Illyrian sessile oak-hornbeam forests
QC2	dinarski nizinski gozd gradna in belega gabra	G1.A1A1	Illyrian sessile oak-hornbeam forests
QC3	predalpski nizinski gozd gradna in belega gabra s trilistno vetrnico	G1.A1A1	Illyrian sessile oak-hornbeam forests
QC4	preddinarski nizinski gozd gradna in belega gabra z vimekom	G1.A1A1	Illyrian sessile oak-hornbeam forests
QC5	predpanonski nizinski gozd gradna in belega gabra	G1.A1A1	Illyrian sessile oak-hornbeam forests
QF	bukov gozd z gradnom	G1.6C21	Illyrian collinar neutrophile beech forests
QO2	dinarski bazofilni gozd puhastega hrasta (z gabrovcem in vilovino)	G1.7431	Illyrian hop-hornbeam mixed oak woods
QO4	preddinarski bazofilni gozd puhastega hrasta z gabrovcem	G1.7431	Illyrian hop-hornbeam mixed oak woods
RC	gozd doba, belega gabra (in ozkolistnega jesena)	G1.A1A2	Illyrian pedunculate oak-hornbeam forests
RR	alpsko rusevje	F2.42	Outer Alpine Pinus mugo scrub
S	vrbovje	G1.1112	Eastern European poplar-willow forests
SeF	primorski bukov gozd	G1.6C31	Illyrian coastal beech forests
SF	preddinarski visokogorski bukov gozd	G1.6C223	Illyrian high montane fir-beech forests
SO	primorski gozd gradna, puhastega hrasta in kraskega jesena	G1.7431	Illyrian hop-hornbeam mixed oak woods
TA	gozd lipovca in ostrolistnega javorja	G1.A463	Illyrian ravine forests
UA	ilirski gozd gorskega javorja in bresta	G1.A463	Illyrian ravine forests
VP	dinarski mraziČni smrekov gozd	G3.1F51	Illyro-Dinaric cold station spruce forests
zar	zarascanje	zar	zar
zar AcF	zarascanje	G1.6C22	Illyrian montane fir-beech forests
zar AF	zarascenje	G1.6C22	Illyrian montane fir-beech forests
zar GP	zarascanje	G3.4C52	Dinaric dolomite Scots pine forests
zar HF4	zarascanje	G1.6C21	Illyrian collinar neutrophile beech forests
zar LQ	zarascanje	G1.7432	Illyrian black pea sessile oak woods
zar OF	zarascanje	G1.676	Pre-Alpine hop-hornbeam beech forests
zar QC4	zarascanje	G1.A1A1	Illyrian sessile oak-hornbeam forests
zar QF	zarascanje	G1.6C21	Illyrian collinar neutrophile beech forests

For these forest types suggested site conditions (Mapping manual 2004) were estimated (Table SI-2). For these purposes climatic data (average annual temperatures and amounts of precipitation - pixel size of used map was 1000×1000 m), digital elevation model (pixel size was 12,5×12,5 m), digital soil map in scale 1:25.000 and geological map in scale 1:100.000 were considered.

Table SI-2. *Estimations (1 – 5) of suggested site conditions for Slovenian EUNIS forest habitat types and their classification according to empirical N critical loads.*

Serial number	EUNIS code	Temperature / Frost period	Soil wetness	Base cation availability	P, N limited	Management intensity	CLempN class
1	F2.42	1	3	3	3	1	1
2	F2.47	1	3	3	3	1	1
3	G1.1112	3	4	2	1	1	2
4	G1.1211	3	4	3	3	3	2
5	G1.2111	3	5	3	3	3	4
6	G1.6334	2	3	3	3	3	4
7	G1.6351	4	3	2	2	4	3
8	G1.676	4	2	3	4	3	4
9	G1.6C1	3	3	2	2	4	3
10	G1.6C21	3	3	5	4	5	5
11	G1.6C22	3	3	5	4	5	5
12	G1.6C223	2	3	2	2	4	3
13	G1.6C31	4	2	4	4	3	5
14	G1.6C4	1	3	3	3	1	2
15	G1.7431	4	1	3	3	2	2
16	G1.7432	3	3	4	4	3	4
17	G1.7C14	4	1	3	3	2	2
18	G1.A1A1	3	4	4	4	4	5
19	G1.A1A2	4	5	3	3	5	5
20	G1.A463	3	4	3	3	2	4
21	G3.11221	2	4	3	3	5	3
22	G3.124	2	3	3	3	2	2
23	G3.1322	3	3	2	2	4	3
24	G3.135	2	4	2	2	4	3
25	G3.1B21	2	3	3	3	2	2
26	G3.1C2	2	3	2	4	2	1
27	G3.1F3	2	4	1	3	4	3
28	G3.1F42	3	3	2	3	3	2
29	G3.1F51	1	3	3	3	2	4
30	G3.425	3	3	2	2	3	3
31	G3.441	3	2	3	3	2	2
32	G3.4C52	4	2	3	3	2	2
33	G3.5215	5	1	3	3	2	2
34	G3.E	1	5	1	5	1	1

Table SI-3. *Empirical critical loads of nitrogen (CLempN) for forest EUNIS habitats subtypes in Slovenia*

Serial number	EUNIS code	Title of EUNIS habitats subtype	CLempN [eq N/ha/a]	CLempN [kg N/ha/a]
1	F2.42	Outer Alpine *Pinus mugo* scrub	350 - 1000	5 - 15
2	F2.47	Pelago dinaride *Pinus mugo* scrub	350 - 1000	5 - 15
3	G1.1112	Eastern European poplar-willow forests	700 - 1000	10 - 15
4	G1.1211	Alpine grey alder galleries	700 - 1000	10 - 15
5	G1.2111	Sedge ash-alder woods	1000 - 1400	15 - 20
6	G1.6334	Southeastern Alpine bittercress beech forests	1000 - 1400	15 - 20
7	G1.6351	Sub-Pannonic beech forests	700 - 1400	10 - 20
8	G1.676	Pre-Alpine hop-hornbeam beech forests	1000 - 1400	15 - 20
9	G1.6C1	Illyrian woodrush-beech forests	700 - 1500	10 - 20
10	G1.6C21	Illyrian collinar neutrophile beech forests	1000 - 1800	15 - 25
11	G1.6C22	Illyrian montane fir-beech forests	1000 - 1800	15 - 25
12	G1.6C223	Illyrian high montane fir-beech forests	*1000 - 1400*	*15 - 20*
12	G1.6C223	Illyrian high montane fir-beech forests	700 - 1400	10 - 20
13	G1.6C31	Illyrian coastal beech forests	1000 - 1800	15 - 25
14	G1.6C4	Illyrian subalpine beech forests	700 - 1000	10 - 15
15	G1.7431	Illyrian hop-hornbeam mixed oak woods	700 - 1000	10 - 15
16	G1.7432	Illyrian black pea sessile oak woods	1000 - 1400	15 - 20
17	G1.7C14	Illyrian hop-hornbeam woods	700 - 1000	10 - 15
18	G1.A1A1	Illyrian sessile oak-hornbeam forests	1000 - 1800	15 - 25
19	G1.A1A2	Illyrian pedunculate oak-hornbeam forests	1000 - 1800	15 - 25
20	G1.A463	Illyrian ravine forests	1000 - 1400	15 - 20
21	G3.11221	Illyrian neutrophile spruce fir forests	700 - 1400	10 - 20
22	G3.124	Dinaric calcareous block fir forests	700 - 1000	10 - 15
23	G3.1322	Illyrian acidophile fir forests	700 - 1400	10 - 20
24	G3.135	*Bazzania* fir forests	700 - 1400	10 - 20
25	G3.1B21	*Adenostyles glabra* subalpine spruce forests	700 - 1000	10 - 15
26	G3.1C2	Calciphile montane inner Alpine spruce forests	350 - 1000	5 - 15
27	G3.1F3	Peri-Alpine bazzania spruce forests	700 - 1400	10 - 20
28	G3.1F42	Illyrio-Alpine montane beech spruce forests	700 - 1000	10 - 15
29	G3.1F51	Illyro-Dinaric cold station spruce forests	1000 - 1400	15 - 20
30	G3.425	Eastern Alpine acidophilous Scots pine woods	700 - 1400	10 - 20
31	G3.441	Alpine spring heath Scots pine forests	700 – 1000	10 - 15
32	G3.4C52	Dinaric dolomite Scots pine forests	700 – 1000	10 - 15
33	G3.5215	Illyrian sub-Mediterranean *Pinus nigra* forests	700 - 1000	10 - 15
34	G3.E	Nemeral bog conifer woodland	350 - 1000	5 - 15

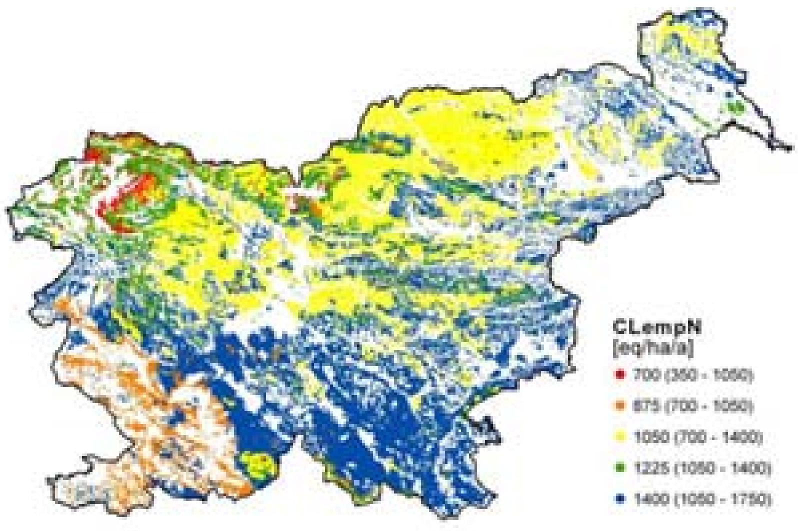

Figure SI-1. *Empirical critical loads of nitrogen for forests.*

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Introduction

In response to the call for data November 2006, the following datasets have been produced:

- Values of chemical variables from dynamic model runs in historic and in future years for different deposition scenarios
- A document describing the sources and methods used to produce the data (this document).

Calculation methods

The dynamic model runs were performed on lakes with the MAGIC model (Cosby et al., 1985, 2001). To achieve a good spatial coverage the calculations of scenario outputs were performed in two steps. In the first step, the MAGIC model was calibrated for 325 lakes in Sweden and 27 deposition scenarios were assessed. The model outputs were sorted into an existing database called the MAGIC library.

The MAGIC library is a web based tool (www.IVL.se/magicbibliotek) developed in 2003 – 2007 for lake acidification assessment for Swedish and Norwegian lakes. The MAGIC library consists from two main parts: a catalogue of lakes with existing MAGIC model calibration and a so called matching tool. The matching tool is used for comparing any given lake (evaluation lake) described by its key parameters in the matching questionnaire with all lakes included in the MAGIC library lake catalogue (library lakes) and to select which library lakes are most similar to the evaluation lake. If a similar lake is found among the library lakes (a good match) it is then assumed that MAGIC calibration and scenario outputs calculated at the library lake are also valid for the evaluation lake.

In the second step, the 2933 lakes sampled in the country-wide lake survey Riksinventering 2000 (RI00) were processed through the MAGIC library and the best matching library lake was selected for every one of them. For 191 (of the 2933) RI00 lakes the MAGIC library did not contain any lake similar enough to justify the assumption that the two lakes (the evaluation and the library lake) share the same acidification history and future. With two exceptions, these 191 lakes all had high current ANC (>200 µeq/l) and therefore the ANC for these lakes was assumed equal to 200µeq/l in all future years for all scenarios and the rest of the parameters were also set to constant, non-acidified values or zero.

