Status Report

Strategies for reducing sulfur dioxide emissions in Europe

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Background paper prepared for the UN/ECE Task Force on Integrated Assessment Modelling, June 3-5, 1992, Bilthoven, the Netherlands.

SR-92-08
July 27, 1992

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STRATEGIES FOR REDUCING SULFUR DIOXIDE EMISSIONS IN EUROPE

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Report to:
The UN/ECE Task Force on Integrated
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Foreword

Since 1984, IIASA's integrated model for the assessment of acidifying emissions in Europe (RAINS) has been developed. It is now rather complete in terms of the air pollutants covered and the options to derive abatement strategies. The model is currently being used to assist negotiations under the Convention on Long-range Transboundary Air Pollution overseen by the United Nations Economic Commission for Europe (UN-ECE, Geneva). On request of the Task Force on Integrated Assessment Modelling, a UN-ECE working group, RAINS was used to explore the costs and environmental impacts of several scenarios for the control of future sulfur dioxide emissions in Europe. This Status Report contains 11 scenarios for reduction of emission of SO_2 in Europe, which were presented and discussed at the Task Force meeting in June 1992 and will be used as background for further discussions on a new Sulfur Protocol. These scenarios show the wide range of options that can be analyzed with RAINS. The RAINS model not only allows for straightforward assessment of countries' current reduction plans, but can also derive cost-effective strategies that are based on environmental considerations (critical loads and target loads) and take into account both location of the emitting sources and their control costs. The report gives a representative overview of the capability of IIASA' RAINS model for the analysis of pollution control strategies in Europe.

Peter E. de Jánosi
Director

Abstract

Based on the Regional Acidification Information and Simulation (RAINS) model the paper explores the following strategies to reduce sulfur emissions in Europe:

* Current Reduction Plans and Maximum Technically Feasible Reductions,
* a reduction of the difference between the deposition in 1990 and the 5 percentile critical loads by 30%,
* achievement of target loads based on the 5 percentile critical loads multiplied by a factor 1.5, 2.0 and 2.5,
* achievement of target loads based on the 50 percentile critical loads,
* reductions based on minimum marginal abatement cost of 2500 DM ton SO_2, combined with an international allotment of the remaining money of 0.2% of GDP,
* attainment of national target loads submitted by a number of countries.

These strategies are evaluated on the basis of: the national emissions levels in the year 2000, the relative emission reductions (compared the year 1980), the annual costs of pollution control measures and resulting sulfur deposition in relation to the critical loads.

Key words: acid rain, sulfur deposition, critical loads, Europe, abatement strategy, cost-effectiveness, sulfur emissions, ecosystems, costs

Acknowledgements

Computations of the atmospheric transport of pollutants in this paper are based on the results of the EMEP/MSC-W project at the Norwegian Meteorological Institute, Oslo. The maps of critical loads and target loads used were established by the Coordination Center for Effects (CCE) at the National Institute of Public Health and Environmental Protection (RIVM), Bilthoven, the Netherlands. The financial support from the Dutch Ministry for Public Housing, Physical Planning and Environment (VROM) is gratefully acknowledged.

Contents

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1. INTRODUCTION

Currently, within the framework of the UN/ECE Convention on Long-Range Transboundary Air Pollution, negotiations are in progress on a new protocol to control sulfur dioxide emissions in Europe. The present protocol calls for all signatories to uniformly reduce their SO_2 emissions by 30% compared to the year 1980 by 1993. A major new element of the current negotiations is the intention to apply an effect-oriented approach by basing the extent of emission reductions on the susceptibility of natural ecosystems to acid deposition. Hence, emission reduction strategies should account for the so called 'critical loads': the maximum exposure levels that can be tolerated by sensitive ecosystems without damage. Generally, flat rate reductions are not cost-effective in reaching regionally varying deposition targets.

The objective of this paper is to analyze the costs and environmental impacts of a number of strategies that are presently being discussed. The paper serves as a background document for the UN/ECE Task Force Meeting on Integrated Assessment Modelling (3-5 June 1992, Bilthoven, the Netherlands). The paper makes use of an integrated assessment model which links information on future energy use with data on emission coefficients, costs and effects of pollution control strategies, long-range atmospheric transport and the sensitivity of ecosystems. For this study the Regional Acidification Information and Simulation (RAINS) model, developed at the International Institute for Applied Systems Analysis was used (Alcamo et al., 1990).

The paper explores the following aspects of alternative sulfur abatement strategies:

* absolute emission levels in the year 2000,
* relative emission reductions (compared to the year 1980),
* annual costs of pollution control measures,
* annual costs in comparison to GDP and per capita,
* sulfur deposition and the percentage of ecosystems with sulfur depositions above critical loads.

The following strategies, or scenarios, are considered in the paper:

* current reduction plans and maximum technically feasible reductions,
* a reduction of the difference between the deposition in 1990 and the 5 percentile critical loads by 30%,
* target loads based on the 5 percentile critical loads multiplied by a factor 1.5, 2.0 and 2.5,
* target loads based on the 50 percentile critical loads,
* reductions based on minimum marginal abatement cost of 2500 DM per ton SO_2, combined with an international allotment of the remaining money of 0.2% of GDP,
* national target loads submitted by a number of countries.

In the remainder of the paper, Section 2 presents a brief description of the method and data used. Section 3 presents the results of the various abatement strategies. Concluding cross scenario comparisons are the subject of Section 4.

2. SCIENTIFIC METHOD AND DATA USED

2.1 The RAINS model

For the purpose of this study the Regional Acidification Information and Simulation (RAINS) model was used. This model was developed at the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. The RAINS model combines information on energy use and agricultural activity levels with emission coefficients for SO_2, NO_x and NH_3 to determine regional emission levels. Data on removal efficiencies of emission control technologies and costs are combined to assess the costs and emission reductions of abatement strategies. Results of the European Monitoring and Evaluation Program (EMEP), developed at the Meteorological Synthesizing Center-West (MSC-W) at the Norwegian Meteorological Institute, Oslo, are used to estimate the deposition of sulfur and nitrogen compounds. A comparison of deposition with maps of critical loads, established at the Coordination Center for Effects-West (CCE), Bilthoven, the Netherlands, allows for the evaluation of environmental impacts. In addition, dynamic simulation of the regional impacts of acid deposition on forest soils, lakes and silvicultural ecosystems is possible. The RAINS model is extensively documented in Alcamo et al. (1990).

The paper employs the latest version (6.0) of the RAINS model. Compared to the previous version the following features are new:

* the number of source regions has been increased from 27 to 38 and now includes 7 regions in the European part of the former USSR, as well as 5 sea regions that account for emissions from ships,
* the background deposition has changed since emissions from sea regions are no longer part of the uncontrolled background
* the more detailed regional structure allows using the latest version of the atmospheric transfer matrices.

The data for the regions in the former USSR is based on a detailed analysis carried out by local experts collaborating with IIASA. Finally, the RAINS database was updated to reflect the latest information on control costs (especially for process emissions), the possibilities of reducing the sulfur content in heavy fuel oil, diesel oil and solid fuels.

Principally, the RAINS model can be operated in two modes: the scenario analysis mode and the optimization mode. The scenario analysis mode allows the user to evaluate the emissions, cost, depositions and environmental impacts of specified emission control strategies derived from energy projections. The optimization mode allows to:

* minimize European-wide emission control costs subject to the condition that region-specific deposition targets are attained;
* minimize total European costs for reaching a total level of emissions,
* maximize emissions removed given a limited European-wide budget.

The first type of optimization takes into account that:

1) emissions from some source regions are more strongly deposited into certain receptor areas (grids) than into other areas,

2) some sources are cheaper to control than others.

Both other types of optimization ignore the source-receptor relationships.

2.2 Future energy use and SO_2 emissions

The RAINS model computes SO_2 emissions on the basis of historical data and projections of energy consumption, fuel characteristics and installed emission control measures. The energy consumption forecasts for the year 2000, used in this paper, are based on the official, national governmental energy policies. The forecasts are derived from publications from international organizations (IEA/OECD, 1991;UN\ECE, 1992) as available in mid March 1992.

2.3 Potential and costs of emission reductions

Regional and national potential for emission control and the associated costs are estimated on the basis of detailed data on the most commonly used emission control technologies. The following techniques have been considered for controlling SO_2 emissions: the use of low sulfur fuels, fuel desulfurization, combustion modification (such as limestone injection and fluidized bed combustion), flue gas desulfurization (wet limestone scrubbing as well as regenerative processes), and the control of industrial process emissions (e.g. through a reduction of the sulfur content in the feedstock or the application of tail gas units for Claus plants in refineries). Currently, the economic evaluation is restricted to the above typical add-on technologies; costs of structural changes, fuel switches and energy conservation are not yet included. Such changes are however the subject of present work (Amann et al., 1991).

The cost evaluation is based on the international operating experience of pollution control equipment in Europe. A free and competitive market for the exchange of emission control technology is assumed throughout Europe. The cost evaluation makes use of technology-specific and country-specific elements (Amann, 1990). Important country specific elements are the sulfur content of the fuels, annual operating hours of plants and boiler size (Amann and Sörensen, 1991).

