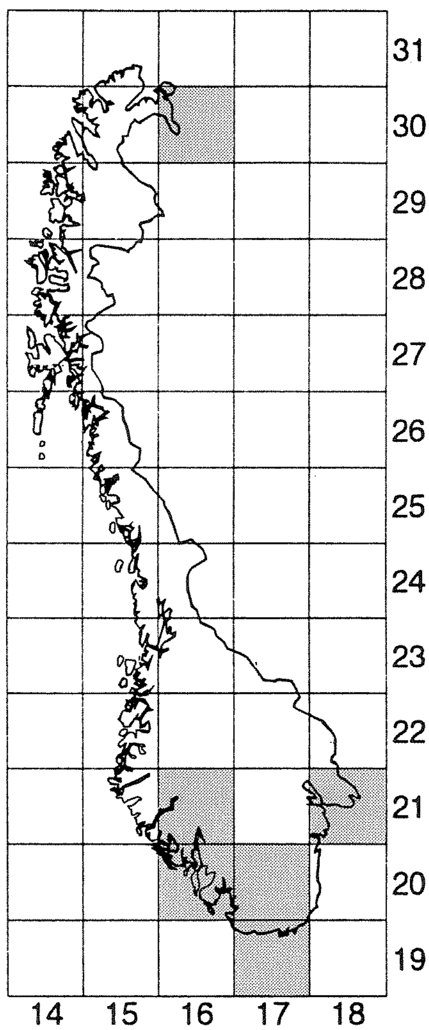
REPORT SNO 3942-98

Binding grid cells - Norway

An evaluation

NATURENS TÅLEGRENSER

Miljøverndepartementet
Fagrapport nr. 97



Norwegian Institute for Water Research

REPORT

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Title	Serial No.	Date
Binding grid cells – Norway An evaluation	3942-98	October 1998
	Report No. Sub-No. O-89210	Pages Price 16
Author(s) Arne Henriksen	Topic group Acid Rain	Distribution
	Geographical area Norway	Printed NIVA

Client(s)	Client ref.
Ministry of Environment (MD)	

Abstract

The quality of the critical load data for so-called “binding grid cells” in Norway has been checked. These are the following EMEP-grids (150km x 150 km): 16,20 16,21 16,30 17,19 17,20 and 18,21. Critical loads have been established for lakes in each 1^{o} longitude by 0.5^{o} latitude grid divided into 16 sub-grids (“NIVA grids”, 12km x 12km)). There are available data for forest soils in 720 grids and surface waters for 2305 grids. Surface waters are considered to be the most sensitive ecosystem in Norway, which is clearly indicated by the fact that for 93% of the grids with values for both ecosystems surface waters are more sensitive than forest soil. The soil critical loads do not influence the critical load percentile distributions significantly in the low range. The critical loads in Norwegian grids are well documented, especially in the most heavily affected areas in southern Norway and they compare well with the derived dose/response function for fish damage and critical load exceedance. For the “binding grid cells” there is additional lake data available to the number of “NIVA grids” in the EMEP-grid. The Birkenes grid (17,20) is the most critical grid. It covers the area of Norway most subjected to acidification, and where the earliest reliable records of fish kills and fish decline were recorded. Since this grid represents an area with the best documentation in Norway with respect fish damage and water chemistry (11% of the lakes analysed) we consider the critical load data for this grid to be the most reliable one in Norway. The lake percentiles for the binding grid cells are generally a little lower than those given by the database submitted to the CCE. This indicates that the lakes selected for the CCE-database slightly *overestimate* the critical load distribution in the grid. Thus, the critical loads are in fact lower than those reported to the CCE. *There is therefore no justification for exclusion of any ecosystem data from the Norwegian critical load database.*

4 keywords, Norwegian	4 keywords, English
1. Sur nedbør	1. Acidic deposition
2. Tålegrenser	2. Critical loads
3. Innsjøer	3. Lakes
4. Fiskeskader	4. Fish damage

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ISBN 82-577-3533-7

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Naturens Tålegrenser

Programmet Naturens Tålegrenser ble satt igang i 1989 i regi av Miljøverndepartementet. Programmet skal blant annet gi innspill til arbeidet med Nordisk Handlingsplan mot Luftforurensninger og til pågående aktiviteter under Konvensjonen for Langtransporterte Grensoverskridende Luftforurensninger (Genevekonvensjonen). I arbeidet under Genevekonvensjonen er det vedtatt at kritiske belastningsgrenser skal legges til grunn ved utarbeidelse av nye avtaler om utslippsbegrensning av svovel, nitrogen og hydrokarboner.