Data sources

Deposition

Historical deposition data was derived from updated EMEP150 grid specific deposition histories 1880- 2000 over Europe according to Schöpp et al (2003). The deposition curves were scaled to fit the present deposition (1998) of the 50×50 km of the investigated forests and lakes. The deposition histories were supplemented with an estimated deposition pattern between 1850 and 1880, scaled to fit the individual sites.

Present day deposition data was estimated from the MATCH model (Robertson et al., 1999; www.smhi.se) in a 20×20 km square grid over Sweden for the years 1997-1998 or 2002-2004. For the lakes, the deposition was scaled to a calibration year (calibration year varied from lake to lake; depending on data availability we used 1985, 1990, 1993, 1995, 1997 or 2000) and adjusted using the observed lake water chemistry to account for the local variation within the 20×20 km squares (Moldan et al., 2004). The total deposition of Cl^-, SO_4^{2-} and base cations was adjusted at each site using lake water chemistry. It was assumed that, as a result of the declining SO_4^{2-} deposition in the years 1985 to 2000, an estimated percentage of the output flux of SO_4^{2-} from the lakes had been desorbed from catchment soils or from the lake sediment. The percentage used was 0-35%, depending on the rate of decline in SO_4^{2-} deposition in the calibration year. The modelled deposition of N species was adjusted to account for variations in dry deposition by assuming that the ratio between the adjusted deposition and the deposition given by the MATCH model was the same for the N species and SO_4^{2-} at each lake.

For the 3 main future scenarios, CLE, MFR and Bkg, (and His between 2000 and 2010) the deposition scenarios from CCE were used. 24 additional scenarios were constructed according to the instructions in the Call for data. This number of scenarios (27) is probably unnecessarily high for Sweden since the differences among scenarios were in most cases really small, both in terms of deposition and in terms of modelled lake parameters. However, the results of all 27 scenarios are reported to avoid the problem of deciding which scenarios to include and which to exclude.

Lakes

The lake water chemistry of limed lakes were corrected by assuming the same Ca:Mg ratio as nearby lakes and assuming that the Mg concentration was not affected by liming. Long-term averages (1961-1990) of runoff volumes provided by the Swedish Meteorological Institute (SMHI) were used. Land use data were taken from the Swedish National Land Survey and the ASTA database (asta.ivl.se). Long-term averages of nutrient uptake in catchments were derived from the Swedish National Forest Inventory 1983-92 for 115 of the lakes and from the ASTA database for the rest of the lakes. Pre-industrial nutrient uptake was set to 0.5 times present day for lake catchments in southern Sweden and zero for 64 of the lakes in northern Sweden, based on existing information about Swedish forests and forestry from the 1870/80-ies.

Soil data for the lake catchments were derived from The Swedish Forest Soil Inventory, a subprogramme within RIS (www-ris.slu.se). Soil depth, amount of exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+ per unit of mass of soil, *CEC*, soil pH and amount of C and N were vertically aggregated for the profiles of each soil sample included for a lake. Soil bulk densities estimated by Karltun (1995) was used and averaged over the profiles. Soil water DOC was assumed to be 8 mg/l for all catchments (based on data from permanent forest monitoring plots in Sweden, ICP Forests, level II).

Nitrogen dynamics

The nitrogen dynamics was modelled in a simplified way without coupling between N deposition and the long term development of the ability of ecosystems to assimilate nitrogen. It was assumed that the percentage of N deposition leached in runoff will remain constant in the future for all scenarios. Such assumption is probably reasonably accurate for the majority of the modelled lakes and their catchments with given N deposition scenarios (no increase in N deposition) and for a given time (up to 2030, 2040, 2050, more uncertainty up to 2100). It needs to be pointed out, however, that this is an optimistic view of future N changes where nitrogen saturation does not progress and where future N deposition does not cause increased leaching of NO^{3-}. If a less optimistic view of future effects of N deposition is adopted (such as e.g. precautionary principle), it could change the outcome of the dynamic modelling in a major way towards worse surface water quality in terms of higher NO^{3-}, higher inorganic aluminium, lower pH and lower ANC.

Climate change

Climate was assumed not to change over the modelled period. To what extent a changing climate will affect the future surface waters quality in response to the 27 modelled deposition scenarios is beyond the scope of the response to the call. However, it needs to be noted that this is another source of uncertainty in the model predictions because the combined effect of changing air pollution and climate could be significantly different from each of the two major driving factors alone.

Comments and conclusions

There is a large variation in ANC among the 2933 evaluated RI00 lakes. In 2030 according to the CLE scenario (Figure 1a), 0.4% of the RI00 lakes will have a negative ANC, 8% will have an ANC between 0 and 50µeq/l, 55% will have an ANC between 50 and 200µeq/l and 37% above 200µeq/l. There is no clear geographical pattern; both lakes with low, intermediate and with high ANC are to be found in most parts of Sweden. According the CLE scenario there are very few lakes with negative ANC in 2030 and these are all in the southern part of Sweden.

The lake water ANC will change under the CLE scenario (Figure SE-1b). The rate and direction of ANC change depends on the sensitivity of the lake and deposition (and land use) history. The majority of the lakes will have an increase in ANC. The increase will in most cases be very modest (between 0 and 10µeq/l over 20 years). This is expected since a majority of all Swedish lakes have never been severely acidified i.e. did not experience any large decrease in ANC and thus should not experience a large ANC increase. The lakes with the strongest increase in ANC are mostly found in the southern part of Sweden, where acidification previously caused the largest ANC decline. There are also many sensitive lakes all over Sweden where ANC will either remain more or less unchanged or even continue to decline under the CLE scenario.

Compared with CLE, the Bkg scenario would result in higher ANC in all but one of the 2933 evaluated lakes. The difference between the CLE and Bkg (Figure SE-1c) is by 2030 not large in most cases. This is because a combination of two factors; I) as pointed out above, not all lakes have been severely acidified and II) twenty years is too short a time to cause any major recovery in the soils base saturation provided the typically low weathering rates common in Scandinavian soils, current land use and remaining deposition. Most, but not all, of the lakes that will show a greater ANC-increase under the Bkg scenario are located in the southern part of Sweden.

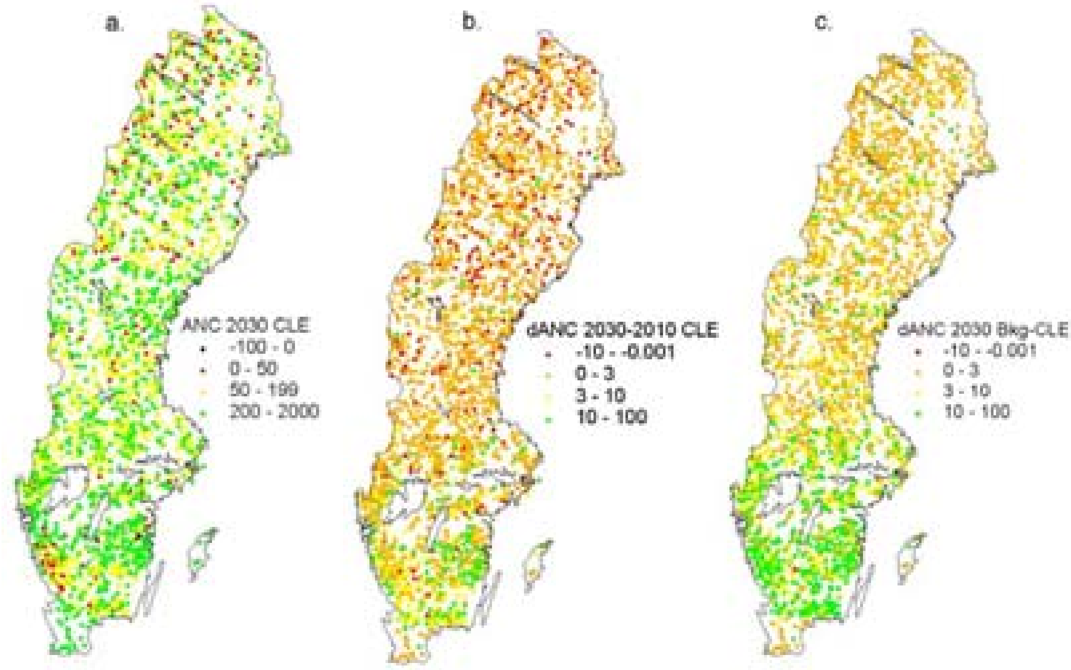

Figure SE-1. *Map of Sweden, with the RI00 lakes marked with different colours according to their ANC values in 2030 under the CLE scenario (a), marked with different colours according to the ANC improvement between 2010 and 2030 under the CLE scenario (b) and marked with different colours according to the difference in ANC 2030 between CLE and the Bkg scenarios (c).*

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Overview

In the CCE Status Report 2005 the sources and methods of Swiss critical loads data were described in some detail. This paper focuses mainly on items changed since then.

As in the last data submission in 2005, the Swiss data set on critical loads of acidity and nutrient nitrogen is compiled from the output of four modelling and mapping approaches:

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, the input data of SAFE were aggregated to one layer in order to run the VSD model. Unlike earlier, input allowing the consideration of nitrogen processes implemented in VSD (immobilisation, denitrification) is now provided.

2) The SMB method for calculating critical loads of nutrient nitrogen (*CLnutN*) was applied on 10,608 forest sites ('managed' forests). 10,348 of these sites originate of the National Forest Inventory (NFI 1990/92), which is based on a 1x1 km^2 raster. They are complemented by the 260 sites with soil profiles. New values for *fde* and *Nimacc* are used (see 'Input for Calculating Nitrogen Processes').

3) The empirical method for mapping *CLnutN* 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 1×1 km^2 raster combining several input maps of nature conservation areas and vegetation types. The total sensitive area amounts to 16,576 km^2. New values were used for fens and molinion.

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). No changes were made since the last data submission.

Modelled critical loads and dynamic data

The data layers of the SMB method and the empirical method partially cover the same areas. Therefore, in former submissions the results of both methods were combined by choosing the minimum *CLnutN* per 1×1 km^2 grid cell. In this submission, the reselection according to the minimum criterion was not made, i.e. all records of the SMB and the empirical method are submitted.

Merging the data sets and determining EcoArea

The dynamic modelling (DM) of critical loads and scenarios of acidification was based on samples from 260 soil profiles consisting of 2 to 9 layers each (see Posch et al., 2005). These sites are merged in the 'inputs' table with 10,348 NFI-sites for which *CLnutN* are calculated by the SMB-method. In the merging process, the 260 DM-sites remain unchanged – with two exceptions: (1) *CLnutN* is recalculated with the SMB-equations and (2) cNacc is calculated as described in the next chapter.

Critical loads of acidity are calculated for 260 DM-sites that are not regularly distributed within the country. The NFI-sites, however, are a systematic sample representing a forest area of 1 km^2, each. Therefore, the area of forest represented by one DM-site was determined by those NFI-sites situated within the respective Thiessen-polygon constructed for the DM-sites (see Figure CH-1), and all acidity parameters were copied from a DM-site to the affiliated NFI-sites. In consequence, EcoArea is 1 km^2 for all sites.