For each emission region in the model, the cost estimates for specific fuel types, economic sectors and abatement technologies are combined with the projected pattern of energy consumption. In this way regional (national) cost curves can be computed that rank the abatement measures according to their marginal costs. Significant differences in emission control costs among countries do not only result from country specific elements such as operating hours but are also, to a significant extent, caused by differences in the structure and level of energy use.

Pollution control costs are expressed in Deutschmark (in constant prices of 1985). In order to get an impression of the relative cost burden, this paper compares pollution control costs with Gross Domestic Product in 1990 (constant prices of 1990) at purchasing power parity. This adjusts for the fact that for the same amount of money in one country one might be able to purchase more or less goods and services, depending on the price level. GDP measured at purchasing power parity gives a better estimate of the true purchasing power of countries. Data on GDP at purchasing power parity are based on OECD (1992), Vienna Institute for Comparative Economic Studies (1991) and IMF (1991). In addition, costs are expressed in DM/capita. For this purpose population data for 1990 were used (FAO, 1991; Lutz, 1992; Statistical Board of the USSR, 1991).

2.4 The atmospheric transport of pollutants

Source-receptor transfer coefficients, which relate (regional) emissions to deposition at receptor points (for each grid), are based on the acid deposition model developed within EMEP (Iversen et al., 1991). The EMEP model follows the trajectories of sulfur and nitrogen in the atmosphere over a period of several days and computes annual 'country-to-grid' transfer matrices of atmospheric long-range transport in Europe. The simulations in this paper are based on the most recent version of the EMEP model using the meteorological average conditions for five years: 1985 and 1987 to 1990.

2.5 Critical loads and national target loads

Critical loads are levels of deposition (sulfur, nitrogen or total acidity) below which, according to current scientific knowledge, no damage to sensitive ecosystems occurs

(Hettelingh et al., 1991). The RAINS model employs the most recent version of the map of critical loads for acid deposition as provided, end March 1992, by the Coordination Center for Effects (CCE) at the National Institute of Public Health and Environmental Protection (RIVM), the Netherlands. The paper restricts calculations to sulfur only.

Base-cation deposition may neutralize the impact of acidifying emissions. Data on net base-cation deposition (uptake minus deposition) have been provided by the CCE, partly on the basis of data collected by NILU (The Norwegian Institute for Air Research), in Oslo. The net base cation balance is used to arrive at corrected critical loads which form the basis of various scenarios in this paper. These corrections (compare Hettelingh et al., 1991, p.17) make use of the following formula:

$$CL(s)cor = CL(s) + sf*(BCU-BCD)$$

CL(s)cor are the critical loads for sulfur corrected for the net base cation balance, CL(s) are the original critical loads for sulfur, sf is the sulfur fraction, BCU is the base cation uptake and BCD is base cation deposition. The data made available by the CCE, however, for several grids imply that when corrected the 1 percentile critical loads become negative since the net base cation balance is sometimes negative. In those cases, after consultation with the CCE, the net base cation balance has been set to zero. Figure 1 displays the corrected map of the 5 percentile critical loads for sulfur as used in this paper.

A number of countries have made interim, preliminary national target loads for the deposition of sulfur in their countries. These target loads are ideally derived from critical loads but take into account political and socio-economic considerations as well. The national target loads used in this paper have been collected by the CCE.

This report uses figures on percentage of ecosystem above critical loads which may require some interpretation. The critical loads mapping exercise involves assigning critical loads to ecosystems in an EMEP grid. Different countries use different species/ecosystem receptors for mapping and these may occupy different areas, usually less than 100% of grid squares. Within the area approach that is currently employed to compute critical loads there are two alternatives for presenting the data for EMEP grid squares. In the 'grid area' approach, critical load data relate to receptors which are defined in terms of their percentage area cover of an EMEP square, the grid square area is 100%. In the 'ecosystem area' approach, the critical load is defined in terms of the total area of the ecosystem of interest within an EMEP grid square, the total ecosystem area is 100%.

Both approaches have disadvantages resulting from the lack of data or absence of relevant ecosystems for parts of EMEP squares. These 'missing areas' in the 'grid area' approach are assigned a critical load value equal to the highest (the least sensitive) critical load estimate in the square. In consequence, when considering 'protection' offered by, or 'damage' resulting from, a particular deposition, the grid area percentages will not necessarily reflect protection or damage of the ecosystems for which critical load estimates have been made. However, they may indicate protection/damage of the grid area itself.

Using the 'ecosystem area' approach, data is only considered for ecosystem areas for which critical loads have been estimated, the areas of non-relevant ecosystems are ignored. In consequence, a small area of receptors in one square may be afforded the same weighting as a large area in another. However, using this method it may be clearer what the receptor type is and how much of it is protected.

It should be noted that attainment of the lowest critical load affords protection to the entire ecosystem area within the grid square.

In this report the 'ecosystem area' approach is used to calculate the percentage of ecosystems in each grid cell exceeding the 5 percentile critical loads. In order to facilitate comparisons between scenarios, the percentage of ecosystems exceeding critical loads is aggregated to one country average. This is done by taking account of the percent of each grid covered by ecosystems, the grid size, and the extent to which a grid is within a country.

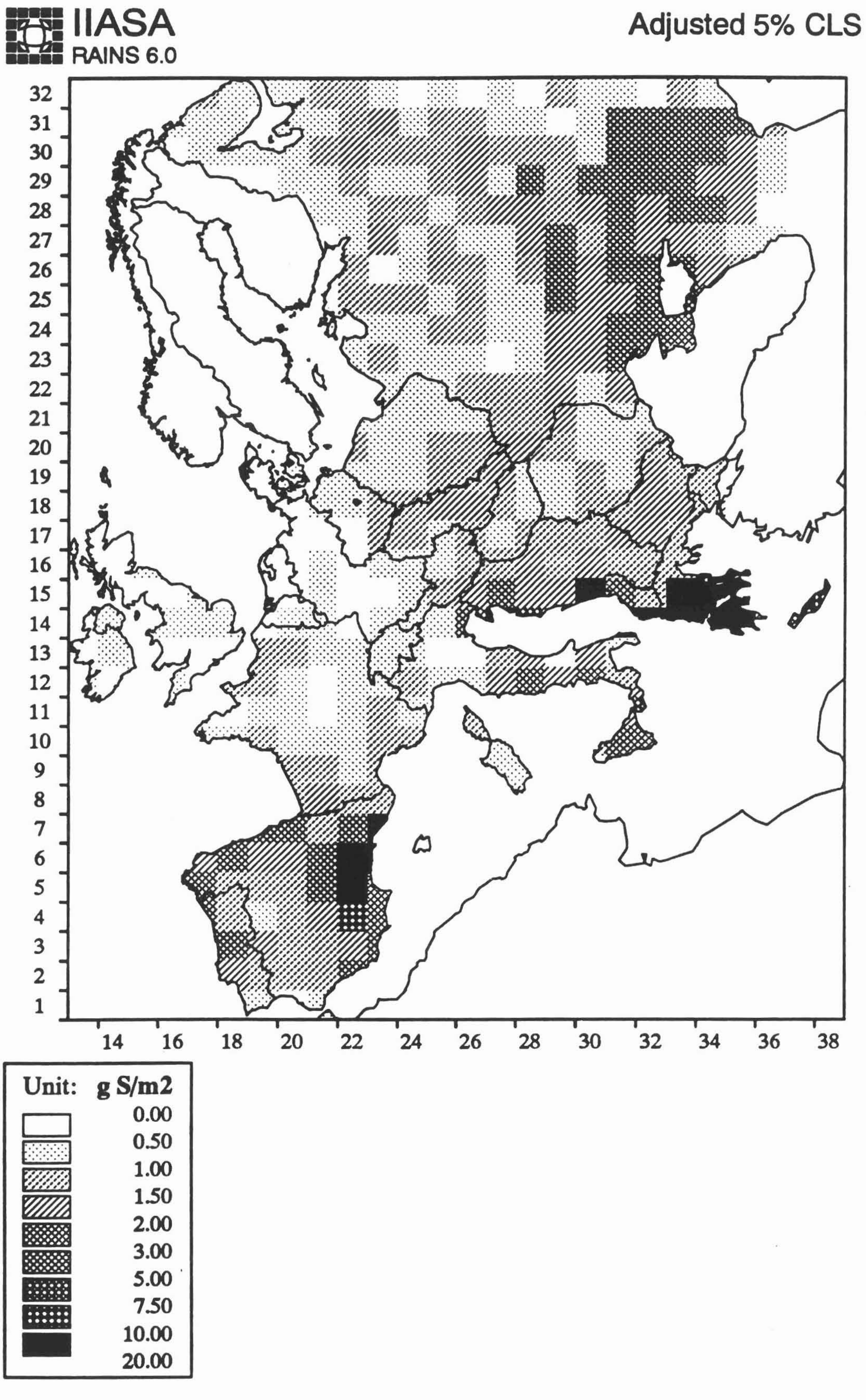


Figure 1. The map of the 5 percentile critical loads for sulfur after correction for the net base cation balance

3 RESULTS OF VARIOUS ABATEMENT STRATEGIES

3.1 The Current Reduction Plans

According to their current reduction plans, a number of countries in Europe will reduce their SO_2 emissions in the year 2000 compared to their 1980 level. Emission data on Current Reduction Plans, as presented in Table 1, are as much as possible based on recent UN/ECE information (UN/ECE, 1992). In cases where no data were reported for the year 2000, data were interpolated from other years. If no data were available at all, RAINS estimates were used on the basis of energy use projections for the year 2000 and information on national and international legislation. In most cases, however, the emission levels that are used for the year 2000 are not levels that countries formally will have to meet. By contrast, the exact emission levels will strongly depend on elements such as economic development, amount of energy use and fuel type, the number and size of new power plants being built as well as new national legislation.