En styringsgruppe i Miljøverndepartementet har det overordnete ansvar for programmet, mens ansvaret for den faglige oppfølgingen er overlatt en arbeidsgruppe bestående av representanter fra Direktoratet for naturforvaltning (DN), Norsk polarinstitutt (NP) og Statens forurensningstilsyn (SFT).

Arbeidsgruppen har for tiden følgende sammensetning:

Gunnar Futsæter - NP
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Else Løbersli - DN
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Styringsgruppen i Miljøverndepartementet består av representanter fra avdelingen for naturvern og kulturminner, avdelingen for vannmiljø, industri- og avfallssaker og avdelingen for internasjonalt samarbeid, luftmiljø og polarsaker.

Henvendelse vedrørende programmet kan rettes til:

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Binding grid cells - Norway

An evaluation

Arne Henriksen

Task Force on Mapping
National Focal Centre
Norwegian Institute for Water Research

Preface

The Task Force on Integrated Assessment Monitoring (TFIAM) has asked the Coordination Centre for Effects to have the National Focal Centres to the Mapping Program “to provide more information on the background of ecosystems in grid cells which turn out to be crucial in the optimization of abatement strategies used for WGS (Working Group on Strategies) negotiations (“binding grid cells”)”.
This information should be provided “in the sense that delegates understand in a more illustrative – non-mathematical – way whether e.g. exclusion of ecosystems (or grid cells) can be justified”. Such information has been requested for 25 grids in Europe. Of these, six are located wholly or partly in Norway: 16,20 - 16,21 - 16,30 - 17,19 - 17,20 and 18,21. In this report we will summarise the mapping methodology used in Norway, and analyse the reliability of the data for the binding grid cells, especially the data quality for the Birkenes grid (17,20).

Oslo, October 1998

Arne Henriksen

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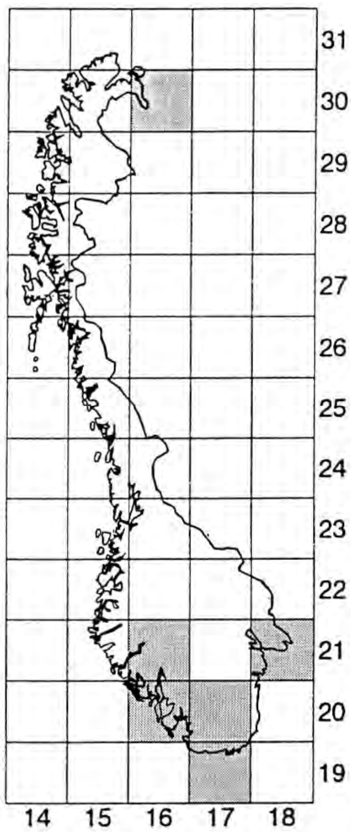
Summary

The critical load data for Europe is aggregated in the 150km x 150km EMEP-grid. (EMEP: Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe). The Task Force on Integrated Assessment Monitoring (TFIAM) has asked the Coordination Center for Effects to have the National Focal Centres (NFC's) to the Mapping Program "to provide more information on the background of ecosystems in grid cells which turn out to be crucial in the optimization of abatement strategies used for the Working Group on Strategies (WGS) negotiations ("binding grid cells")". For Norway, the "binding grid cells" are the following EMEP-grids: 16,20 - 16,21 - 16,30 - 17,19 - 17,20 and 18,21. Critical loads have been established for each 1º longitude by 0.5º latitude grid divided into 16 sub-grids ("NIVA grids"). Each grid covers about 12x12 km in southern Norway, and with decreasing grid width at higher latitudes. There are available data for forest soils in 720 grids and surface waters for 2305 grids. Surface waters are considered to be the most sensitive ecosystem in Norway, which is clearly indicated by the fact that for 93% of the grids with values for both ecosystems surface waters are more sensitive than forest soils. If we include both ecosystems, or if we include only surface waters, the calculations do not affect the results significantly. For the "binding grid cells" there is more lake data available than the number of "NIVA grids" in the EMEP-grid. We have compared percentile values for the CCE database and the lake database for critical loads of acidity. For the lower percentiles the lake database show lower values than the CCE database. Of special interest is the Birkenes grid (17,20). This grid covers the area of Norway most subjected to acidification, and where the earliest reliable records of fish kills and fish decline were recorded. Today, with present (1994) S-deposition and present leaching of nitrogen the critical load of acidity is exceeded in 92% of this grid, whereas with full N-leaching (the FAB-model) 98% of the area will be exceeded. Since this grid represents an area with the best documentation in Norway (and the world?) with respect to fish damage and water chemistry (11% of the lakes analysed) we consider the critical load data for this grid to be the most reliable one in Norway. The lake percentiles for the binding grid cells are generally a little lower than those given by the database submitted to the CCE. This indicates that the lakes selected for the CCE-database slightly *overestimate* the critical load distribution in the grid. Thus, the critical loads are in fact lower than those reported to the CCE. *There is therefore no justification for exclusion of any ecosystem data from the Norwegian critical load database*.