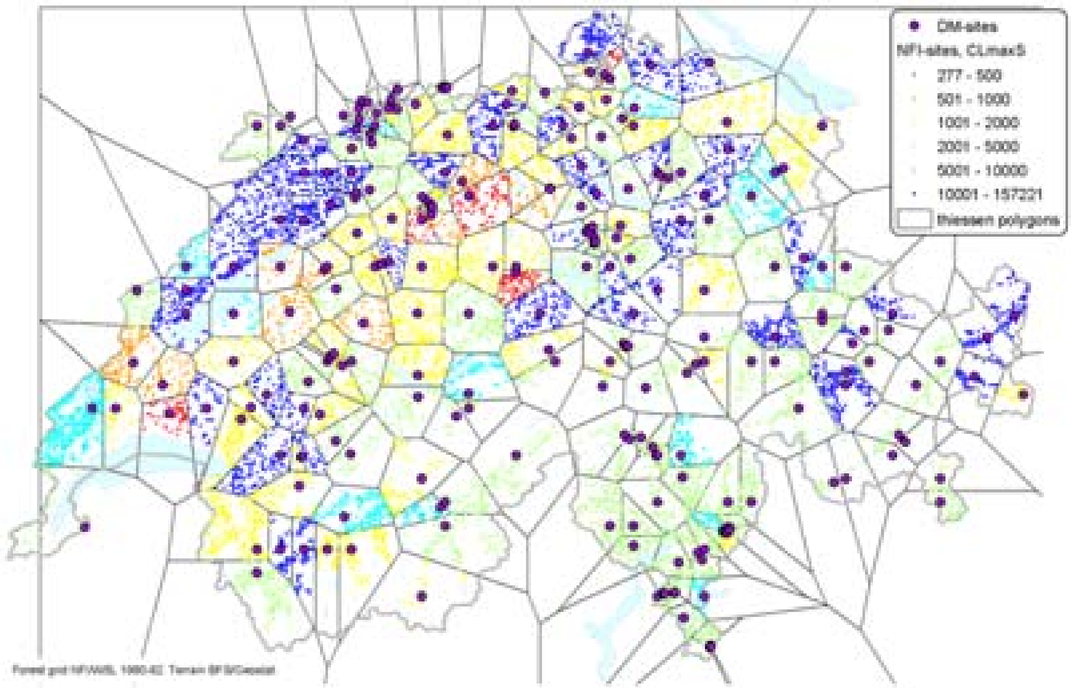

Figure CH-1. *The acidity parameters (e.g. CLmaxS in eq ha^{-1} a^{-1}) at the DM-sites are spatially expanded to the NFI-sites using Thiessen-polygons.*

Input for calculating nitrogen processes

The nitrogen related input for the SMB and for the dynamic modelling were harmonised as far as possible.

N immobilisation:

For the acceptable immobilisation rate of nitrogen (*Nimacc*) the following values are used:

Nimacc = 1.5 kg N ha^{-1} a^{-1} (107 mol$_c$ ha^{-1} a^{-1}) at low altitudes (<500 m a.s.l.)
Nimacc = 2.5 kg N ha^{-1} a^{-1} (179 mol$_c$ ha^{-1} a^{-1}) at high altitudes (>1500 m a.s.l.)

At altitudes between, *Nimacc* is calculated by linear interpolation.

These values are lower than in the submission of 2005 but they are still higher than the proposal in the Mapping Manual (UBA, 2004). This means that a 'conservative' calculation of *CLnutN* is made.

Net growth uptake of nitrogen:

Although the derivation of the uptake of nitrogen differs between the DM- and the SMB-dataset, a serious consistency problem does not arise, as all calculations are carried out with the respective input data.

For calculating CLnutN with the SMB method, the uptake was estimated from predicted long-term harvesting rates and average element contents to 0.7–7.0 kg N $ha^{-1}a^{-1}$. In the SAFE/VSD model, the uptake is calculated at critical loads conditions considering potential growth and nutrient ratios.

Denitrification:

The denitrification factor *fde* is estimated essentially from the wetness of the soils considered. For the DM-sites, this information is derived from the soil layer descriptions and the wetness classification scheme of the digital soil map BEK (SFSO, 2000) according to the procedure described by Braun (2006). To approach the *fde* distribution, which Braun finally obtained by applying a reasonably complex derivation scheme, but to still remain with the easier applicable classification approach, due to limited data at the NFI-sites, we have used

fde = 0.1*(2+wetness class) for the DM-sites.

Table CH-1. *Values of f_{de} selected at DM-sites and NFI-sites for different classes of soil wetness.*

	DM-sites			*NFI-sites*	
f_{de}	*wetness class BEK*	Vernässungsgrad	*depth of saturated horizon*	*fde*	*VERNASS class*
0.2	0	keine Vernässung	-	0.2	0
0.3	1	grundfeucht	below 90 cm, but capillary rise	0.3	1
0.4	2	schwach grundnass	60-90 cm	0.4	2
0.5	3	mässig grundnass*	45-60 cm	0.55	3
0.6	4	ziemlich stark grundnass*	30-45 cm	0.55	3
0.7	5	stark grundnass	above 30 cm	0.7	4

Regarding the NFI-sites we correlate the NFI wetness classification variable (VERNASS) with the respective BEK variable, assuming that the 4 NFI classes match the 5 classes of the BEK soil map as shown in Table CH-1.

Nitrogen leaching:

In the data call, the NFCs are urged to re-visit their CLnutN calculations and update them if appropriate based on revised critical N concentrations (*cNacc*) proposed in De Vries et al. (2007) and by the CCE (CCE, 2006; Table 4). For Switzerland, the proposed values for cNacc were tested (see section 'Explanatory Note' below). Some of the proposed values led to implausible high N leaching and CLnutN, mainly in high precipitation areas.

Therefore it was decided to continue using the acceptable N leaching rates (*Nleacc*), which were used already in former data submissions. They are basically drawn from the older Mapping Manual (UBA, 1996):

Nleacc = 4 kg N ha^{-1} a^{-1} (286 mol_c ha^{-1} a^{-1}) at low altitudes (<500 m a.s.l.)
Nleacc = 2 kg N ha^{-1} a^{-1} (143 mol_c ha^{-1} a^{-1}) at high altitudes (>2000 m a.s.l.)

At altitudes between, $N_{le(acc)}$ is calculated by linear interpolation. The submitted acceptable N concentration was calculated as: *cNacc* = 100* *Nleacc* / Q*le*.

Nitrogen leaching under different *CLN* calculation approaches

The VSD/SMB model has been used to simulate the dynamics of soil acidification and to calculate critical loads of sulphur (S) and nitrogen (N) for 260 forest sites in Switzerland.

For the data submission, the acceptable N leaching rate was set to 4 kg N $ha^{-1}a^{-1}$ (286 $mol_c ha^{-1}a^{-1}$) at low altitudes (<500 m a.s.l.) and to 2 kg N $ha^{-1}a^{-1}$ (143 $mol_c ha^{-1}a^{-1}$) at high altitudes (>2000 m a.s.l.). At altitudes between, *Nleacc* was calculated by linear interpolation.

Also alternatively, selected critical N concentrations in soil solution (*cNacc*) according to De Vries et al. (2007) were used for calculating the N leaching rate:

0.4 mg N L^{-1} upper limit to avoid nutrient imbalances in forest trees;
1.0 mg N L^{-1} to avoid elevated N leaching/N saturation from/of forest soils;
2.5-4.0 mg N L^{-1} to avoid vegetation changes in coniferous forests;
3.5-6.5 mg N L^{-1} to avoid vegetation changes in deciduous forests.

The effect of different *cNacc* on *CLnutN* can be summarised as follows:

Generally, nutrient N critical loads fall between the minimum and maximum critical loads of N (Figure CH-2). The range of values modelled is substantial, the spread of the e.g. median nutrient N critical load being 33 kg N $ha^{-1}a^{-1}$ (9.7 kg N $ha^{-1}a^{-1}$ using the nutrient imbalances, 43.1 kg N $ha^{-1}a^{-1}$ using the vegetation changes limit). With the moderate 1 mg N L^{-1} limiting concentration in the soil solution, the N leaching at these sites scatters between 1.3 and 15.8 kg N $ha^{-1}a^{-1}$. 70% of the sites have N leaching rates above the maximum 4 kg N $ha^{-1}a^{-1}$ acceptable N leaching originally used as critical limit. Logically, if higher concentration thresholds are being applied, e.g. those for vegetation changes in forests of Western Europe, the allowed N leaching increases substantially. Figure CH-2 (right) compares the leaching rates obtained from applying the selected thresholds. Such high N leaching values may also lead to unacceptable acidification and nutrient problems due to simultaneous base cation losses.

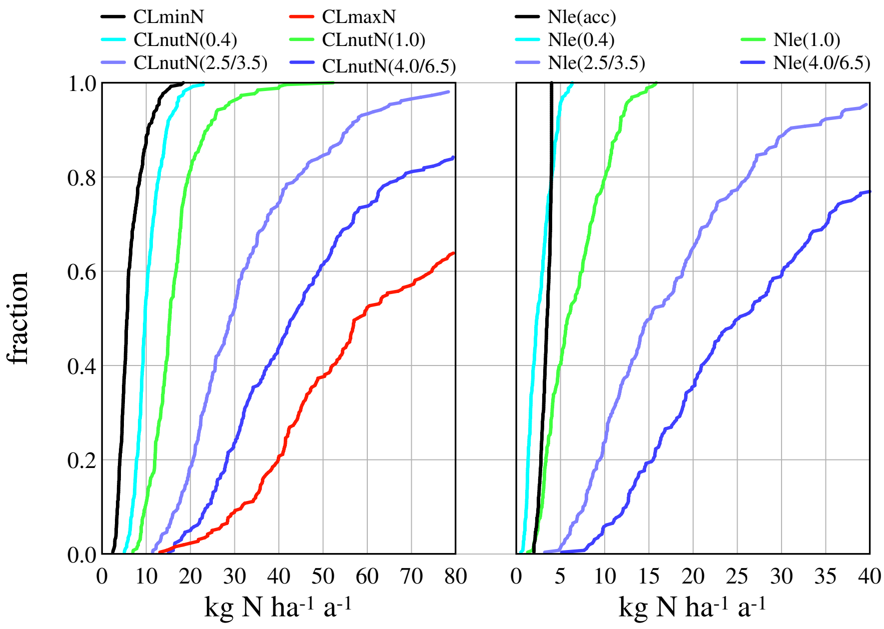

Figure CH-2. *Cumulative frequency distributions of Nutrient N critical loads (left) and N leaching rates (right) under different critical concentrations in soil solution.*

Empirical critical loads of nutrient nitrogen

The application of the empirical method is based on vegetation data compiled from various sources (Hegg et al., 1993; EDI, 1991; WSL, 1993) and aggregated to a 1×1 km^2 raster. 25 sensitive vegetation types were identified and included in the critical load data set (Table CH-2). If more than one type occurs within a 1×1 km^2 grid-cell the lowest value of CLnutN was selected for this cell.

Maps of empirical critical loads using the same 25 vegetation types were originally produced by FOEFL (1996). For this submission, the values for molinion, rich fens and poor fens were reduced by 5 kg N ha^{-1} a^{-1} each, with respect to the revised critical loads in Achermann and Bobbink (2003).

A remark to the *CLnutN* for forests: For calculating *CLnutN* using the SMB method, all managed forests (i.e. they are accessible and not shrub forests) were selected. For the empirical method, only forest types with a specific nature protection value (mainly special ground flora) were chosen. However, there is a certain spatial overlap and therefore there are 765 records with an *EmpSiteID*, which relates from the NFI-sites (SMB method) to the empirical critical loads.