According to the Current Reduction Plans (CRP) (see Tables 1A and 1B), SO_2 emissions are expected to decline by 39% over their 1980 level, bringing total SO_2 emissions down to 33520 kton in the year 2000. The associated pollution control costs amount to 15.4 billion DM/year. This is equivalent to 0.8% of the GDP (expressed at purchasing power parity), of the 12 countries involved. The average costs per capita are 20 DM/year. Averaged over Europe, 22% of the ecosystems will experience deposition levels above the critical loads.

Although the current Sulfur Protocol calls for a uniform 30% reduction over the year 1980 for all signatories, major differences among countries can be observed.
Emission reductions are high in Western and Northern Europe and, generally, are more modest in Eastern and Southern Europe. The expected reductions are uncertain in the regions of the former USSR, since it is unclear to what extent these regions will take over the 30% reduction commitment made by the former USSR. The reduction is expected to be significant in the Ukraine, caused by changes in energy consumption.

Absolute costs levels are high in Germany (both East and West) and the Ukraine. Compared to the GDP (at purchasing power parity), expected costs are high in Germany-East, Kola-Karelia, Finland and Ukraine. Per capita expenditures are high in the same countries with high expenditures compared to their GDP, but also in Austria and the Netherlands.

Although the average percent of ecosystems exceeding critical loads all over Europe is only 22%, exceedances are rather high (see Figure 2) in N-W Europe (The Netherlands, Luxembourg, Belgium) and Eastern Europe (CSFR, Poland and Bulgaria). In Southern Europe the deposition will, generally, be below critical loads (Albania, Greece, Portugal, Spain and Turkey). The current data base does not allow to perform the computation for Germany-East and -West as well as for the regions of the former USSR (except for the Baltic region) separately.

SCENARIO 1. CURRENT REDUCTION PLANS, 2000						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138[1]	-37[5]	0	.	0	0
Austria	78[2]	80	579	0.28	76	29
Belgium	430[2]	48	253	0.10	26	94
Bulgaria	520[2]	50	274	0.35	30	79
CSFR	2170[3]	30	121	0.06	8	85
Denmark	176[2]	61	65	0.05	13	35
Finland	116[2]	80	605	0.46	122	23
France	1101[4]	67	266	0.02	5	15
Germany, West	520[2]	84	3935	0.21	63	56
Germany, East	230[2]	95	2335	1.05	144	56
Greece	595[4]	-49[5]	248	0.21	24	2
Hungary	1094[1]	33	0	0.00	0	66
Ireland	240[4]	-8[5]	0	0.00	0	14
Italy	1976[4]	48	681	0.05	12	36
Luxembourg	10[1]	58	5	0.04	13	95
Netherlands	106[1]	77	869	0.23	58	95
Norway	70[1]	51	29	0.03	7	72
Poland	2900[2]	29	570	0.24	15	82
Portugal	304[4]	-14[5]	23	0.02	2	2
Romania	2592[4]	-44[5]	0	0.00	0	14

Notes:
1. Unabated emissions.
2. UN/ECE (1992).
3. 30% reduction over 1980.
4. RAINS estimate (compare Rentz et al., 1990).
5. Increase in emissions compared to 1980.

Table 1A. Current Reduction Plans for the year 2000.

SCENARIO 1. CURRENT REDUCTION PLANS, 2000						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	2145[1]	34	242	0.03	6	0
Sweden	182[6]	65[6]	306	0.13	36	25
Switzerland	60[2]	52	23	0.01	3	35
Turkey	2889[1]	-236[5]	0	0.00	0	5
UK	2552[2]	47	558	0.04	10	43
Yugoslavia	1576[1]	-21[5]	0	0.00	0	18
Baltic Sea	73[4]	0	0	.	.	.
North Sea	173[4]	0	0	.	.	.
Atlantic Ocean	316[4]	0	0	.	.	.
Mediter. Sea	12[4]	0	0	.	.	.
Black Sea	0[4]	0	0	.	.	.
Kola Karelia	448[3]	30	185	1.04	95	8
St.Petersburg	347[3]	30	0	0.00	0	8
Baltic Region	435[3]	30	162	0.20	18	12
Byelorussia	456[2]	38	91	0.10	9	8
Ukraine	1696[2]	56	2071	0.44	40	8
Moldavia	231[3]	30	97	0.24	22	8
Rem. Eur. CIS	4563[3]	30	835	0.08	7	8
TOTAL	33520	39	15428	0.12	20	22

Notes:

1. Unabated emissions.
2. UN/ECE (1992).
3. 30% reduction over 1980.
4. RAINS estimate (compare Iversen et al., 1991).
5. Increase in emissions compared to 1980.
6. Figures based on UN/ECE (1992). New official submission expects an emission level of 100 kton SO_2 in 2000 (an 80% cutback).

Table 1B. Current Reduction Plans for the year 2000.

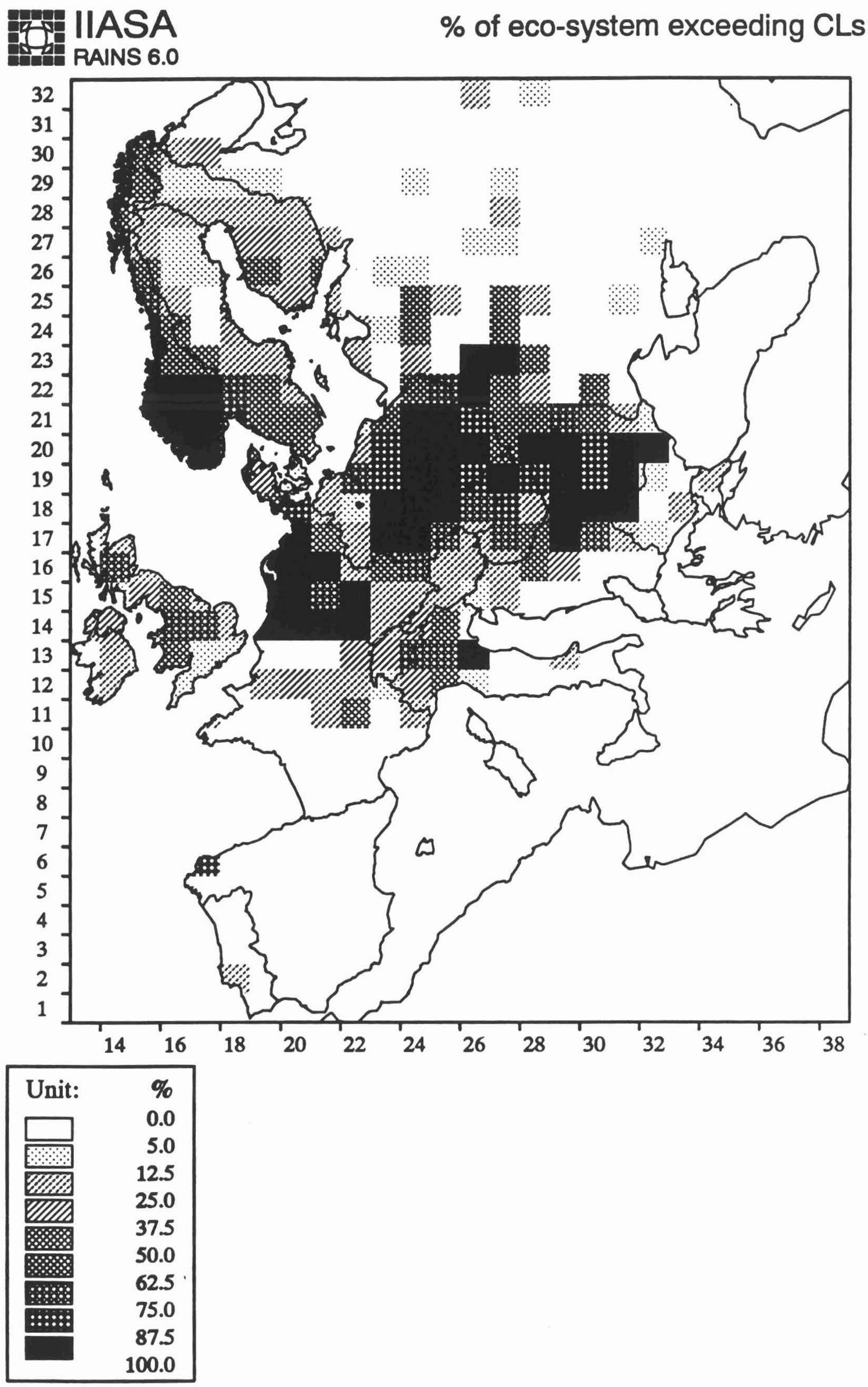


Figure 2. Current Reduction Plans (% of ecosystems with sulfur deposition above critical loads).