1. Mapping methodology - Norway

1.1 Introduction

A critical load for an ecosystem is defined as "the deposition below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt, 1988). Over the past years methodologies for computing critical loads have been elaborated for acidification and eutrophication and compiled by the Mapping Programme under the Working Group on Effects which operates under the UN/ECE Convention of Long-range Transboundary Air Pollution (LRTRAP) (UN/ECE, 1996). On a national level, critical load data are compiled and submitted to the Coordination Center for Effects (CCE), located at the Dutch National Institute for Public Health and the Environment (RIVM). RIVM collates and merges these national data into European maps and databases, which are approved by the Mapping Programme and the Working Group on Effects before being used in emmission reduction negotiations under the LRTAP Convention.



Critical loads of sulphur was used in the negotiations of the 1994 Second Sulphur Protocol (UN/ECE 1994), and the concept is now being used in the negotiations for the new Nitrogen Protocol. The critical load data for Europe is aggregated in the 150km x 150km EMEP-grid. (EMEP: Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe). During the preimi-nary assessments carried out by IIASA (International Institute for Applied Systems Analysis) it turned out that several EMEP-grids determined the necessary emmission reductions for all European countries. These grids have been named "binding grid cells". The Task Force on Integrated Assessment Monitoring (TFIAM) has therefore asked the Coordination Centre for Effects to have the National Focal Centres to the Mapping Program " to provide more infor-mation on the background of ecosystems in grid cells which turn out to be crucial in the optimi-zation of abatement strategies used for the Working Group on Effects (WGS) negotiations". For Norway, the "binding grid cells" are the following EMEP-grids: 16,20 16,21 - 16,30 - 17,19 - 17,20 and 18,21 (see Figure 1).

Figure 1. The EMEP grid cells covering Norway.
The "binding grid cells" are shaded.

1.2 Receptors mapped:

Thre receptors have been mapped for Norway: surface waters, forest soils and vegetation.

1.2.1 Surface Waters

Calculation Methods: The Steady State Water Chemistry (SSWC) method has been used to calculate critical loads of acidity and critical load exceedance for sulphur and for present exceedance for sulphur and nitrogen, using a variable ANC_{limit} (Henriksen et al. 1995).

Grid Size: Each 1º longitude by 0.5º latitude grid was divided into 16 sub-grids ("NIVAgrids"), each covering about 12 x 12 km in southern Norway, and with decreasing grid width at higher latitudes. The land areal covered by each of the 2305 grids has been calculated.

The chemistry of surface water within a sub-grid was estimated by comparing available water chemistry data for lakes (and rivers if no lakes available) within each grid. The chemistry of the lake that was judged to be the most typical was chosen to represent the grid. If there were wide variations within a sub-grid, the most sensitive area was selected if it amounted to more than 25% of the grid's area. Sensitivity was evaluated on the basis of water chemistry, topography and bedrock geology. Geology was determined from the geological map of Norway (1:1,000,000) prepared by the Norwegian Geological Survey. Mean annual runoff data is from runoff maps prepared by the Norwegian Water and Energy Works. The database was revised in November 1996.

Precipitation: A weighted average total deposition value for each so-called NILU-grid (Norwegian Institute for Air Research) (a 3 by 3 subdivision of an EMEP-grid) has been calculated from ambient air concentrations and wet deposition taking land use data (coverage of different receptors) into account (Tørseth and Pedersen 1994). Weighted means for the period 1988-1992 was used. The deposition values for each of the surface water grids (see above) was estimated from the NILU-grid data base.