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

Ecosystem type	*CLN* range	Relevant vegetation types in Switzerland	*CLnutN*	EUNIS code
Coniferous forests (acidic)	10-20	Molinio-Pinetum *(Pfeifengras-Föhrenwald)*	17	G3.44
		Ononido-Pinion *(Hauhechel-Föhrenwald)*	12	G3.43
		Cytiso-Pinion *(Geissklee-Föhrenwald)*	12	G3.4
		Calluno-Pinetum *(Heidekraut-Föhrenwald)*	12	G3.3
Deciduous forests (acidic)	10-20	Quercion robori-petraeae *(Traubeneichenwald)*	15	G1.7
Calcareous forests	10-20	Quercion pubescentis *(Flaumeichenwald)*	15	G1.71
		Fraxino orno-Ostryon *(Mannaeschen-Hopfenbuchwald)*	15	G1.73
		Erico-Pinion mugi (Ca) *(Erika-Bergföhrenwald auf Kalk)*	15	G3.44
		Erico-Pinion sylvestris *(Erika-Föhrenwald)*	15	G3.44
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)*	20	E1.26
Molinia caerulea meadows	15-25	Molinion (caeruleae) *(Pfeifengrasrieder)*	20	E3.51
Mountain hay meadows, (sub)-alpine grassland	10-20	Chrysopogonetum grylli *(Goldbart-Halbtrockenrasen)*	15	E1.2
		Seslerio-Bromion (Koelerio-Seslerion) *(Blaugras-Trespen-Halbtrockenrasen)*	12	E1.2
		Festucetum paniculatae *(Goldschwingelrasen)*	12	E4.3
		Stipo-Poion molinerii *(Engadiner Steppenrasen)*, alpine	10	E1.24
		Elynion *(Nacktriedrasen)*, alpine	10	E4.42
		Seslerion (variae) *(Blaugrashalden)*, alpine	10	E4.43
		Caricion ferrugineae *(Rostseggenhalden)*, alpine	10	E4.41
Poor fens	10-20	Scheuchzerietalia *(Scheuchzergras)*	15	D2.21
		Caricion fuscae *(Braunseggenried)*	20	D2.2
Rich fens	15-25	Caricion davallianae *(Davallsseggenried)*	20	D4.1
Raised bogs	5-10	Sphagnion fusci *(Hochmoor)*	8	D1.1
Shallow soft-water bodies	5-10	Littorellion *(Strandling-Gesellschaften)*	8	C1.1

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Modelled critical loads and dynamic data

Introduction

In response to this call the UK are submitting dynamic modelling outputs for 310 surface water sites and, for the first time, outputs for seven distinct terrestrial habitats. Dynamic modelling for the surface water habitats was carried out using MAGIC (version 7.77) and for the terrestrial habitats using VSD (scenVSD / Access version supplied by the CCE 20th March 2007).

No changes have been made to the steady-state critical loads for the surface water or terrestrial habitats. Updates have only been made to the tables submitted to reflect changes to the 'DM status'; methods and inputs for calculating the steady-state critical loads remain unchanged from those submitted to the CCE in 2004 (Hall et al., 2004). Although the VSD also generates modelled values of nutrient nitrogen critical loads, these have not been submitted, since further work is required in the UK to discuss and agree critical nitrogen concentrations for the different habitat types under consideration. The nutrient nitrogen critical loads submitted to the CCE in 2004, based on empirical values for non-woodland habitats and unmanaged woodland, and based on mass balances for managed woodlands, remain valid. In addition, the UK submitted empirical critical loads of nutrient nitrogen for feature habitats of Special Areas of Conservation to the CCE in February 2007.

Methods and data sources

Dynamic modelling of surface water habitats

For surface waters, the MAGIC model was applied to 310 previously calibrated UK lakes and streams, covering acid sensitive regions of Wales (Snowdonia and Cambrian Mountains), England (Lake District and South Pennines), Scotland (Galloway and Cairngorms) and Northern Ireland (Mourne Mountains). These sites were previously used to calculate target loads, and the methods and data sources used to calibrate the model were described in detail in the 2005 CCE progress report (Hall et al., 2005). For the present call, a set of region-specific forecast scenarios was calculated as the average proportional change (relative to a 2000 base year) in SO_4, NO_x and NH_y deposition for all EMEP squares covering that region. A single forecast scenario was run through to 2010, with the range of 27 scenarios specified in the call applied thereafter. For each site, all forecasts were run for all successful MAGIC calibrations (between 1 and 10 per site), and the median predicted value of each variable used in the data submission.

Dynamic modelling of terrestrial habitats

For each of the seven terrestrial habitats, results were calculated for all UK 1 km^2 grid squares which contained 1 ha or more of the habitat, where soil data were available (Table UK-1). Soil data were unavailable principally for acid-insensitive soil types which were not covered by the survey of Evans et al. (2004).

Parameters for running VSD for terrestrial habitats are listed in three main locations:

1. The Access form (CalcDM) used to set up a batch run (see Table UK-2)
2. The inputs table within the Access database (see Table UK-3)
3. The deposition tables within the Access database. EMEP values as supplied by the CCE were used.

Values were assigned to some parameters on the basis of soil type alone, or habitat and soil type. Soil type was defined as the dominant soil type within the 1 km^2 and parameters assigned according to soil group, subgroup, or broad soil class i.e. mineral, organomineral or peat (Hall et al., 2004). Different methods were applied to the calculation of acidity critical loads for non-woodlands and woodlands on mineral, organomineral and peat soils (Hall et al 2004). Woodland type was categorised as managed coniferous, managed broadleaved, and unmanaged (broadleaved and coniferous) (Hall et al., 2004). For assigning values to soil parameters, all unmanaged woodlands were assumed to be broadleaved.

Table UK-1. *Numbers of 1 km² squares with 1 ha of seven terrestrial habitat classes in the UK. Data were only submitted for squares where soil data were available.*

Eunis code	Habitat	Number of 1 km^2 squares	
		Total	Data submitted
D1	Bog	19079	17053
E42	Montane	5614	3018
E	acid grassland	77974	66568
F	dwarf shrub heath	78985	67334
G1	managed broadleaf deciduous woodland	75698	38469
G3	managed coniferous woodland	37528	20525
G1 & G3	unmanaged woodland (broadleaf deciduous or coniferous)	38054	26615

Table UK-2. *Parameters in the CalcDM form.*

Parameter	Value used	Data source and notes
Oliver constant (1)	4.5	default value supplied by CCE
Oliver constant (2)	0	as above
Oliver constant (3)	0	as above
sea salt corr.	0	no seasalt correction
Exchange kinetics	Gaines-Thomas	
CNrat_max	a) 43.6 gC/gN b) 20.8 gC/gN	Upper leaching thresholds for a) conifer/heathland and b) deciduous / grassland (Rowe et al., 2006)
CNrat_min	7.5 gC/gN	Lower leaching threshold (Rowe et al., 2006)

Table UK-3. *Parameters in the 'inputs' table.*

Parameter	Value used	Notes
SiteID		Unique 1 km site codes assigned by UK NFC
EmpSiteID	= SiteID	as above
Lon	-	from NFC data
Lat	-	from NFC data
I50	-	from NFC data
J50	-	from NFC data
EcoArea	0 – 1	Proportion of the grid square under this habitat (km^2 km^{-2})
CLmaxS	-	As previously calculated (Hall et al., 2004a,b)
CLminN	-	as above
CLmaxN	-	as above
CLnutN	-	not used
nANCcrit	-	As previously calculated (Hall et al., 2004a,b)
cNacc	-	Critical concentrations not yet agreed in UK, so data withheld
Crittype	-	soil / habitat dependent (Hall et al., 2004a,b)
Critvalue	-	soil / habitat dependent (Hall et al., 2004a,b)
Thick	0.5	Default value
Bulkdens	-	From NSRI data: mean for the soil group (e.g. 61 brown podzol)
Cadep	-	CBED model estimates (total Ca deposition from all sources) (Dore et al., 2003)
Mgdep	-	CBED model estimates (total base cation deposition minus total Ca deposition) (Dore et al., 2003)
Kdep	-	Assumed in constant ratio of 0.019 x Cldep (i.e. sea-salt ratio, assuming this is the only source of deposition for this ion)
Nadep	-	Assumed in constant ratio of 0.86 x Cldep (i.e. sea-salt ratio, assuming this is the only source of deposition for this ion)

Parameter	Value used	Notes
Cldep	-	FRAME model estimate (Dore et al., 2003)
Cawe	-	Soil type dependent - see Hall et al. (2004a,b)
Mgwe	-	Assumed 1/3 of (total base cation weathering – Ca weathering) (Hall et al., 2004a,b)
Kwe	-	Assumed 1/3 of (total base cation weathering – Ca weathering) (Hall et al., 2004a,b)
Nawe	-	Assumed 1/3 of (total base cation weathering – Ca weathering) (Hall et al., 2004a,b)
Caupt	-	Assumed 0 - see Hall et al. (2004a,b)
Mgupt	-	Assumed 0 - see Hall et al. (2004a,b)
Kupt	-	Assumed 0 - see Hall et al. (2004a,b)
Qle	-	see Hall et al. (2004a,b)
lgKAlox	-	Set by soil broad class: mineral soils 8.5; organomineral soils 7.6; peats 6.5 (Harald Sverdrup, pers. com.)
expAl	3	Default value
pCO2fac	-	Set by soil broad class: mineral soils 40; organomineral soils 100; peats 100 (Mike Billett, pers. com.)
cOrgacids	-	Set by soil broad class: mineral soils 25; organomineral soils 32; peats 65 (Chris Evans, unpublished data: means for total of 66 soil solution datasets)
Nimacc	-	Assigned by soil *group* (e.g. 61 brown podzol) (Hall et al., 2004a,b)
Nupt	-	see Hall et al. (2004a,b)
fde	-	fixed Nde value used, entered in this field as Nde * -0.0001
Nde	-	see Hall et al. (2004a,b)
CEC	-	[a]
Bsat	-	[a]
Yearbsat	2004	[a]
lgKAlBc	-	Mean for the soil *group* (e.g. 61 brown podzol) from measured soil and soil solution chemistry at 133 representative UK sites (Evans et al., 2004)
lgKHBc	2.3	Default value
Cpool	-	From NSRI data: mean for the soil *group* (e.g. 61 brown podzol), 0–30 cm.
CNrat	-	[a]
yearCN	2004	[a]
DMstatus	-	
EUNIScode	-	
CC	-	

[a]From Evans et al. (2004): mean for the combination of soil *subgroup* (e.g. 611 typical brown podzol) and broad habitat (grassland, heathland, deciduous woodland or coniferous woodland). Grassland values used for montane habitats. Heathland values used for bog habitats.

Empirical critical loads of nutrient nitrogen

Introduction

In 2004 the UK submitted critical loads of acidity and nutrient nitrogen for UK Biodiversity Action Plan broad habitats sensitive to acidification and/or eutrophication. For eutrophication, empirical critical loads of nutrient nitrogen, as agreed at the Berne workshop (Achermann and Bobbink, 2003) and in the UK (Hall et al., 2004) were applied to all habitats except managed woodlands for which the mass balance equation was used. In response to this call for data no changes have been made to the UK critical loads for broad habitats and hence no new habitat data have been submitted.

This submission from the UK is focused on applying the empirical nutrient nitrogen critical loads to the Special Areas of Conservation (SACs), a sub-set of the UK's Natura 2000 sites. There are 611 SACs in the UK ranging in area from <0.01 km^2 to >1500 km^2, and designated to protect between one and 21 features (Annex I habitats or Annex II species) per site. In conjunction with the UK conservation agencies and the UK environment agencies a method has been developed to assign 'site relevant' critical loads to the designated features of SACs. These data are being used by the environment agencies to enable the identification of sites at risk from critical load exceedance. This is to inform the assessment of the impacts of 'plans and projects' in relation to the provisions of Article 6.3 of the Habitats Directive. The data are also currently being used to inform the UK's air pollution assessment for the purposes of reporting on Favourable Conservation Status under Article 17 of the Habitats Directive.