3.2 Maximum Technically Feasible Reductions

Tables 2A and 2B sketch the maximum feasible emission reductions that can be achieved if all emission control options considered in the RAINS model would be fully implemented. This scenario assumes the validity of the official energy projections for the year 2000. No account is taken of fuel-switches and energy conservation measures other than, or on top of, the ones assumed in the official energy projections. As a result of this scenario total European emissions would decline by 88% compared to the 1980 level and would not be higher than 6443 kton in the year 2000. The associated emission control costs would be more than 84 billion DM/year, reflecting the fact that marginal costs increase sharply if more stringent emission control measures have to be implemented. Annual costs would be some 0.68% of European GDP at purchasing power parity (PPP) or 111 DM/capita per year. This maximum control scenario leads to emission reductions in countries of up to 95%. It also assumes that the sulfur content of heavy fuel oil used by ships in the Baltic Sea, the North Sea, the Atlantic Ocean (the part in the EMEP model), and the Mediterranean Sea would be lowered to 0.6% sulfur.

Although the annual costs would be nearly six times higher than the Current Reduction Plans, 4% of the ecosystems would still experience deposition levels above critical loads (see also Figure 3). Stated differently: although expenditures would be 6 times higher than for the current commitments, the percentage of ecosystems not having deposition loads higher than critical loads, would only increase from 78% to 94%. Thereby, even the maximum technically feasible reductions, based on current abatement technology, would not be able to prevent damage to large parts of the ecosystems in several countries, especially in the Netherlands and Norway but also the United Kingdom. In most other countries, however, the percentage of ecosystems protected would be close to 100%.

SCENARIO 2. MAXIMUM TECHNICALLY FEASIBLE REDUCTIONS, 2000						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	32	68	204	.	63	0
Austria	44	89	991	0.48	131	0
Belgium	52	94	2589	0.98	264	4
Bulgaria	70	93	1260	1.59	140	0
CSFR	631	80	2780	1.38	178	3
Denmark	21	95	747	0.54	145	5
Finland	53	91	1232	0.93	248	2
France	125	96	4848	0.30	86	0
Germany, West	224	93	8492	0.46	135	6
Germany, East	226	95	2644	1.18	163	6
Greece	74	82	1511	1.26	148	0
Hungary	396	76	876	0.87	83	3
Ireland	18	92	388	0.64	111	0
Italy	167	96	5731	0.38	99	0
Luxembourg	1	96	241	2.02	639	0
Netherlands	47	90	1800	0.47	120	35
Norway	27	81	241	0.22	57	58
Poland	499	88	5552	2.32	147	1
Portugal	17	94	1066	0.81	104	0
Romania	337	81	2786	2.51	120	0

Table 2A. Maximum Technically Feasible Reductions

SCENARIO 2. MAXIMUM TECHNICALLY FEASIBLE REDUCTIONS, 2000						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	166	95	5359	0.72	137	0
Sweden	83	84	1070	0.46	125	9
Switzerland	43	66	180	0.08	27	0
Turkey	813	5	6046	1.97	108	0
UK	386	92	6281	0.43	109	14
Yugoslavia	160	88	2969	1.50	125	0
Baltic Sea	17	77	100	.	.	.
North Sea	41	76	238	.	.	.
Atlantic Ocean	76	76	434	.	.	.
Mediter. Sea	2	83	16	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	102	84	724	4.06	371	0
St.Petersburg	33	93	600	0.79	72	0
Baltic Region	67	89	983	1.21	111	0
Byelorussia	47	94	953	1.02	93	0
Ukraine	604	84	3986	0.84	77	0
Moldavia	39	88	378	0.95	87	0
Rem. Eur. CIS	703	89	8138	0.76	69	0
TOTAL	6443	88	84434	0.68	111	4

Table 2B. Maximum Technically Feasible Reductions

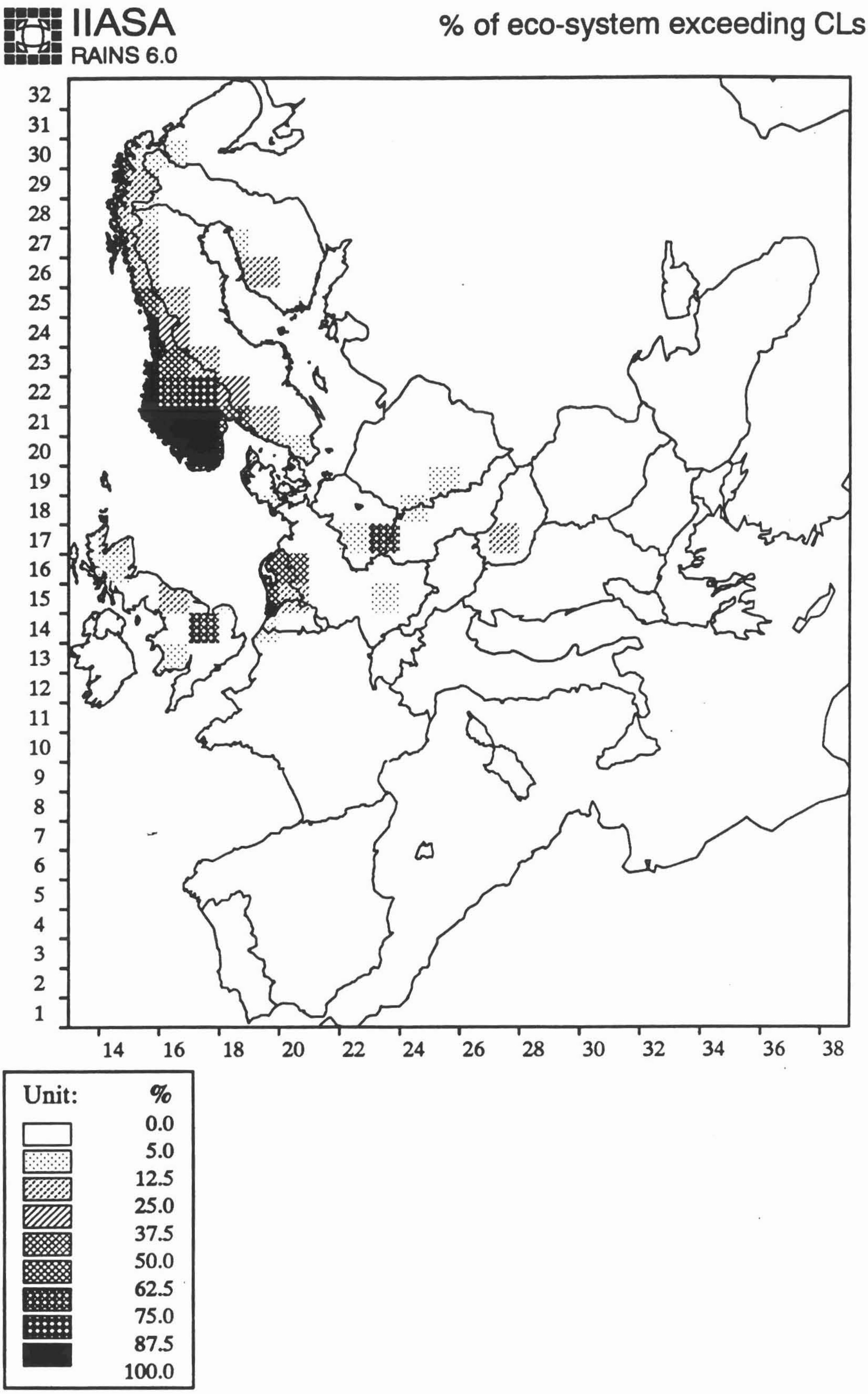


Figure 3. Maximum Feasible Reductions

3.3 Reduction of 30% of the difference between the 5 percentile critical loads and the deposition in 1990

3.3.1 Free optimization without Current Reduction Plans

This scenario (scenario 3) aims at reducing the difference between the sulfur deposition in 1990 and the 5 percentile of the critical loads by 30%. The deposition in 1990 has been calculated on the basis of official emission data insofar as available (UN/ECE, 1992; Iversen et. al., 1991) using the five-year average meteorology. The difference between these base cation corrected critical loads and the 1990 deposition was reduced by 30% and the resulting deposition data were used as target loads for this scenario.

Tables 3A and 3B show that the reduction in emissions required for this scenario is only 31%, which is less than the Current Reduction Plans. The emission control costs of this scenario are 8.2 billion DM/year. This amounts to 0.07% of the European GDP. The percentage of ecosystems remaining above critical loads is 28% (only 22% with current plans).