Data Sources: National regional lake surveys and monitoring programs.

1.2.2 Forest Soils

Calculation Method: The MAGIC (Model of Acidification of Groundwater in Catchments) dynamic model was used to produce maps for critical loads of acidity and exceedance for sulphur and nitrogen to forest soils (Cosby et al. 1985a, 1985b). Criterion is the Ca/Al molar ratio 1.0 in upper 60-cm soil solution.

Grid Size: The same grid system as for surface water was used. Of these 706 grids are in productive coniferous (spruce, pine) and deciduous (birch) forests. The remaining grids cover unproductive forests and non-forested areas, for which critical loads for forest soils cannot be calculated.

Data Sources: National monitoring data.

Soil: The calculations are based on data from the NIJOS (Norwegian Institute of Land Inventory) forest monitoring plots on a 9 x 9 km grid and on the surface water data base referred to above. All input data are aggregated to the 12km x 12km grid net. The NIJOS soils data are from areas in productive spruce and pine forests. A soil pit was objectively located within the representative vegetation type five meters from the plot centre in the 9km x 9km grid. The soil pit was dug to at least 50 cm where possible. Soil profile samples were taken and analysed according to standard procedures.

1.2.3 Critical Loads for Nutrient Nitrogen - Vegetation

Critical loads for nutrient nitrogen for vegetation has been estimated for Norway using empirically derived values for vegetation types. The vegetation types are taken from a 3x3 km network of forest sample plots as recorded by the National Forest Inventory. The same grid system as for water and soil (see above) was used. Only areas under the coniferous forest line are included. The most sensitive vegetation types are presumably ombrotrophic bogs and Calluna heath. A critical load value of 5 kg N ha^{-1} yr^{-1} has been used for ombrotrophic bogs, a value of 15 kg N ha^{-1} yr^{-1} for Calluna heath and a value of 20 kg N ha^{-1} yr^{-1} for other forest types. The critical load map reflects the occurrence of Calluna heath on the West Coast, whereas the bog areas occur throughout Norway. Alpine areas are not included in the data set and thus do not appear on the map (Esser and Tomter, 1996).

2. Characteristics of ecosystems in the "binding grid cells"

Fish populations started to decline as early as in the 1910's-1920's, in Norway, but the link between the fish decline and the increasing acidity of precipitation was established as late as around 1970. Since then, acidification of freshwaters has been considered as Norway's most serious environmental problem. The Birkenes grid (17,20) covers the most acidified areas of Norway, because of highly sensitive waters and high acidic deposition.

The calculation of critical loads for various receptors (surface water, forest soils) is an approach which seeks to link emission abatement strategies to the capacities of ecosystems to withstand and buffer the effects of acidic deposition. Data from the "1000 lake survey" carried out in Norway in 1986 (Henriksen et al. 1988) were used to derive a dose/response function, giving the probability of damage to fish populations as a function of the critical load exceedance by means of a logistic regression model for fish damage (Henriksen et al. 1999 submitted). A corresponding function based on a fish damage database (brown trout, Arctic char and perch) and the national critical load database for Norway compared well with the derived dose/response function. When the critical load is not exceeded there is only a very small probability that the fish population will be damaged, but when the critical load is exceeded the chance of damage increases with the amount of exceedance. At critical load the probability of damage to fish populations is about 20%, which is rather precise in connection with risk analyses.

Since surface water is the most sensitive ecosystem in Norway (see Figure 2), most work has been focussed on this ecosystem. Therefore, national maps and calculations for exceeded areas and analyses for effects of future deposition scenarios for Norway has been based on the surface water database.

The CCE calculations for Norway, however, also include the soil data. We have compared the calculations of the critical load percentiles for each EMEP-grid for both lakes and soils and for lakes only (Table 1). The critical load values for the percentiles are very similar in both cases, the soil data does not influence the critical load distributions significantly in the low range. This is expected, because the critical loads for soils are higher than those for surface water for 93% of the grids (Figure 2).