This database has been submitted as an example of how empirical nutrient nitrogen critical loads may be applied to designated areas. This reflects the increasing demand for such an approach through drivers such as the Habitats Directive. It should be noted that if these data are used in conjunction with the UK habitat critical loads submitted in 2004 there will be some duplication of the total ecosystem areas.

Methods

The method for assigning site relevant critical loads was as follows:

The individual features (Annex I habitats or Annex II plant species) were assessed in terms of their sensitivity to eutrophication; 83 of the 90 features (77 habitats, 13 plant species) associated with the UK SACs are considered sensitive to eutrophication. 'Non-plant' species listed in Annex II have not been included in this assessment.

The corresponding EUNIS habitat class(es) of the sensitive features were identified. This can be done using either the EUNIS web site (http://eunis.eea.europa.eu/index.jsp) or the the Habitats Dictionary of the National Biodiversity Network (http://www.nbn.org.uk/habitats/); both sources have lookup tables from Annex I to EUNIS or vice versa.

Where the sensitive feature was a plant species, it was related to the EUNIS habitat in which it occurs.

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 where appropriate (ie, where there was some 'equivalence' between habitats). However, for 10 of the features (8 habitats, 2 plant species) identified as being sensitive to eutrophication there are currently no appropriate critical loads available (Table UK-4).

The critical load values identified by EUNIS class above were assigned to each corresponding feature for each SAC, i.e. no additional site-specific or spatial information was used in the assignment.

Table UK-4. *Annex 1 habitats and Annex II plant species found in the UK and for which there are no appropriate nutrient nitrogen critical loads available.*

Annex I habitats Annex II species	*Interest Name*
H1230	*Vegetated sea cliffs of the Atlantic and Baltic coasts*
H1340	*Inland salt meadows*
H2160	*Dunes with Hippophae rhamnoides (sea-buckthorn)*
H3140	*Hard oligo-mesotrophic waters with benthic vegetation of Chara ssp.*
H3150	*Natural eutrophic lakes often dominated by pondweed*
H3170	*Mediterranean temporary ponds*
H3180	*Turloughs*
H3260	*Water courses of plain to montane levels with floating vegetation (water-crowfoot)*
S1390	*Marsupella profunda (Western rustwort)*
S1833	*Najax flexilis (Slender naiad)*

Table UK-5 below lists the remaining 73 sensitive designated features together with the EUNIS class used to set the critical load values. For consistency with the habitat critical loads data previously submitted, the agreed UK 'mapping values' have been used (Hall et al., 2003a; 2003b); where no mapping value had previously been defined the mid-range value has been applied. It should be noted that the environment agencies in their site screening assessments have applied a more precautionary approach and used the value at the lower end of each range.

As stated above the number of features associated with an individual site varies, however, information on the location and area occupied by each feature within the sites is not currently readily available. Therefore for this data submission the ‘EcoArea’ associated with each data record is based on the total SAC site area divided by the number of features for which nutrient nitrogen critical loads are available. Further, for some sites more than one feature is associated with the same EUNIS class; where this is the case the feature areas (as defined above) have been aggregated to enable the data to be submitted as a single record per EUNIS class per SAC.

Table UK-5. *EUNIS habitat critical loads assigned to Annex I habitats and species.*

Annex I habitat Annex II species	EUNIS class (same or most similar to Annex I habitat)	CLnutN (kg N $ha^{-1}a^{-1}$)	UK Mapping Value (kg N $ha^{-1}a^{-1}$)
H1130 Estuaries	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H1140 Mudflats & sandflats	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H1150 Coastal lagoons	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H1220 Perennial vegetation of stony banks	B1.3 Shifting coastal dunes	10-20	15
H1310 Salicornia & other annuals on mud & sand	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H1320 Spartina swards	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H1330 Atlantic salt meadows	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H1420 Mediterranean & thermo-Atlantic halophilous scrubs	A2.64/A2.65 Pioneer & low-mid salt marshes	30-40	35*
H2110 Embryonic shifting dunes	B1.3 Shifting coastal dunes	10-20	15
H2120 Shifting dunes along shore (Ammophila arenaria)	B1.3 Shifting coastal dunes	10-20	15
H2130 Fixed dunes with herbaceous vegetation	B1.4 Coastal stable dune grasslands	10-20	15
H2140 Decalcified fixed dunes (Empetrum nigrum)	B1.5 Coastal dune heaths	10-20	15*
H2150 Atlantic decalcified fixed dunes	B1.5 Coastal dune heaths	10-20	15*
H2170 Dunes (Salix repens ssp. Argentea)	B1.8 Moist to wet dune slacks	10-25	17.5*
H2190 Humid dune slacks	B1.8 Moist to wet dune slacks	10-25	17.5*
H21A0 Machairs	B1.4 Coastal stable dune grasslands	10-20	15
H2250 Coastal dunes (Juniperus spp.)	B1.5 Coastal dune heaths	10-20	15*
H2330 Inland dunes (open Corynephorus & Agrostis)	E1.94 Inland dune pioneer grasslands	10-20	15*
H3110 Oligotrophic waters containing few minerals	C1.1 Permanent oligotrophic waters: softwater lakes	5-10	7.5*
H3130 Oligotrophic to mesotrophic standing waters with vegetation	C1.1 Permanent oligotrophic waters: softwater lakes	5-10	7.5*
H3160 Natural dystrophic lakes & ponds	C1.1 Permanent oligotrophic waters: softwater lakes	5-10	7.5*
H4010 Northern Atlantic wet heaths (Erica tetralix)	F4.11 Northern wet heath: Erica tetralix dominated	10-25	15
H4020 Temperate Atlantic wet heaths (Erica cilliaris & tetralix)	F4.11 Northern wet heath: Erica tetralix dominated	10-25	15
H4030 European dry heaths	F4.2 Dry heaths	10-20	12
H4040 Dry Atlantic coastal heaths (Erica vegans)	F4.2 Dry heaths	10-20	12
H4060 Alpine & boreal heaths	F2 Arctic, alpine, subalpine scrub habitats	5-15	10*
H4080 Sub-Arctic Salix spp. Scrub	F2 Arctic, alpine, subalpine scrub habitats	5-15	10*
H5110 Stable xerothermophilous formations (Buxus sempervirens)	E1.26 Sub-Atlantic semi-dry calcareous grasslands	15-25	20
H5130 Juniperus communis on heaths or calcareous grasslands	F4.2 Dry heaths	10-20	12
H6130 Calaminarian grasslands of Violetalia calaminariae	E1.26 Sub-Atlantic semi-dry calcareous grasslands	15-25	20
H6150 Siliceous alpine & boreal	E4.3 Alpine & subalpine grasslands	10-15	12.5*

Annex I habitat Annex II species	EUNIS class (same or most similar to Annex I habitat)	CLnutN (kg N $ha^{-1}a^{-1}$)	UK Mapping Value (kg N $ha^{-1}a^{-1}$)
grasslands			
H6170 Alpine & subalpine calcareous grasslands	E4.3 Alpine & subalpine grasslands	10-15	12.5*
H6210 Semi-natural dry grasslands & scrubland facies (calcareous)	E1.26 Sub-Atlantic semi-dry calcareous grasslands	15-25	20
H6211 Semi-natural dry grasslands & scrubland facies (orchid sites)	E1.26 Sub-Atlantic semi-dry calcareous grasslands	15-25	20
H6230 Species-rich Nardus grassland (siliceous, mountain)	E1.7 Non-mediterranean dry acid & neutral closed grassland	10-20	15
H6410 Molinia meadows (calcareous, peaty, clay-silt soils)	E3.51 Moist & wet oligotrophic grasslands: Molinia caerulea	15-25	20*
H6430 Hydrophilous tall herb fringe communities (plains, montane)	E4.3 Alpine & subalpine grasslands	10-15	12.5*
H6510 Lowland hay meadows	E2.2 Low & medium altitude hay meadows	20-30	25*
H6520 Mountain hay meadows	E2.3 Mountain hay meadows	10-20	15*
H7110 Active raised bogs	D1 Raised & blanket bogs	5-10	10
H7120 Degraded raised bogs capable of natural regeneration	D1 Raised & blanket bogs	5-10	10
H7130 Blanket bogs	D1 Raised & blanket bogs	5-10	10
H7140 Transition mires & quaking bogs	D1 Raised & blanket bogs	5-10	10
H7150 Depressions on peat substrates (Rhynchosporion)	D1 Raised & blanket bogs	5-10	10
H7210 Calcareous fens (Cladium mariscus)	D4.1 Rich fens	15-35	25*
H7220 Petrifying springs with tufa formation	D4.2 Mountain rich fens	15-25	20*
H7230 Alkaline fens	D4.1 Rich fens	15-35	25*
H7240 Alpine pioneer formations (Caricion bicoloris-atrofuscae)	D4.2 Mountain rich fens	15-25	20*
H8110 Siliceous scree of montane to snow levels	F2 Arctic, alpine, subalpine scrub habitats	5-15	10*
H8120 Calcareous & calcshist screes of montane/alpine levels	F2 Arctic, alpine, subalpine scrub habitats	5-15	10*
H8210 Calcareous rocky slopes with chasmophytic vegetation	E4.3 Alpine & subalpine grasslands	10-15	12.5*
H8220 Siliceous rock slopes with chasmophytic vegetation	F2 Arctic, alpine, subalpine scrub habitats	5-15	10*
H8240 Limestone pavements	E4.3 Alpine & subalpine grasslands	10-15	12.5*
H9120 Taxus in the shrublayer	G Temperate & boreal forests: ground flora	10-15	12
H9130 Asperulo-Fagetum beech forests	G Temperate & boreal forests: ground flora	10-15	12
H9160 Sub-Atlantic & medio-European oak oak-hornbeam forests	G Temperate & boreal forests: ground flora	10-15	12
H9180 Tilio-Acerion forests of slopes, screes & ravines	G Temperate & boreal forests: ground flora	10-15	12
H9190 Old acidophilous oak with Quercus robur on sandy plains	G Temperate & boreal forests: ground flora	10-15	12
H91A0 Old sessile oak with Ilex & Blechnum (British Isles)	G Temperate & boreal forests: epiphytic lichens	10-15	10
H91C0 Caledonian forest	G Temperate & boreal forests: ground flora	10-15	12
H91D0 Bog woodland	D1 Raised & blanket bogs	5-10	10
H91J0 Taxus baccata woods (British Isles)	G Temperate & boreal forests: ground flora	10-15	12
S1386 Buxbaumia viridis	G Temperate & boreal forests: ground flora	10-15	12
S1393 Drepanocladus (Hamatocaulis) vernicosus	D2.2 Poor fens	10-20	15
S1395 Petalophyllum ralfsii	B1.8 Moist to wet dune slacks	10-25	17.5*
S1421 Trichomanes speciosum	G Temperate & boreal forests: ground flora	10-15	12
S1441 Rumex rupestris	B1.8 Moist to wet dune slacks	10-25	17.5*
S1528 Saxifraga hirculus	E4.3 Alpine & subalpine grasslands	10-15	12.5*
S1614 Apium repens	E2.2 Low & medium altitude hay meadows	20-30	25*
S1654 Gentianella anglica	E1.26 Sub-Atlantic semi-dry calcareous grassland	15-25	20

Annex I habitat Annex II species	EUNIS class (same or most similar to Annex I habitat)	CLnutN (kg N $ha^{-1}a^{-1}$)	UK Mapping Value (kg N $ha^{-1}a^{-1}$)
S1831 Luronium natans	C1.1 Permanent oligotrophic waters: softwater lakes	5-10	7.5*
S1902 Cypripedium calceolus	G Temperate & boreal forests: ground flora	10-15	12
S1903 Liparis loeselii	B1.8 Moist to wet dune slacks	10-25	17.5*

* No UK Mapping Value set for this EUNIS class, so mid-range value applied.