For most countries the reductions required are less than what they currently plan: Austria, Belgium, Bulgaria, Finland, France, Germany-W and Germany-E, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, Switzerland, Kola-Karelia, Byelorussia, the Ukraine, Moldavia and the remaining part of the CIS. Additional measures would have to be taken in the CSFR, Denmark, Hungary, Norway, Poland, Romania, Turkey, the United Kingdom, Yugoslavia, the Baltic Sea and the North Sea, and St. Petersburg.

Since the emission reduction is only modest compared to the Current Reduction Plans the percentage of ecosystems above critical loads is higher in most countries than for Current Reduction Plans. The following countries would have a lower share of ecosystems above critical loads, when compared to the currently planned reductions: Bulgaria, Hungary, Ireland, the United Kingdom and Yugoslavia.

SCENARIO 3. REDUCE DIFFERENCE BETWEEN 1990 DEPOSITION AND CRITICAL LOADS BY 30%						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	1
Austria	347	11	0	0.00	0	46
Belgium	451	46	225	0.09	23	98
Bulgaria	753	27	49	0.06	5	72
CSFR	1933	38	315	0.16	20	86
Denmark	168	63	71	0.05	14	43
Finland	269	54	192	0.14	39	31
France	1282	62	115	0.01	2	27
Germany, West	1630	49	748	0.04	12	82
Germany, East	1446	66	609	0.27	37	82
Greece	907	-127	0	0.00	0	7
Hungary	805	51	136	0.13	13	64
Ireland	171	23	0	0.00	0	12
Italy	2073	45	610	0.04	11	37
Luxembourg	12	50	1	0.01	3	95
Netherlands	223	52	373	0.10	25	95
Norway	36	75	112	0.10	26	73
Poland	2777	32	653	0.27	17	83
Portugal	322	-21	7	0.01	1	3
Romania	1904	-6	359	0.32	15	20

Table 3A. Reduction by 30% of the difference between the 1990 deposition and the 5 percentile critical loads

SCENARIO 3. REDUCE DIFFERENCE BETWEEN 1990 DEPOSITION AND CRITICAL LOADS BY 30%

	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	2859	12	24	0.00	1	0
Sweden	244	53	183	0.08	21	29
Switzerland	70	44	6	0.00	1	49
Turkey	2636	-207	182	0.06	3	8
UK	1834	62	1071	0.07	19	33
Yugoslavia	1273	2	388	0.20	16	15
Baltic Sea	40	45	61	.	.	.
North Sea	156	10	31	.	.	.
Atlantic Ocean	316	0	0	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	483	25	159	0.89	81	17
St.Petersburg	334	33	0	0.00	0	17
Baltic Region	387	38	211	0.26	24	17
Byelorussia	498	33	48	0.05	5	17
Ukraine	3995	-4	594	0.13	11	17
Moldavia	288	13	59	0.15	14	17
Rem. Eur. CIS	4857	25	694	0.06	6	17
TOTAL	37929	31	8286	0.07	11	28

Table 3B. Reduction by 30% of the difference between the 1990 deposition and the 5 percentile critical loads

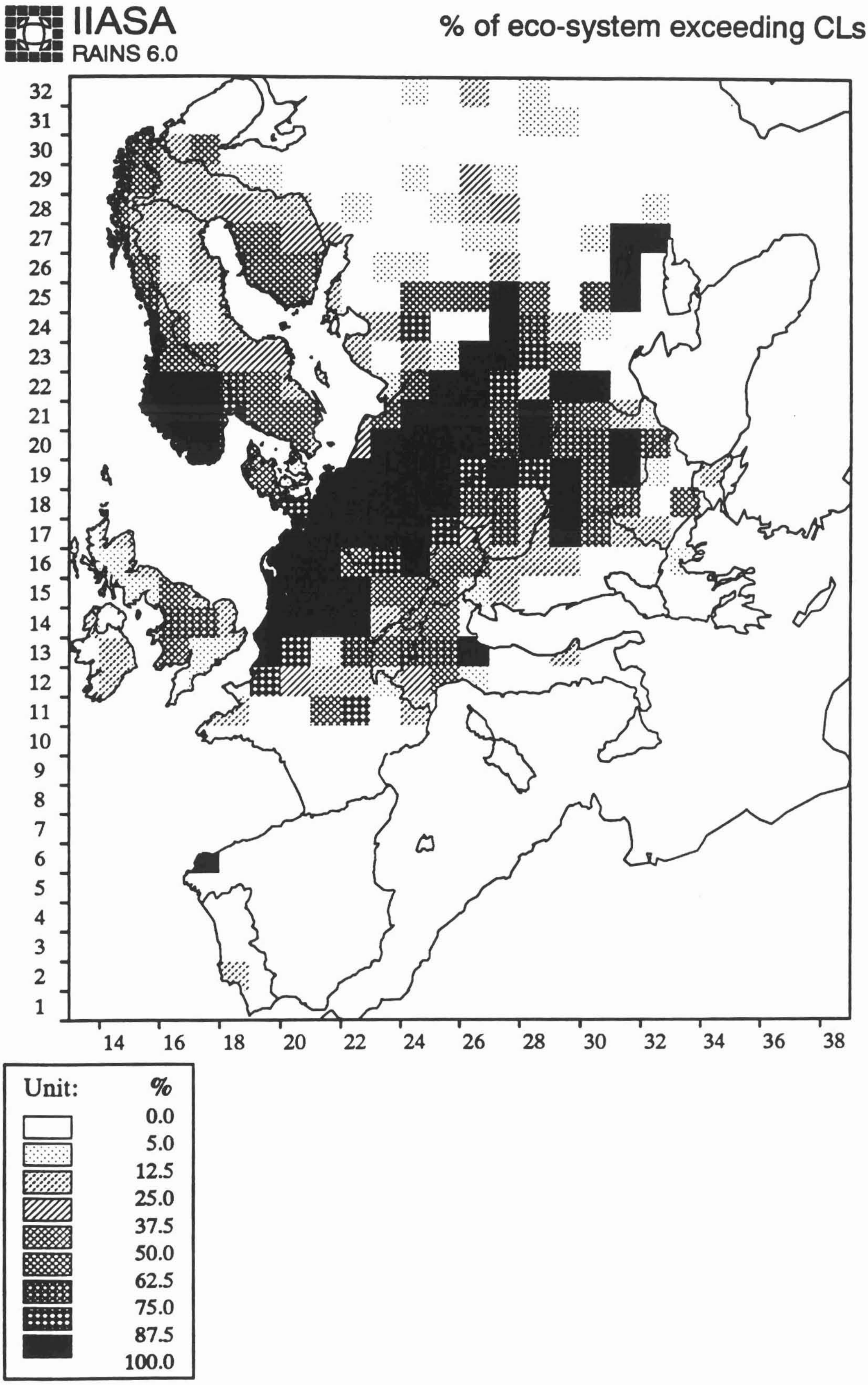


Figure 4. Reduction by 30% of the difference between the 1990 deposition and the 5 percentile critical loads

3.3.2 Reduction of 30% of the difference between the 5 percentile critical loads and the deposition in 1990 with Current Reduction Plans as minimum commitments

This scenario (scenario 4) starts from the same target loads as scenario 3: a reduction of the difference between 1990 deposition and the (corrected) 5 percentile critical loads for sulfur by 30%. In addition, however, countries are required to at least reduce their emissions according to their Current Reduction Plans.

The results of this scenario are displayed in Tables 4A and 4B. These tables show that the overall reduction in European emissions in the year 2000 would be 41% over 1980. That is only slightly higher than the 39% reduction under the Current Reduction Plans. The associated pollution control costs would be comparable to the Current Reduction Plans; annual emission control costs would be 32 billion DM per year. This equals 0.13% of European GDP (at purchasing power parity) and 21 DM/capita per year. With 20%, the average percentage of ecosystems above critical loads would be slightly smaller than the 22% resulting from current reduction plans. Under this scenario most countries would simply carry out their current reduction plans. The only countries/regions that would have to reduce emissions further are: Hungary, Ireland, Romania, the United Kingdom, Yugoslavia, and St. Petersburg. Consequently, under this scenario the environmental impacts, in terms of percentage ecosystems not exceeding critical loads, would not differ significantly from those resulting from the Current Reduction Plans. Notable exceptions are: Bulgaria, Denmark, Hungary, Romania and Yugoslavia. The spatial distribution of ecosystems exceeding critical loads is therefore more or less comparable to that of the currently planned reductions (Figure 5). In summary, compared to the Current Reduction Plans, this scenario appears to make a minor contribution towards the achievement of critical loads.

SCENARIO 4. REDUCE DIFFERENCE BETWEEN 1990 DEPOSITION AND CRITICAL LOADS BY 30% PLUS CURRENT REDUCTION PLANS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	0
Austria	78	80	579	0.28	76	27
Belgium	430	48	253	0.10	26	94
Bulgaria	520	50	273	0.35	30	63
CSFR	2170	30	121	0.06	8	85
Denmark	176	61	65	0.05	13	32
Finland	116	80	603	0.45	121	23
France	1101	67	266	0.02	5	14
Germany, West	520	84	3935	0.21	63	54
Germany, East	230	95	2335	1.05	144	54
Greece	595	-49	249	0.21	24	1
Hungary	873	47	99	0.10	9	62
Ireland	171	23	0	0.00	0	12
Italy	1976	48	681	0.05	12	36
Luxembourg	10	58	5	0.04	13	95
Netherlands	106	77	869	0.23	58	95
Norway	59	58	43	0.04	10	71
Poland	2900	29	570	0.24	15	79
Portugal	304	-14	23	0.02	2	2
Romania	2012	-12	301	0.27	13	10

Table 4A. Reduction of 30% of the difference between the 1990 deposition and the 5 percentile critical loads plus Current Reduction Plans.