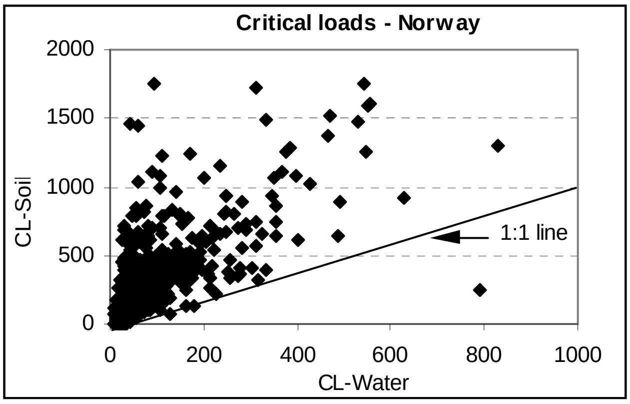


Figure 2. Comparison of critical loads for surface water and for forest soils in "NIVA grids" (720) where both ecosystems are present.

Table 1. *Two, five and 25 percentiles for critical loads of acidity based on the Norwegian critical load database for two ecosystems (lakes and soil) and for one ecosystem only (lakes) for binding grid cells. Unit: keq/ha/yr. Data provided by CCE.*

	2 %			*5 %*			*25 %*		
EMEP-grid	Lakes + soil	Lakes only	Difference percent	Lakes + soil	Lakes only	Difference percent	Lakes + soil	Lakes only	Difference percent
1621	109	114	-4,6	220	177	19,5	378	358	5,3
1622	120	120	0,0	154	154	0,0	269	269	0,0
1630	230	230	0,0	230	230	0,0	322	283	12,1
1719	163	163	0,0	163	163	0,0	259	259	0,0
1720	99	99	0,0	124	124	0,0	175	166	5,1
1821	190	159	16,3	284	284	0,0	424	365	13,9

Each EMEP grid contains a number of "NIVA grids" depending of the size of the grid. For each "NIVA grid" we have assessed representative water chemistry by selecting a lake located in that grid (see above). Thus, a number of lakes corresponding to the number of "NIVA grids" in an EMEP-grid has been selected to represent that EMEP grid. These lakes were largely selected from our national lake surveys carried out in 1986 and 1995, representing ca. 2000 lakes all over Norway (Henriksen et al. 1998). We have summarised the number of "NIVA grids" and the number of lakes available for each of the binding EMEP-grids together with the land area covered by each EMEP-grid (Table 2). For all EMEP-grids there are more lakes available than "NIVA grids", and for the Birkenes grid (17,20) we have available a total of 499 lakes (11% of the lake population > 0.04 km^2 in the grid) to cover 112 "NIVA grids".

We have further calculated percentile values for the CCE database and our lake database for critical loads of acidity and compared them (Figure 3). For the lower percentiles the lake database show lower values than the CCE database. Of special interest is the Birkenes grid (17,20) This grid covers the area of Norway most subjected to acidification, and where we had the earliest reliable records of fish kills and fish decline. Today, with present (1994) S-deposition and present leaching of nitrogen the critical load of acidity is exceeded in 92% of the grid, whereas with full N-leaching (FAB-model) 98% of the area will be exceeded. *Since this grid represents an area with the best documentation in Norway (and the world) with respect fish damage and water chemistry (11% of the lakes analysed) we consider the critical load data for this grid to be the most reliable one in Norway*. The lake percentiles are generally a little lower than given by the database submitted to the CCE, indicating that the lakes selected for the CCE-database slightly *overestimate* the critical load distribution in the grid i.e. *the critical loads are lower than those reported to the CCE.*