Conclusions

This method enabled empirical nutrient nitrogen critical loads to be assigned to 73 out of the 83 designated features (Annex I habitats or Annex II plant species) within the UK SACs considered to be sensitive to eutrophication. Ten features were identified for which it was not possible to assign appropriate critical loads.

In terms of sites, of the 611 SACs in the UK, 516 contain features (Annex I habitats or Annex II plant species) sensitive to eutrophication. Using the methodology described above it was possible to assign nutrient nitrogen critical loads to the features of 472 of the SACs in the UK.

Whilst it is possible using the available databases on the web to relate the Annex I habitats to their corresponding EUNIS classes, there may not always be a direct relationship or correspondence. In addition, nutrient nitrogen critical loads are not available for all the EUNIS classes identified and expert opinion has been used to select a similar class where possible.

For many of the EUNIS classes in Table UK-5 a critical load value within each range had previously been agreed (i.e. UK mapping value) for use in data submissions and for exceedance calculations; where this was not the case the mid-range value has been applied. However, there is still some uncertainty about where within the range the critical load should be set. The UK environment agencies have chosen to use the range minima in their assessments because of the precautionary approach enshrined within Article 6.3 of the Habitats Regulations. Ashmore and Hicks (2006) have proposed a decision support matrix incorporating some of the endorsement theory approaches developed by Wadsworth and Hall (2007) for acidity. This method would make use of the Ellenberg scores for fertility (N), acidity (R), and moisture (F) identified for given classes of the National Vegetation Classification (Rodwell, 1991), together with user inputs on rare species occurrence and management activities. By assigning a 'weight of evidence' to each of these parameters at the site-level an overall endorsement for using the critical load at the lower, middle or upper part of the range can be determined. Such approaches will be examined further within the UK and their applicability and ease of use ascertained.

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Appendix A Instructions for submitting empirical critical loads of nitrogen

Coordination Centre for Effects (CCE), Bilthoven, November 2006

1. Introduction

This document contains the instructions for the submission of data to the CCE on empirical critical loads in relation to a surplus of nitrogen.

Your submission should contain the following key outputs:

(1) **Empirical critical loads of nitrogen;** and input variables to allow consistency checks and inter-country comparisons (see Table 1)
(2) **A document describing the sources and methods used to produce the data.**

Please note:

- The deadline for the submissions is **25 February 2007**.
- The preferred file format of the data is an Access database file (mdb), but also files with formats of Excel or comma separated ASCII files are accepted. The easiest way to comply with the requested format is to use the Access database that is made available by the CCE.
- This call for data is linked to the call for data on critical loads for acidification and eutrophication. In that call you will be asked to relate the ecosystems of both submissions. We recommend the use of a single dataset that is representative of your country.
- Please email your submission to jaap.slootweg@mnp.nl . The data can be attached to the email, but large data files can also be uploaded using ftp to ftp://ftp.mnp.rivm.nl/cce/incoming/. If you have used ftp, please inform Jaap Slootweg with an email!
- The LRTAP Convention's harmonization land cover data/map is available from the Stockholm Environment Institute (SEI) for the majority of the European countries. You can also contact the Jaap Slootweg of the CCE if you wish to make use of this data.
- All information is also available on our website under ***News*** at www.mnp.nl/cce

2. Data structure

The data structure is summarized in Table 1.

The easiest way to assemble and submit data is to use the template **Access** database that is provided by the CCE **(call07EmpN.mdb**).

Every ecosystem within an EMEP50-grid cell for which a critical load is provided is represented in the Table 1 by one line (record), and every record has 9 entries, holding site information on the empirical critical load and related information.

Table 1. Attributes of the table '*EmpNload*' (9 columns)

Variable	Explanation	Note
SiteID	Identifier for the site	1)
Lon	Longitude (decimal degrees)	2)
Lat	Latitude (decimal degrees)	2)
I50	EMEP50 horizontal coordinate	3)
J50	EMEP50 vertical coordinate	3)
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	4)
CLempN	Empirical critical load of nitrogen (eq ha^{-1} a^{-1})	
Protection	0 : No specific nature protection applies 1 : Special Protection Area (SPA), Birds Directive applies 2 : Special Area of Protection (SAC), Habitats Directive applies 9 : a national nature protection program applies	
EUNIScode	EUNIS code, max. 5 characters	

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 48º30', etc.)
3) Indices (2-byte integers) of the 50km x 50km EMEP-grid cell in which the receptor is located. It is the grid with North Pole at (8,110) as described in chapter 8 of the Mapping Manual.
4) Please remove spurious records with an ecosystem area smaller than 0.01 km^2.

3. 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 the agreed logic to derive empirical critical load values for nitrogen deposition that is provided in Chapter 5.2 of the Mapping Manual (www.icpmapping.org) and only list and describe the deviations from the Mapping Manual.

The CCE reporting requirements are currently best served by using the WORD-template provided or with a plain single-column WORD layout.

Appendix B. Instructions for submitting critical loads of N and S and dynamic modelling data

Coordination Centre for Effects (CCE), Bilthoven, November 2006

Introduction

This document contains the instructions for the submission of data to the CCE on critical loads of sulphur and nitrogen as well as dynamic modelling output.

Your submission should contain the following key outputs:

(3) **Updated critical loads,** as well as input variables to allow consistency checks and inter-country comparisons (Table 1 [Table 3 for surface waters])
(4) **Values of chemical variables from dynamic model runs in historic and in future years for different deposition scenarios** (Table 2)
(5) **A document describing the sources and methods used to produce the data.**

What's new and/or important to know?

- **Deadline** for submissions is **19 March 2007**.
- 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 an Access database that is made available by the CCE.
- Please email your **submission** to jaap.slootweg@mnp.nl . The data can be attached to the email, but large data files can also be uploaded to ftp://ftp.mnp.rivm.nl/cce/incoming/ using ftp. If you have used ftp, please inform Jaap Slootweg by an email.
- Table 1 contains a new column 'EmpSiteID', which should hold the ID of the site as used when (and if) an empirical N critical load for the same site has been derived. This allows **linking with the call for empirical CLs** (obviously, SiteID and EmpSiteID can be identical! If no empirical CL has been determined, leave blank).
- We urge NFCs to re-visit their calculations of critical loads of nutrient N in the light of **updated critical (acceptable) N concentrations** in the soil solution. These updated values can be found in Table 4 below. Note also that the variable 'Nleacc' in Table 1 has been changed into 'cNacc', which should hold the chosen acceptable (critical) N concentration (in meq m^{-3} = μeq L^{-1}) used in calculating CLnutN.
- In contrast to previous calls, *no* target load calculations are requested, merely the output of **dynamic modelling runs** of 7 chemical variables in 9 years for a number of deposition scenarios (see below for details). Accordingly, the structure of Table 2 has changed to accommodate this new request.
- Historic depositions and the **deposition scenarios** for nitrogen and sulphur are available from the CCE upon request.
- 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 has extended possibilities for performing consistency checks on your critical load database.
- All information is also available on our website under ***News***: www.mnp.nl/cce/

Data structure

The data structure is summarized in Tables 1 to 3 described below. The database you submit should contain at least 2 Tables, '*inputs*', '*scenvars*'. It may also include a table '*h2oinputs*', which is designed for surface water model (MAGIC).

The easiest way to assemble and submit data is to use the **Access** database, which is available from the CCE website www.mnp.nl/cce/ under *News*. The CCE also prepared a new version of the dynamic modelling software (VSD model) for this call. This software – tailored to every NFC (incl. national depositions) – is available from the CCE upon request (contact jaap.slootweg@mnp.nl). NFCs who wish to make more detailed analyses of individual sites can use the (updated) 'VSDStudio' software, developed in collaboration with Alterra and available on the CCE website.

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! These checks generate screen messages, which should be followed up.

Every ecosystem within an EMEP50 grid cell for which critical loads are provided is represented in the Table 1 by one line (record), and every record has 48 entries, holding site information on critical loads and input data for CLs and dynamic modelling. The new column 'EmpSiteID' allows linking these data to the submission of empirical CLs of N.

1. Data structure of critical loads and input data:

Table 1. Attributes of the table '*inputs*' (for surface waters see Table 3).

Variable	**Explanation**	**Note**
SiteID	Identifier of the site	1)
EmpSiteID	Identifier of this site in the submission on empirical Critical Loads	2)
Lon	Longitude (decimal degrees)	3)
Lat	Latitude (decimal degrees)	3)
I50	EMEP50 horizontal coordinate	4)
J50	EMEP50 vertical coordinate	4)
EcoArea	Area of the ecosystem within the EMEP grid cell (km^2)	5)
CLmaxS	Maximum critical load of sulphur (eq ha^{-1} a^{-1})	
CLminN	Minimum critical load of nitrogen (eq ha^{-1} a^{-1})	
CLmaxN	Maximum critical load of nitrogen (eq ha^{-1} a^{-1})	
CLnutN	Critical load of nutrient nitrogen (eq ha^{-1} a^{-1})	
nANCcrit	The quantity $-ANC_{le(crit)}$ (eq ha^{-1} a^{-1})	6)
cNacc	Acceptable (critical) N concentration for CLnutN calculation (meq m^{-3})	7)
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]; = –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})	DM)
Cadep	Total deposition of calcium (eq ha^{-1} a^{-1})	8)
Mgdep	Total deposition of magnesium (eq ha^{-1} a^{-1})	8)
Kdep	Total deposition of potassium (eq ha^{-1} a^{-1})	8)
Nadep	Total deposition of sodium (eq ha^{-1} a^{-1})	8)
Cldep	Total deposition of chloride (eq ha^{-1} a^{-1})	8)
Cawe	Weathering of calcium (eq ha^{-1} a^{-1})	8)
Mgwe	Weathering of magnesium (eq ha^{-1} a^{-1})	8)
Kwe	Weathering of potassium (eq ha^{-1} a^{-1})	8)
Nawe	Weathering of sodium (eq ha^{-1} a^{-1})	8)
Caupt	Net growth uptake of calcium (eq ha^{-1} a^{-1})	8) 9)
Mgupt	Net growth uptake of magnesium (eq ha^{-1} a^{-1})	8) 9)
Kupt	Net growth uptake of potassium (eq ha^{-1} a^{-1})	8) 9)
Qle	Amount of water percolating through the root zone (mm a^{-1})	8)