SCENARIO 4. REDUCE DIFFERENCE BETWEEN 1990 DEPOSITION AND CRITICAL LOADS BY 30% PLUS CURRENT REDUCTION PLANS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	2145	34	242	0.03	6	0
Sweden	182	65	306	0.13	36	24
Switzerland	60	52	23	0.01	3	34
Turkey	2889	-236	0	0.00	0	5
UK	2384	51	678	0.05	12	42
Yugoslavia	1319	-1	309	0.16	13	13
Baltic Sea	74	-1	0	.	.	.
North Sea	174	-1	0	.	.	.
Atlantic Ocean	317	0	0	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	448	30	185	1.04	95	7
St.Petersburg	334	33	0	0.00	0	7
Baltic Region	435	30	162	0.20	18	11
Byelorussia	456	38	91	0.10	9	7
Ukraine	1696	56	2071	0.44	40	7
Moldavia	231	30	97	0.24	22	7
Rem. Eur. CIS	4563	30	835	0.08	7	7
TOTAL	32204	41	16269	0.13	21	20

Table 4B. Reduction of 30% the difference between the 1990 deposition and the 5 percentile critical loads plus Current Reduction Plans.

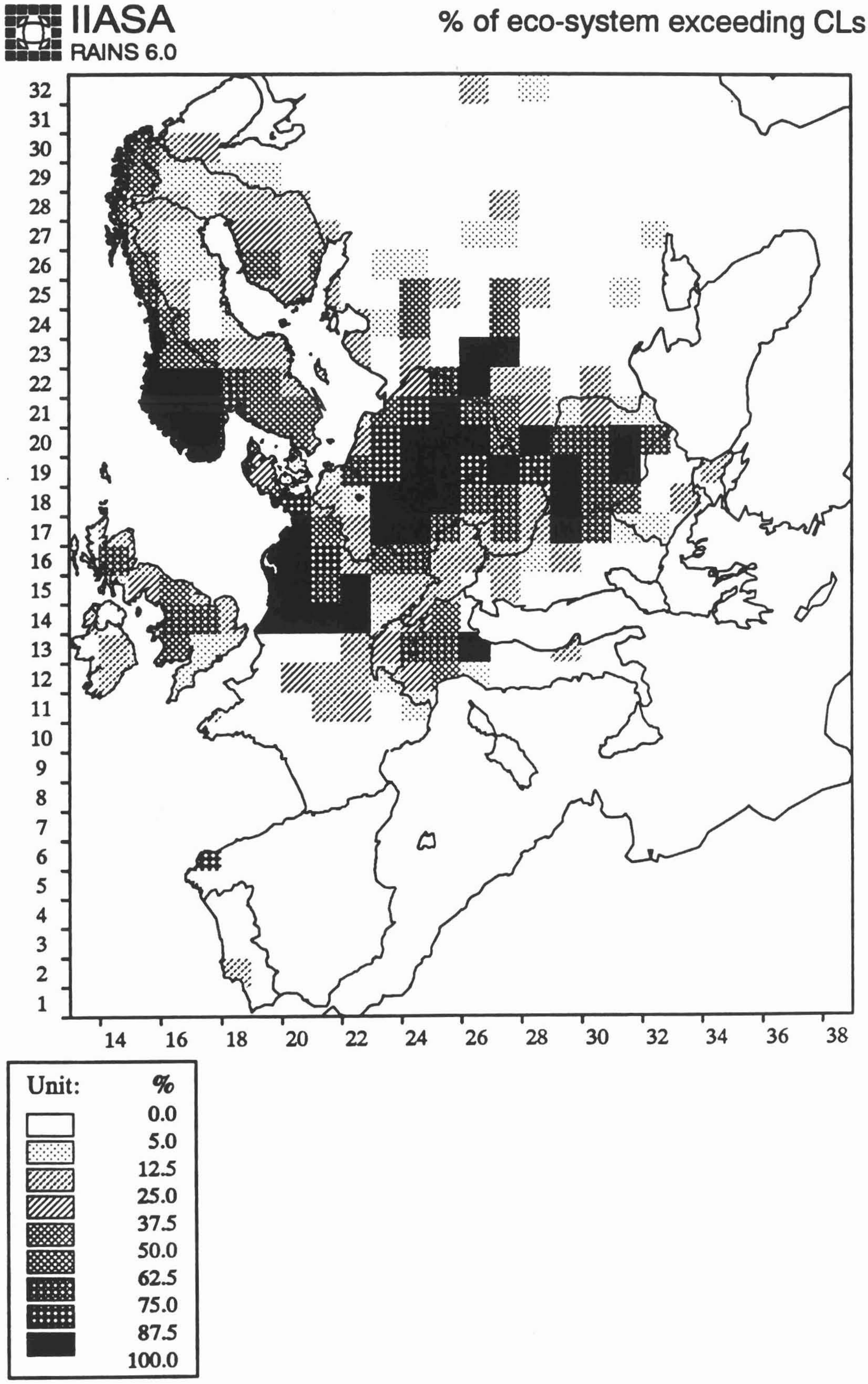


Figure 5. Reduction by 30% of the difference between the 1990 deposition and the 5 percentile critical loads plus current reduction plans.

3.4 1.5, 2.0 and 2.5 times the 5 percentile critical loads

3.4.1 Introduction

The scenarios presented in this section are all derived from the 5 percentile maps of critical loads for sulfur, taking into account the net base cation balance (see Figure 1). The resulting target loads are then multiplied by factors of 1.5, 2.0 and 2.5. Even multiplying by these factors, in 44 (for the factor 1.5) EMEP grids the target loads are not feasible. For the analysis the target loads for these grids were not taken into account in all three scenarios (1.5, 2.0 and 2.5 times the corrected critical loads). None of the three scenarios takes Current Reduction Plans as constraints.

3.4.2 1.5 times the corrected 5 percentile critical loads for sulfur

Tables 5A and 5B present the results for scenario 5 where the 5 percentile of the critical loads where multiplied with a factor 1.5. The emission reduction required under this scenario boils down to 73% over 1980. The emission control costs of this scenario would be 45.5 billion DM per year, three times more than the costs of the currently envisaged reductions. Costs would be 0.36% of GDP (at PPP) and 60 DM/capita per year. As a result only 5% of all ecosystems in Europe would experience levels of deposition exceeding critical loads.

The emission reduction required would be more than 90% in a number of countries: Belgium, Denmark, France, Germany-W and Germany-E, Italy and the United Kingdom. The costs as percent of GDP (at PPP) would be relatively high in Yugoslavia (1.34%), Kola-Karelia (2.71%), Poland (1.81%), CSFR (0.99%) and Romania (1.50%). Three countries would not have to carry any costs: Greece, Portugal and Turkey.

Even with this significant reduction in SO_2 emissions, two countries, the Netherlands and Norway, would have a relatively large share of ecosystems exceeding critical loads. In most other countries, however, the percentage of ecosystems exceeding critical loads is zero or close to zero.

SCENARIO 5. 1.5 TIMES 5 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	130	-29	6	.	2	0
Austria	46	88	819	0.40	108	0
Belgium	67	92	1822	0.69	186	7
Bulgaria	447	57	354	0.45	39	2
CSFR	656	79	1995	0.99	127	4
Denmark	22	95	762	0.55	148	5
Finland	81	86	858	0.65	172	5
France	253	92	2779	0.17	49	1
Germany, West	231	93	6707	0.36	107	7
Germany, East	237	94	2095	0.94	129	7
Greece	907	-127	0	0.00	0	0
Hungary	396	76	912	0.90	86	3
Ireland	58	74	130	0.22	37	1
Italy	354	91	3481	0.23	60	2
Luxembourg	4	83	39	0.33	103	3
Netherlands	79	83	999	0.26	67	68
Norway	34	76	119	0.11	28	60
Poland	567	86	4324	1.81	114	3
Portugal	333	-25	0	0.00	0	3
Romania	457	75	1667	1.50	72	0

Table 5A. 1.5 times the corrected 5 percentile critical loads for sulfur

SCENARIO 5. 1.5 TIMES 5 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	1280	61	835	0.11	21	0
Sweden	90	82	723	0.31	84	10
Switzerland	44	65	91	0.04	14	0
Turkey	2889	-236	0	0.00	0	2
UK	443	91	4129	0.28	72	15
Yugoslavia	167	87	2640	1.34	111	0
Baltic Sea	18	75	101	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	317	0	0	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	157	75	483	2.71	248	0
St.Petersburg	121	76	184	0.24	22	0
Baltic Region	112	82	652	0.80	73	0
Byelorussia	112	85	520	0.55	51	0
Ukraine	1052	73	2485	0.52	48	0
Moldavia	111	66	178	0.45	41	0
Rem. Eur. CIS	2456	62	2373	0.22	20	0
TOTAL	14782	73	45500	0.36	60	5