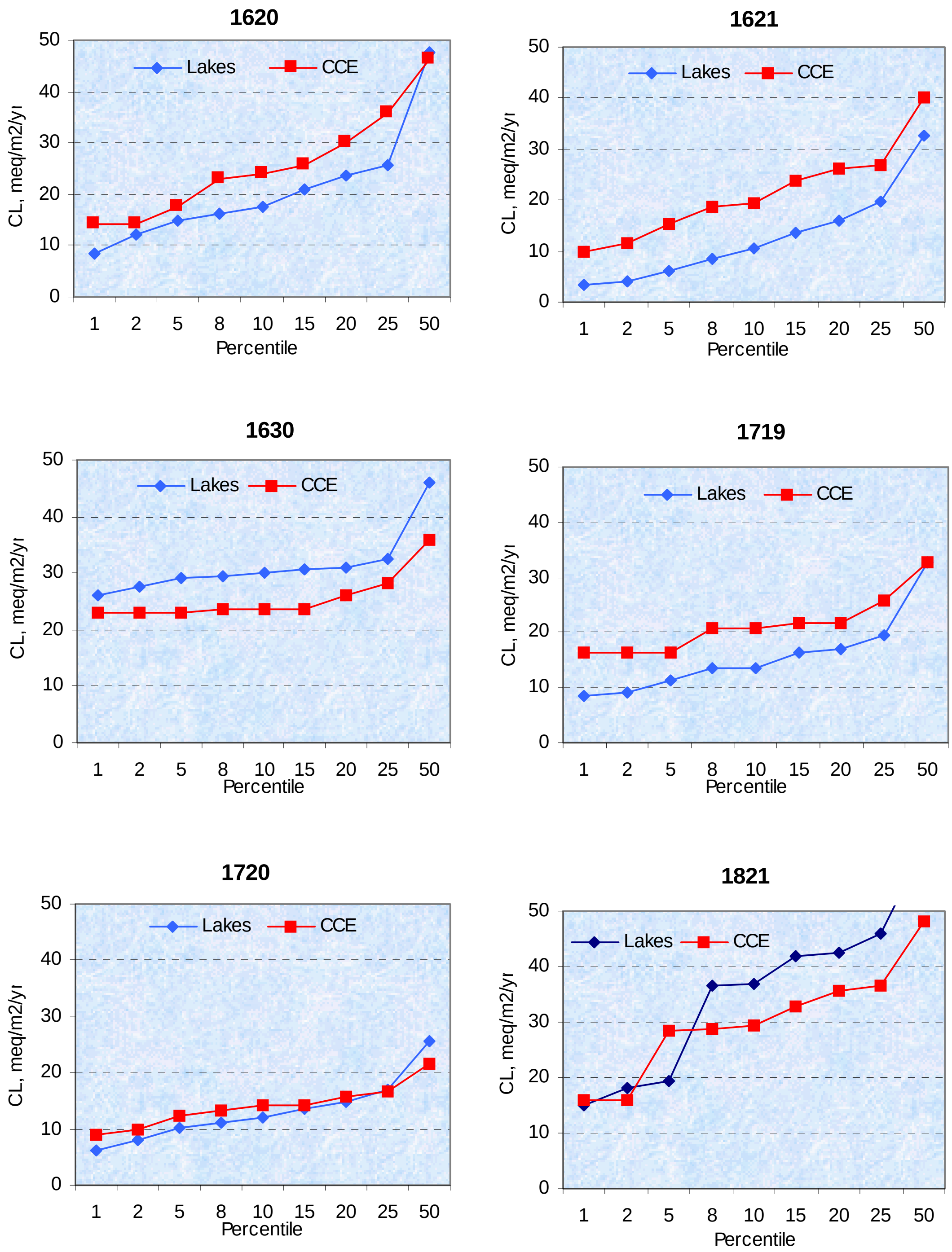


Figure 3.. Percentiles for critical loads of acidity (CLA) for 6 binding EMEP-grids based on the Norwegian critical load database for lakes (CCE) and for the lake database (Lakes) based on the national lake surveys in 1986 and in 1995. The lake database was used for the critical load assessments for Norway.

Table 2. *Characteristics for binding grid cells. Column 2: No of lakes in lake database in each EMEP-grid. Column 3: No. of values ("NIVA grids" in each EMEP-grid) in CCE database, Column 4: total land area of each EMEP-grid.*

EMEP -grid	No. of lakes	No. of "NIVA grids"	Land area, km^2
1620	91	76	10203
1621	133	121	21818
1630	27	22	2123
1719	75	20	2917
1720	499	112	22293
1821	68	51	7917

3. Conclusions

- Freshwater is the ecosystem most sensitive to acidic deposition in Norway.
- The soil critical loads do not influence the critical load percentile distributions significantly in the low range.
- The critical loads in Norwegian grids are well documented, especially in the most heavily affected areas in southern Norway.
- The national critical load database for Norway compared well with the derived dose/response function for fish damage and critical load exceedance.
- When the critical load is not exceeded there is only a small probability that the fish population will be damaged, but when the critical load is exceeded the chance of damage increases with the amount of exceedance
- At critical load there is about 20% risk of fish damage (brown trout, Arctic char and perch).
- There is no justification for exclusion of any ecosystem data from the Norwegian critical load database.