Variable	Explanation	Note
lgKAlox	Equilibrium constant for the Al-H relationship (log_{10}) (The variable formerly known as Kgibb)	10)
expAl	Exponent for the Al-H relationship (=3 for gibbsite equilibrium)	10)
pCO2fac	Partial CO_2-pressure in soil solution as multiple of the atmospheric CO_2 pressure (-)	8)
cOrgacids	Total concentration of organic acids (m*DOC) (eq m^{-3})	8)
Nimacc	Acceptable nitrogen immobilised in the soil (eq ha^{-1} a^{-1})	11)
Nupt	Net growth uptake of nitrogen (eq ha^{-1} a^{-1})	8) 9)
fde	Denitrification fraction ($0 \leq fde < 1$) (-)	8) 12)
Nde	Amount of nitrogen denitrified (eq ha^{-1} a^{-1})	8) 12)
CEC	Cation exchange capacity (meq kg^{-1})	DM)
bsat	Base saturation (-)	DM)
yearbsat	Year in which the base saturation was determined	DM)
lgKAlBc	Exchange constant for Al vs Bc (log_{10})	DM)
lgKHBc	Exchange constant for H vs Bc (log_{10})	DM)
Cpool	Amount of carbon in the topsoil (g m^{-2})	DM)
CNrat	C/N ratio in the topsoil (g/g)	DM)
yearCN	Year in which the CNrat and Cpool were determined	DM)
DMstatus	= –1: *no* dynamic modelling for this site (and thus no entry in Table 2) = 1: dynamic modelling output is given in Table 2	DM)
EUNIScode	EUNIS code, max. 4 characters	13)

Notes on Table 1 (see last column):

5) Use integer values only (4-bytes)!
6) This integer should correlate to 'SiteID' in the Table '*EmpNload*' of your submission for empirical critical loads. Obviously, 'SiteID' and 'EmpsiteID' in this Table can be identical (and ideally are!).
7) 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 48º30', etc.)
8) Indices (2-byte integers) of the 50km×50km EMEP-grid cell in which the receptor is located. It is the grid with the North Pole at (8,110); see also chap.8 of the Mapping Manual (www.icpmapping.org).
9) Please remove spurious records with an ecosystem area smaller than 1 ha.
10) The *negative* Acidity Neutralising Capacity (ANC), equal to $Al_{le(crit)} + H_{le(crit)} - HCO3_{le(crit)}$ [$-OrgAcids_{le(crit)}$].
11) This replaces the earlier 'Nleacc'! Note it is in meq m^{-3}.
12) Values used in the critical load calculations.
13) These are net uptakes, equal to the annual average amount removed from the site by harvesting.
14) From the equation $[Al]=KAl_{ox}\cdot[H]^{expAl}$ (with [Al] and [H] in mol L^{-1}). For help with unit conversions see Annex III of the Mapping Manual.
15) In general this will *not* be the amount immobilised at present! If data permit calculate Nimacc as $N_i+N_{fire}+N_{eros}+N_{vol}-N_{fix}$ (see Mapping Manual).
16) These two are mutually exclusive, i.e. one of them has to be null!
17) You can find information on EUNIS (updated 2004!) at http://eunis.eea.eu.int/

DM) These variables are used for dynamic modelling only.

2. Data structure for dynamic modelling output:

To be able to analyse changes over time of the chemical status of ecosystems, dynamic modelling has to be carried out. From these model runs the following 7 variables for 4 'historic' years (1980, 1990, 2000, 2010) and 5 future years (2020, 2030, 2040, 2050, 2100) for a number of deposition scenarios (see below) are requested (concentrations are from the soil solution or, when aquatic systems are modelled, in the surface water)(meq m^{-3}):

1. $[Al^{3+}]$ (meq m^{-3} = μeq L^{-1})
2. [Bc]=[Ca+Mg+K] (meq m^{-3})
3. pH
4. ANC concentration (meq m^{-3})
5. base saturation (fraction)
6. C:N ratio (g g^{-1})
7. Nitrogen (= $[NO_3]+[NH_4]$) concentration (meq m^{-3})

These variables are independent of any scenario from 1980 until 2010 – and thus calculated only once (and labelled 'His') – while for the years thereafter output is required for every deposition scenario. The scenarios are composed of three base scenarios (CLE, MFR and bkg) and a number of intermediate deposition paths, depending on the distance between the CLE and MFR scenario. A description of how to determine these additional scenarios is given below.

Table 2. Attributes of the table 'scenvars'.

Variable	Explanation
SiteID	Identifier for the site (relate to Table 1)
ScenName	Name of the scenario (His,CLE,MFR,bkg,SbN,NbS,D*mn*, *m*=1…; *n*=1…)
year	Year
depN	total nitrogen deposition in that 'year' (eq ha^{-1} a^{-1})
depS	sulphur deposition (excluding sea-salt fraction) in that 'year' (eq ha^{-1} a^{-1})
cAl	Aluminium concentration [meq m^{-3}]
cBc	Base cation concentration [meq m^{-3}]
pH	pH [–]
ANC	ANC concentration [meq m^{-3}]
bsat	base saturation (fraction)
CNrat	C:N ratio (g g^{-1})
cN	Nitrogen ($[NO_2]$ + $[NH_3]$) concentration [meq m^{-3}]

3. Aquatic ecosystems

For aquatic ecosystems Table 1 should be replaced by Table 3 below; Table 2 remains unchanged.

Table 3. Attributes of the table 'h2oinputs'.

Variable	**Explanation**
SiteID	Identifier for the site
EmpSiteID	Identifier for this site in the submission of empirical Critical Loads
Lon	Longitude (decimal degrees)
Lat	Latitude (decimal degrees)
I50	EMEP50 horizontal coordinate
J50	EMEP50 vertical coordinate
EcoArea	Area of the ecosystem(whole catchment) within the EMEPgrid (km^2)
CLmaxS	Maximum critical load of sulphur (eq ha^{-1} a^{-1})
CLminN	Minimum critical load of nitrogen (eq ha^{-1} a^{-1})
CLmaxN	Maximum critical load of nitrogen (eq ha^{-1} a^{-1})
CLnutN	Critical load of nutrient nitrogen (eq ha^{-1} a^{-1})
crittype	Criterion used: 6: [ANC] (eq/m^3); 0: other
critvalue	Value of the criterion used
SoilYear	Year for soil measurements
ExCa	Exchangeable pool of calcium in given year (%)

Variable	Explanation
ExMg	Exchangeable pool of magnesium in given year (%)
ExNa	Exchangeable pool of sodium in given year (%)
ExK	Exchangeable pool of potassium in given year (%)
thick	Thickness of the soil (m)
Porosity	Soil pore fraction (%)
bulkdens	Bulk density of the soil (g cm^{-3})
Nimacc	Acceptable amount of nitrogen immobilised in the soil (eq ha^{-1} a^{-1})
CEC	Cation exchange capacity (meq kg^{-1})
HlfSat	Half saturation of SO4 ads isotherm (ueq L^{-1})
Emx	Maximum SO4 ads capacity (meq kg^{-1})
Nitrif	Nitrification in the catchment (meq m^{-2} a^{-1})
Denitrf	Denitrification rate in catchment (meq m^{-2} a^{-1})
Cpool	Amount of carbon in the topsoil in the given yearCN(g m^{-2})
Npool	Amount of nitrogen in the topsoil in the given yearCN(g m^{-2})
CNRange	C/N ratio range where N accumulation occurs (mol mol^{-1})
CNUpper	Upper limit of C/N ratio where N accumulation occurs (mol mol^{-1})
CaUpt	Net growth uptake of calcium (meq m^{-2} a^{-1})
MgUpt	Net growth uptake of magnesium (meq m^{-2} a^{-1})
KUpt	Net growth uptake of potassium (meq m^{-2} a^{-1})
NaUpt	Net growth uptake of sodium (meq m^{-2} a^{-1})
SO4Upt	Net growth uptake of sulphate (meq m^{-2} a^{-1})
NH4Upt	Net growth uptake of ammonia (meq m^{-2} a^{-1})
DepYear	Year for deposition measurements
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})
NH4dep	Total deposition of ammonia (eq ha^{-1} a^{-1})
NO3dep	Total deposition of nitrate (eq ha^{-1} a^{-1})
LakeYear	Year for lake measurements
Calake	Measured concentration of calcium in lake(µmol L^{-1})
Mglake	Measured concentration of magnesium in lake(µmol L^{-1})
Nalake	Measured concentration of sodium in lake(µmol L^{-1})
Klake	Measured concentration of potassium in lake(µmol L^{-1})
NH4lake	Measured concentration of ammonia in lake(µmol L^{-1})
SO4lake	Measured concentration of sulphate in lake(µmol L^{-1})
Cllake	Measured concentration of chloride in lake(µmol L^{-1})
NO3lake	Measured concentration of nitrate in lake(µmol L^{-1})
RelArea	The area of the lake relative to the catchment (%)
RelForArea	The area of the forest relative to the catchment (%)
RetTime	Retention time in the lake (a)
Qs	Annual runoff flux (m a^{-1})
expAl	Exponent for the Al-H relationship ()
pCO2	Partial CO2-pressure in the lake in relation to the atmospheric CO2 pressure (%atm)
DOC	DOC concentration in the lake (µmol L^{-1})
Nitriflake	Nitrification in the lake (%)
Cased	Sedimentation velocity of calcium in the lake (m a^{-1})
Mgsed	Sedimentation velocity of magnesium in the lake (m a^{-1})
Nased	Sedimentation velocity of sodium in the lake (m a^{-1})
Ksed	Sedimentation velocity of potassium in the lake (m a^{-1})
NH4sed	Sedimentation velocity of ammonia in the lake (m a^{-1})
SO4sed	Sedimentation velocity of sulphate in the lake (m a^{-1})
Clsed	Sedimentation velocity of chloride in the lake (m a^{-1})

Variable	Explanation
NO3sed	Sedimentation velocity of nitrate in the lake (m a^{-1})
UptNH4lake	Uptake of ammonia in the lake (in % of measured value)
UptNO3lake	Uptake of Nitrate in the lake (in % of measured value)
DMstatus	–1: *no* dynamic modelling for this site 1: dynamic modelling information is given in Table 2
EUNIScode	EUNIS code (C1=standing waters; C2=running waters)

Updated critical concentrations for CL_{nut}(N) calculations

In a revised version of a CCE/Alterra Report (De Vries et al.: *Developments in deriving critical limits and modeling critical loads of nitrogen for terrestrial ecosystems in Europe*) the critical concentrations given in the Mapping Manual have been revised/updated. These updates are listed in Table 4. NFCs are urged to re-visit their CL_{nut}(N) calculations and update them if appropriate.

The values in Table 4 are converted to meq m^{-3} by multiplying them with 1000/14=71.428; and it is these multiplied values which should be entered under 'cNacc' in Table 1.

Table 4: Critical (acceptable) N concentrations in soil solution for calculating CLnutN.

Impact	Critical N concentration (mg N L^{-1})	
	Mapping Manual	**Update**
Vegetation changes in Northern Europe:		
Lichens to cranberry (lingonberries)	0.2-0.4	**0.2-0.4**
Cranberry to blueberry	0.4-0.6	**0.4-0.6**
Blueberry to grass	1-2	**1-2**
Grass to herbs	3-5	**3-5**
Vegetation changes in Western Europe:		
Coniferous forest		**2.5-4**
Deciduous forest	-	**3.5-6.5**
Grass lands		**3**
Heath lands	-	**3-6**
Other impacts on forests		
Nutrient imbalances	0.2-0.4	(0.2-0.4)
Elevated nitrogen leaching/N saturation	-	**1**
Fine root biomass/root length	-	**1-3**
Sensitivity to frost and fungal diseases	-	**3-5**

Deposition scenarios

The dynamic model should be run with the historic deposition until 2010 and from 2020 till 2100 with one of the 7 to 27 scenarios, with linear transition between 2010 and 2020 and staying constant thereafter. All scenarios are derived from 3 given scenarios: (1) 'Current LEgislation' (**CLE**), assuming implementation of current legislation (Gothenburg Protocol, NEC directive, etc.) by 2010; (2) 'Maximum Feasible Reductions' (**MFR**), assuming the implementation of maximum technically feasible reductions; and (3) a deposition scenario based on EMEP MSC-W calculated background values (**bkg**). While the emissions for first two scenarios are prepared by CIAM, the third one is directly obtained from EMEP MSC-W. All deposition calculations have been carried out with EMEP/MSC-West's eulerian model.