Table 5B. 1.5 times the corrected 5 percentile critical loads for sulfur

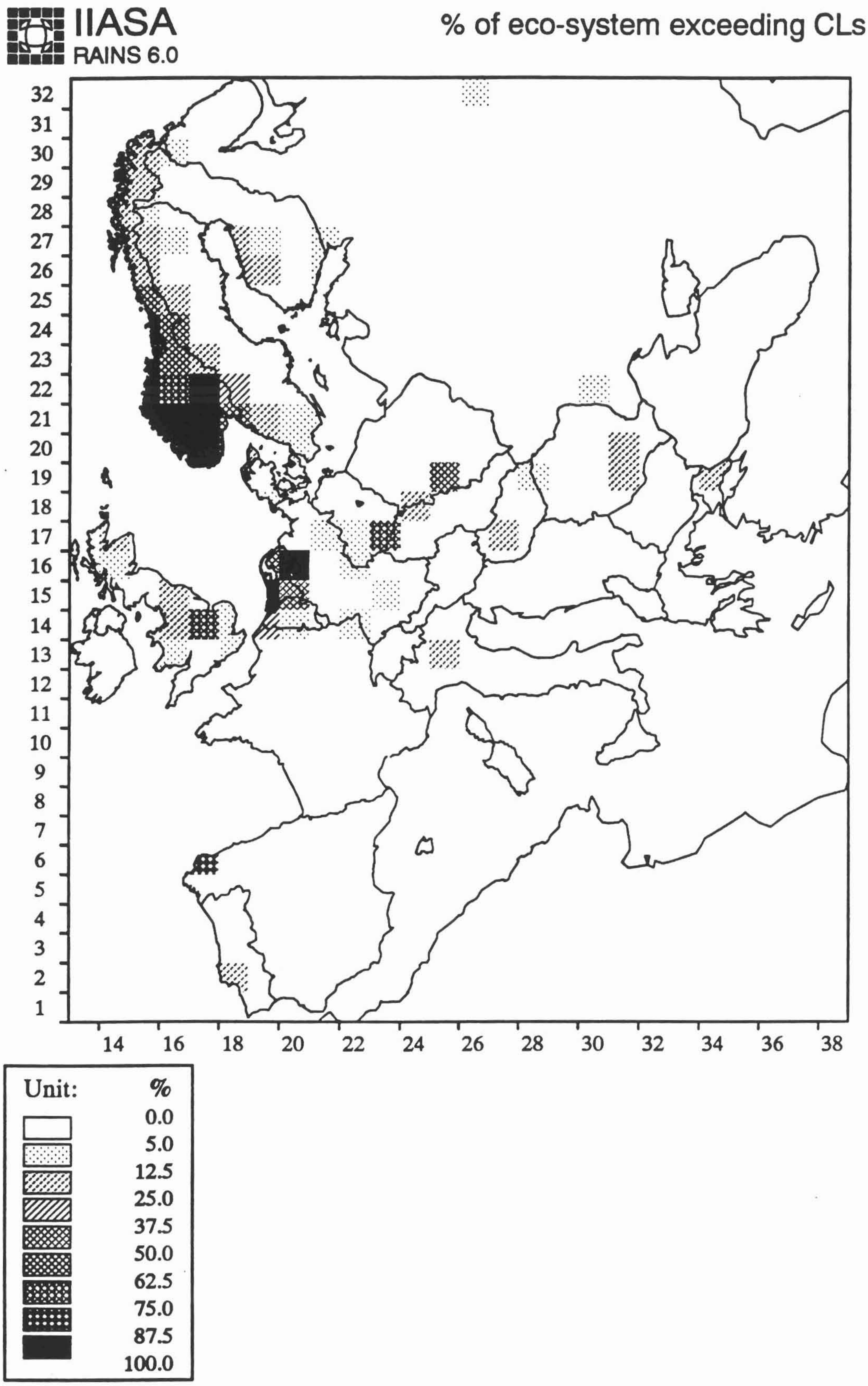


Figure 6. 1.5 times the corrected 5 percentile critical loads for sulfur

3.4.3 2.0 times the corrected 5 percentile critical loads for sulfur

Tables 6A and 6B show that if the (base cation corrected) 5 percentile of the critical loads were multiplied by a factor 2, the emission reduction required would only be 60% (compared to 75 for the previous scenario). Emission control costs would be nearly 32 billion DM/year. This equals 0.26% of GDP (at PPP) and 42 DM/per capita per year. As a result of this scenario, 9% of all ecosystems in Europe would be exposed to deposition levels exceeding critical loads.

In this scenario, emission reductions are relatively high in Northern- and Western Europe, but would still be less than Current Reduction Plans for a number of countries: Austria, Germany-East, the Netherlands, Byelorussia and the Ukraine. Annual costs would be fairly high in Kola-Karelia, Poland, Romania and the CSFR. Again in Norway and the Netherlands a large share of all ecosystems would still exceed critical loads for sulfur. In contrast to the previous scenario, the percentage of ecosystems exceeding critical loads would also be significant in Belgium and the CSFR. Generally, with a few exceptions, the share of ecosystems above critical loads would be higher than in the previous scenario in every country (compare Figure 7).

3.4.4 2.5 times the corrected 5 percentile critical loads for sulfur

If the base cation adjusted 5 percentile critical loads for sulfur would be multiplied with a factor 2.5, the average emission reduction in Europe would be 52%. With 24 billion DM/year, annual costs would be 60% higher than the costs of the Current Reduction Plans and 0.19% of GDP would be required to cover the costs. The per capita contribution would be 32 DM annually. Fifteen percent of the ecosystems in Europe would be above critical loads (compare Tables 7A and 7B and Figure 8).

Annual costs compared to GDP (at PPP) would be fairly high in Poland, CSFR, Romania, Kola-Karelia, and Germany-East. Again, in a number of countries, emission reductions required would be less than currently planned. As in the previous scenario, the percentage of ecosystems above critical loads would be very high in the Netherlands and Norway. In Belgium, Bulgaria, the CSFR, and Poland it would also be high with more than 30% of the ecosystems above critical loads.

SCENARIO 6. 2.0 TIMES 5 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	0
Austria	140	64	308	0.15	41	2
Belgium	172	79	906	0.34	92	29
Bulgaria	813	21	0	0.00	0	18
CSFR	867	72	1235	0.61	79	31
Denmark	35	92	565	0.41	110	7
Finland	87	85	817	0.62	164	9
France	350	90	1970	0.12	35	1
Germany, West	248	92	6538	0.35	104	16
Germany, East	408	90	1379	0.62	85	16
Greece	907	-127	0	0.00	0	5
Hungary	428	74	538	0.53	51	6
Ireland	115	48	48	0.08	14	1
Italy	438	88	3093	0.21	54	3
Luxembourg	7	71	19	0.16	50	6
Netherlands	193	59	463	0.12	31	95
Norway	65	54	33	0.03	8	66
Poland	1028	75	3182	1.33	84	19
Portugal	333	-25	0	0.00	0	3
Romania	668	63	1340	1.21	58	12

Table 6A. 2.0 times the corrected 5 percentile critical loads for sulfur

SCENARIO 6. 2.0 TIMES 5 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	1727	47	496	0.07	13	0
Sweden	115	78	509	0.22	59	14
Switzerland	51	60	47	0.02	7	4
Turkey	2889	-236	0	0.00	0	7
UK	544	89	3453	0.24	60	16
Yugoslavia	1205	7	507	0.26	21	5
Baltic Sea	18	75	101	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	317	0	0	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	281	56	313	1.75	160	3
St.Petersburg	121	76	184	0.24	22	3
Baltic Region	294	53	303	0.37	34	2
Byelorussia	564	24	2	0.00	0	3
Ukraine	3052	21	1200	0.25	23	3
Moldavia	158	52	146	0.37	33	3
Rem. Eur. CIS	2947	55	2008	0.19	17	3
TOTAL	21777	60	31941	0.26	42	9