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UN/ECE 1996. *Manual on Methodologies and Criteria for Mapping Critical Levels/Loads and geographical areas where they are exceeded*. UN/ECE Convention on Long-range Transboundary Air Pollution, Federal Environmental Agency (Umweltbundesamt), Texte 71/96, Berlin.

Appendix A. Letter from Coordination Center for Effects to the National Focal Centers to the Mapping Program

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research for
man and environment
RIJKSINSTITUUT VOOR VOLKSGEZONDHEID EN MILIEU
NATIONAL INSTITUTE OF PUBLIC HEALTH AND THE ENVIRONMENT

To: NFCs to the Mapping Program

Bilthoven	: 24 September 1998
Our reference	: 367/98 MNV JPH/pds
Your reference	: -
Subject	: request for background ecosystem information in "binding grid cells"
Faxnumber	: + 31.30.274 4435

Dear colleague,

Following a request to the CCE by the TFIAM chairman, you are kindly requested to provide more information on the background of ecosystems in grid cells which turn out to be crucial in the optimization of abatement strategies used for WGS negotiations ("*binding grid cells*").

The CCE is facilitating this request within the remit of its clearing house function as described in the CCE mandate.

Binding grid cells, often happen to include ecosystems with critical loads for acidification and/or eutrophication, which are low to the extent that *sufficient* emission reduction alternatives can not be identified anywhere in Europe. Ultimately, if no mathematical solution is found, a decision of the modellers/negotiators is required to relax the constraints in a grid cell, in order to ensure a solution.

While the identity of these grid cells may vary with the kind of optimization, the TFIAM chairman wishes to anticipate discussions in the TFIAM (or WGS) on the actual ecosystems in binding grid cells.

Therefore, NFCs are requested to provide background information on the characteristics of low critical loads in the sense that delegates understand in a more illustrative – non mathematical - way whether e.g. exclusion of ecosystems (or grid cells) can be justified. For example, background information could include details on the economic, recreational or juridical (e.g. national park, monument, submission under the habitat directive) status of ecosystems associated with the critical loads computed in a grid cell.

At this time, the TFIAM chairman is seeking further information via the NFC network of the Mapping Program responsible for the assessment of critical loads, in particular for the following EMEP 150km x 150 km grid cells:

(13,13) in Ireland
(14,13) in Ireland
(17,13) in UK
(18,13) in UK
(18,14) in UK
(17,6) in Spain
(20,15) in Netherlands / Germany / Belgium
(20,16) in Netherlands / Germany
(20,17) in Netherlands / Germany
(24,13) in Switzerland / Italy
(24,14) in Austria / Germany / Italy / Switzerland / Liechtenstein
(25,13) in Italy
(25,25) in Belarus / Russian Fed.
(31,22) in Moldova / Ukraine
(16,30) in Russian Fed. / Finland / Norway
(16,20), (16,21), (17,19), (17,20) all in Norway
(18,21) in Norway / Sweden
(26,17) in Slovak Rep. / Austria / Hungary / Czech Rep.
(26,18) in Slovak Rep. / Czech Rep.
(27,18) in Slovak Rep. / Hungary
(27,19) in Slovak Rep. / Hungary / Ukraine

I trust that you make sure to supply this information to the TFIAM, WGS and WGE *representative of your own country*. In addition please address the requested information to the chairman of the TFIAM via the CCE, who can then make use of it – as appropriate – in its reporting to the WGS.

Please don't hesitate to contact the TFIAM chairman or the CCE if you need any further information.

Yours sincerely,

Prof. Jean-Paul Hettelingh
Head, CCE

cc.:
K.Bull, Chairman WGE
H.D.Gregor; Chairman TFM
R.Maas, Chairman TFIAM
L.Björkbom, Chairman WGS
R.Chrast, UN/ECE-Secretariat
H. Wuester, UN/ECE-Secretariat

Antonie van Leeuwenhoeklaan 9, P.O. Box 1, 3720 BA BILTHOVEN, The Netherlands. Telephone + 31 30 2749111 Telex 47215 rivm nl. Telefax + 31 30 2742971

Appendix B. Naturens Tålegrenser - Oversikt over utgitte rapporter

1 Nygaard, P. H., 1989. Forurensningers effekt på naturlig vegetasjon en litteraturstudie. Norsk institutt for skogforskning (NISK), Ås.

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