These three scenarios are used to create other scenarios, the number of which depends on the difference between the CLE and MFR scenario in a given grid cell. Figure 1 illustrates the scheme according to which N and S deposition scenarios are generated (Note: in the software provided by the CCE these calculations are carried out automatically).

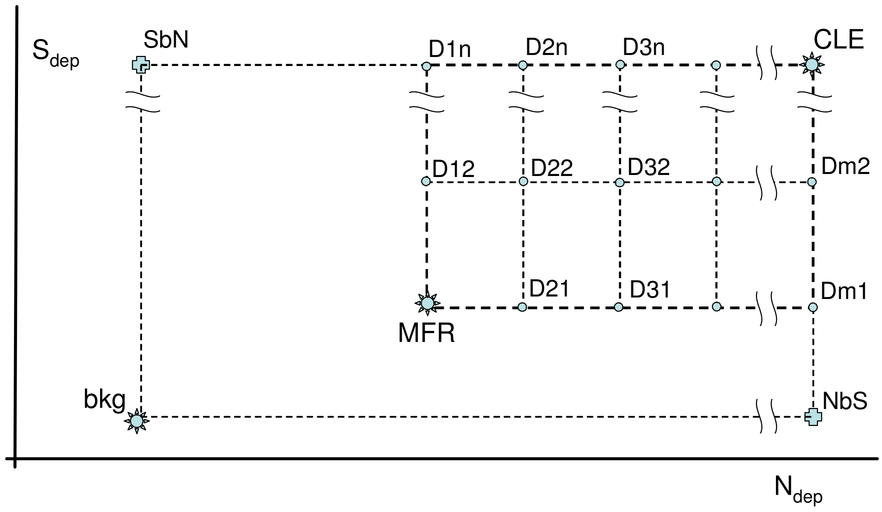

Figure 1: Graphic representation in the (N_{dep},S_{dep})-plane of the N and S deposition scenarios for 2020–2100 derived from the CLE, MFR and bkg scenarios. Also shown is the naming of the scenarios (Note: D11=MFR, D*mn*=CLE, *m* between 1 and (max.) 6, *n* between 1 and (max.) 4).

The number of N-deposition values between that of the CLE scenario, N_{CLE}, and the MFR scenario, N_{MFR}, is computed as $nx = (N_{CLE}–N_{MFR})/dN$, with dN=0.01 eq m^{-2} a^{-1} (=100 eq ha^{-1} a^{-1}), i.e. successive N-deposition values should be (max.) *dN* apart. However, we also limit *nx* to a maximum of 6. Thus, if $N_{CLE}–N_{MFR}$ is greater than $6 \cdot dN$, *dN* is taken as $(N_{CLE}–N_{MFR})/6$. Analogous for S-deposition, but with a maximum number of *ny*=4. Thus the minimum number of deposition pairs is 4 (MFR, D21, D12, CLE), and the maximum number is 6×4=24. Adding the three scenarios related to the background deposition (bkg, SbN, NbS; see Fig.1), gives 7–27 scenarios per site for which dynamic modelling output is requested.
[…]

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 and describe the deviations from the Manual.

The CCE reporting requirements are currently best served by using the WORD-template provided or with a plain single-column WORD layout.

Appendix C. Guidance notes for lead authors of the IPCC fourth assessment report on addressing uncertainties

(Source: http://ipcc-wg1.ucar.edu/wg1/Report/AR4_UncertaintyGuidanceNote.pdf.)

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties

The following notes are intended to assist Lead Authors (LAs) of the Fourth Assessment Report (AR4) to deal with uncertainties consistently. They address approaches to developing expert judgments, evaluating uncertainties, and communicating uncertainty and confidence in findings that arise in the context of the assessment process. Where alternative approaches are used in the relevant literature, those should be used but where possible related to the approaches given here. Further background material and more detailed coverage of these issues are available in the guidance paper on uncertainties developed for the Third Assessment Report [1] and the report of an IPCC Workshop on Uncertainty and Risk [2].

The working group reports will assess material from different disciplines and will cover a diversity of approaches to uncertainty, reflecting differences in the underlying literature. In particular, the nature of information, indicators and analyses used in the natural sciences is quite different from that used in the social sciences. WG I focuses on the former, WG III on the latter, and WG II covers both. The purpose of this guidance note is to define common approaches and language that can be used broadly across all three working groups. Each working group may need to supplement these notes with more specific guidance on particular issues consistent with the common approach given here.

Plan to treat issues of uncertainty and confidence

1. Consider approaches to uncertainty in your chapter at an early stage. Prioritize issues for analysis. Identify key policy relevant findings as they emerge and give greater attention to assessing uncertainties and confidence in those. Avoid trivializing statements just to increase their confidence.

2. Determine the areas in your chapter where a range of views may need to be described, and those where LAs may need to form a collective view on uncertainty or confidence. Agree on a carefully moderated (chaired) and balanced process for doing this.

Review the information available

3. Consider all plausible sources of uncertainty using a systematic typology of uncertainty such as the simple one shown in Table 1. Many studies have shown that structural uncertainty, as defined in Table 1, tends to be underestimated by experts [3]. Consider previous estimates of ranges, distributions, or other measures of uncertainty and the extent to which they cover all plausible sources of uncertainty.

Table 1. A simple typology of uncertainties

Type	Indicative examples of sources	Typical approaches or considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests; comparison of models with observations.

4. Assess issues of risk where supported by published work. Where probabilistic approaches are available, consider ranges of outcomes and their associated likelihoods with attention to outcomes of potential high consequence. An alternative approach is to provide information for decisions that would be robust in the sense of avoiding adverse outcomes for a wide range of future possibilities [4]. (Note that the term "risk" has several different usages. If used it should be defined in context.)

Make expert judgments

5. Be prepared to make expert judgments and explain those by providing a traceable account of the steps used to arrive at estimates of uncertainty or confidence for key findings – e.g. an agreed hierarchy of information, standards of evidence applied, approaches to combining or reconciling multiple lines of evidence, and explanation of critical factors.

6. Be aware of a tendency for a group to converge on an expressed view and become overconfident in it [3]. Views and estimates can also become anchored on previous versions or values to a greater extent than is justified. Recognize when individual views are adjusting as a result of group interactions and allow adequate time for such changes in viewpoint to be reviewed.

Use the appropriate level of precision to describe findings

7. Assess the current level of understanding on key issues and precede statements on confidence or uncertainty with a general summary of the corresponding state of knowledge. Table 2 below provides a consistent language for this.

8. Develop clear statements for key findings that are quantitative and give explicit time frames as far as possible. Define carefully the corresponding variables or outcomes, their context, and any conditional assumptions. Where scenarios are used, explain the range of assumptions and how they affect the outcome. Then consider the most appropriate way to describe the relevant uncertainties or level of confidence by going as far down the hierarchy given below as you feel appropriate (from expressions of less to more confidence and less to more probabilistic approaches) [5]:

   A. *Direction of change is ambiguous or the issue assessed is not amenable to prediction:* Describe the governing factors, key indicators, and relationships. If a trend could be either positive or negative, explain the pre-conditions or evidence for each.

   B. *An expected trend or direction can be identified (increase, decrease, no significant change):* Explain the basis for this and the extent to which opposite changes would not be expected. Include changes that have a reasonable likelihood even where they are not certain. If you describe a collective level of confidence in words, use the language options in Table 2 or 3.

   C. *An order of magnitude can be given for the degree of change (i.e. sign and magnitude to within a factor of 10):* Explain the basis for estimates given and indicate assumptions made. The order of magnitude should not change for reasonable ranges in such assumptions. If you describe a collective level of confidence in words, use the language options in Table 2 or 3.

   D. *A range can be given for the change in a variable as upper and lower bounds, or as the 5th and 95th percentiles, based on objective analysis or expert judgment:* Explain the basis for the range given, noting factors that determine the outer bounds. If you cannot be confident in the range, use a less precise approach. If you describe a collective level of confidence or likelihood of an outcome in words, use the language options in Tables 3 or 4.

   E. *A likelihood or probability of occurrence can be determined for an event or for representative outcomes, e.g. based on multiple observations, model ensemble runs, or expert judgment:* State any assumptions made and estimate the role of structural uncertainties. Describe likelihoods using the calibrated language given in Table 4 or present them quantitatively.

F. *A probability distribution can be determined for changes in a continuous variable either objectively or through use of a formal quantitative survey of expert views*: Present the PDF graphically and/or provide the 5th and 95th percentiles of the distribution. Explain the methodology used to produce the PDF, any assumptions made, and estimate the role of structural uncertainties.

Communicate carefully, using calibrated language

9. Be aware that the way in which a statement is framed will have an effect on how it is interpreted [6]. (A 10% chance of dying is interpreted more negatively than a 90% chance of surviving.) Use neutral language, avoid value laden statements, consider redundant statements to ensure balance (e.g. chances of dying and of surviving), and express different but comparable risks in a consistent way.

10. To avoid the uncertainty perceived by the reader being different from that intended, use language that minimizes possible misinterpretation and ambiguity. Note that terms such as "virtually certain", "probable", or "likely", can engage the reader effectively, but may be interpreted very differently by different people unless some calibration scale is provided [7].

11. Three forms of language are given in Tables 2, 3 and 4 to describe different aspects of confidence and uncertainty and to provide consistency across the AR4.

12. Table 2 considers both the amount of evidence available in support of findings and the degree of consensus among experts on its interpretation. The terms defined here are intended to be used in a relative sense to summarize judgments of the scientific understanding relevant to an issue, or to express uncertainty in a finding where there is no basis for making more quantitative statements. A finer scale for describing either the amount of evidence (columns) or degree of consensus (rows) may be introduced where appropriate, however, if a mid-range category is used authors should avoid over-using that as a 'safe' option that communicates little information to the reader. Where the level of confidence is '*high agreement much evidence*', or where otherwise appropriate, describe uncertainties using Table 3 or 4.

Table 2. Qualitatively defined levels of understanding

Level of agreement or consensus →			
	High agreement limited evidence	...	*High agreement much evidence*
	...	...	...
	Low agreement limited evidence	...	*Low agreement much evidence*

Amount of evidence (theory, observations, models) →

13. A *level of confidence*, as defined in Table 3, can be used to characterize uncertainty that is based on expert judgment as to the correctness of a model, an analysis or a statement. The last two terms in this scale should be reserved for areas of major concern that need to be considered from a risk or opportunity perspective, and the reason for their use should be carefully explained.

Table 3. Quantitatively calibrated levels of confidence.

Terminology	Degree of confidence in being correct
Very High confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

14. *Likelihood*, as defined in Table 4, refers to a probabilistic assessment of some well defined outcome having occurred or occurring in the future. The categories defined in this table should be considered as having 'fuzzy' boundaries. Use other probability ranges where more appropriate but do not then use the terminology in table 4. Likelihood may be based on quantitative analysis or an elicitation of expert views. The central range of this scale should not be used to express a lack of knowledge – see paragraph 12 and Table 2 for that situation. There is evidence that readers may adjust their interpretation of this likelihood language according to the magnitude of perceived potential consequences [8].

Table 4. Likelihood Scale.

Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

15. Consider the use of tabular, diagrammatic or graphical approaches to show the primary sources of uncertainties in key findings, the range of outcomes, and the factors and relationships determining levels of confidence.

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