Table 6B. 2.0 times the corrected 5 percentile critical loads for sulfur

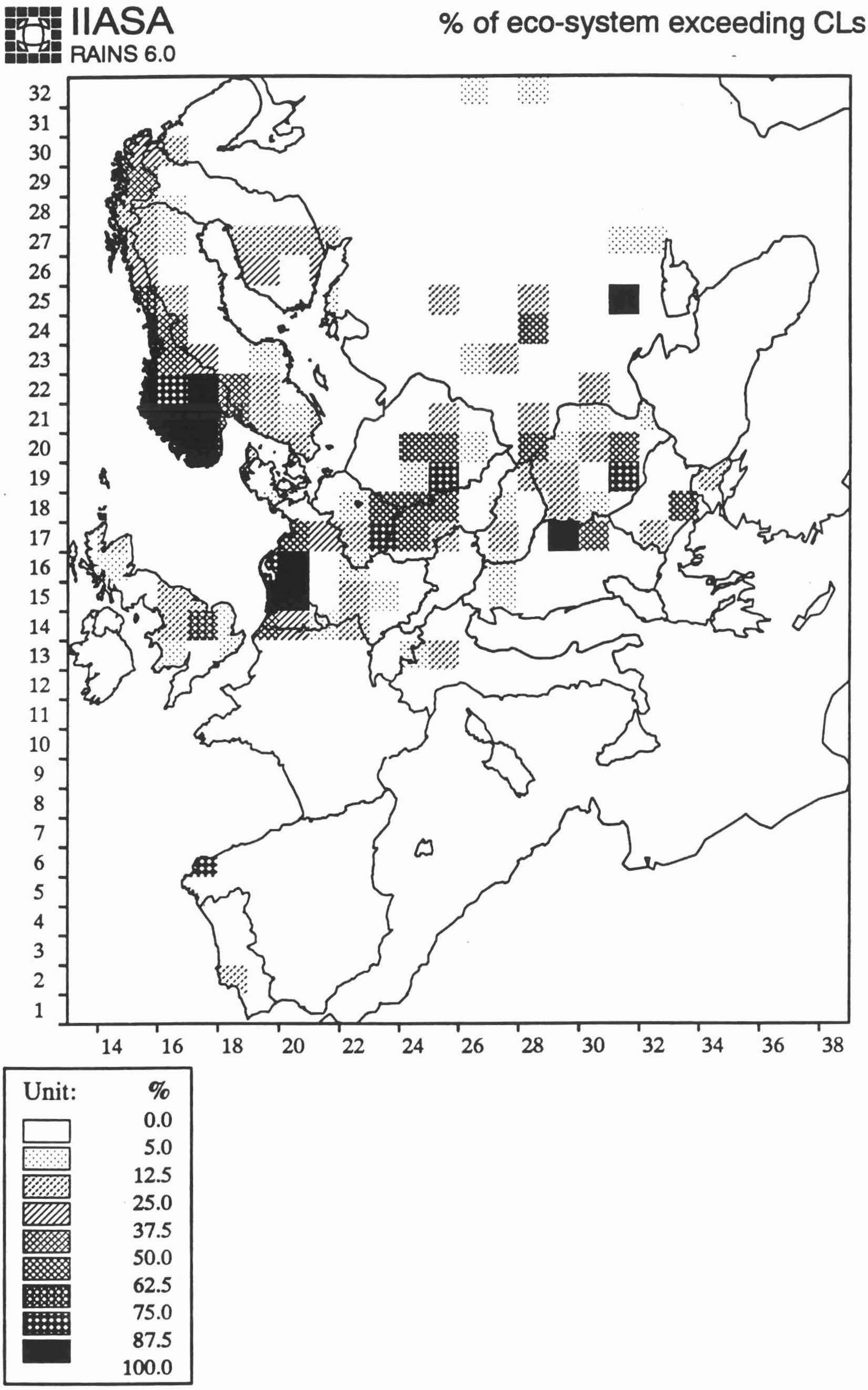


Figure 7. 2.0 times the corrected 5 percentile critical loads for sulfur

SCENARIO 7. 2.5 TIMES 5 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	0
Austria	251	36	94	0.05	12	7
Belgium	172	79	906	0.34	92	40
Bulgaria	813	21	0	0.00	0	31
CSFR	867	72	1235	0.61	79	35
Denmark	42	91	491	0.35	95	11
Finland	131	78	493	0.37	99	17
France	451	86	1545	0.10	27	2
Germany, West	402	87	5011	0.27	80	24
Germany, East	412	90	1368	0.61	84	24
Greece	907	-127	0	0.00	0	5
Hungary	541	67	279	0.28	26	23
Ireland	115	48	48	0.08	14	2
Italy	568	85	2575	0.17	45	7
Luxembourg	7	71	19	0.16	50	7
Netherlands	193	59	463	0.12	31	95
Norway	65	54	33	0.03	8	69
Poland	1332	68	2430	1.02	64	36
Portugal	333	-25	0	0.00	0	3
Romania	875	51	1091	0.98	47	14

Table 7A. 2.5 times the corrected 5 percentile critical loads for sulfur

SCENARIO 7. 2.5 TIMES 5 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	2174	33	233	0.03	6	0
Sweden	167	68	335	0.14	39	17
Switzerland	51	60	47	0.02	7	7
Turkey	2889	-236	0	0.00	0	8
UK	987	80	2488	0.17	43	22
Yugoslavia	1525	-17	39	0.02	2	10
Baltic Sea	18	75	101	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	317	0	0	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	465	27	172	0.96	88	8
St.Petersburg	121	76	184	0.24	22	8
Baltic Region	300	52	298	0.37	34	2
Byelorussia	564	24	2	0.00	0	8
Ukraine	3839	0	694	0.15	13	8
Moldavia	206	38	114	0.29	26	8
Rem. Eur. CIS	3865	41	1326	0.12	11	8
TOTAL	26157	52	24352	0.19	32	15

Table 7B. 2.5 times the corrected 5 percentile critical loads for sulfur

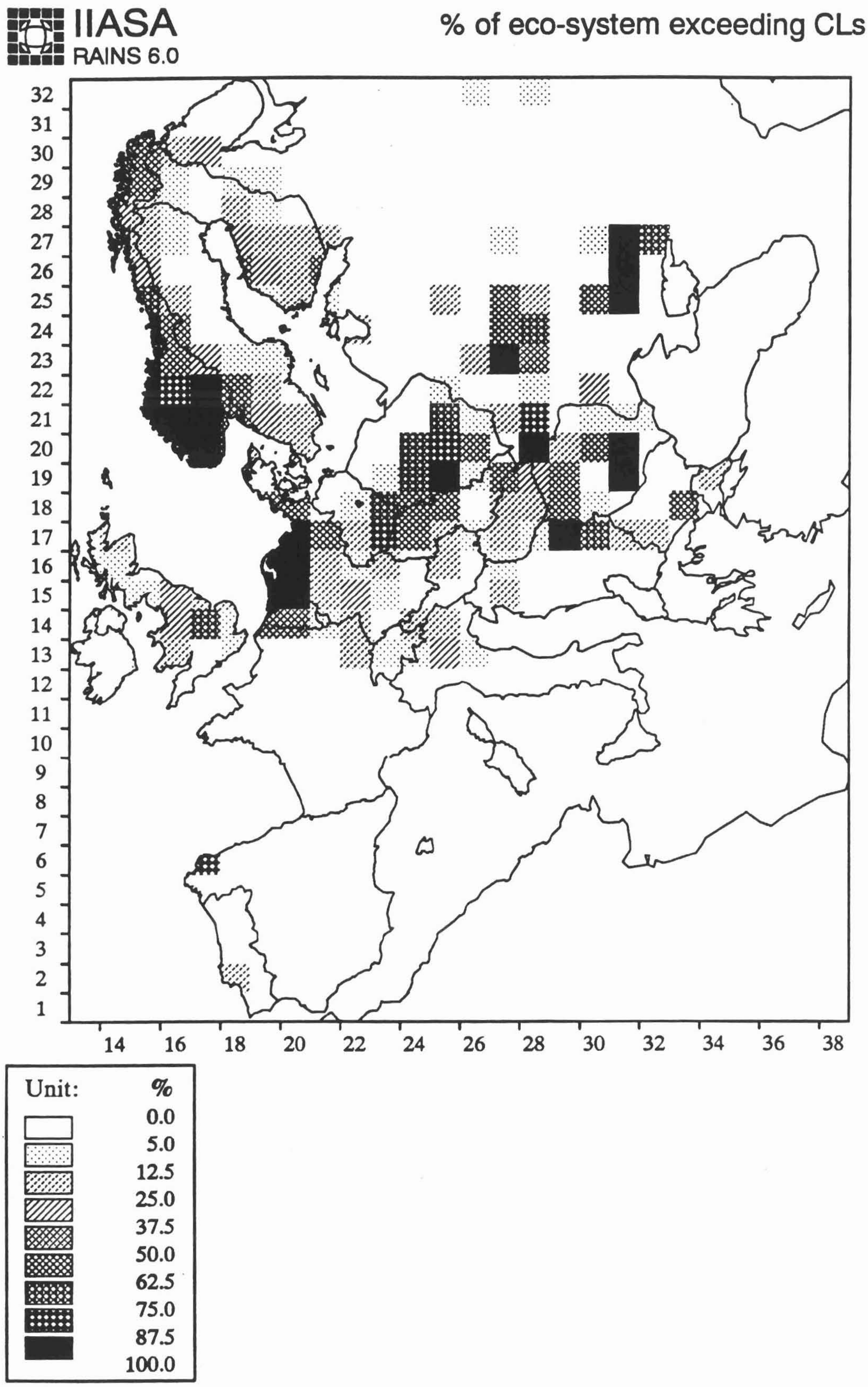


Figure 8. 2.5 times the corrected 5 percentile critical loads for sulfur

3.5 50 percentile critical loads

3.5.1 50 percentile critical loads without further constraints

This abatement strategy (scenario 8) starts from the 50 percentile of critical loads for sulfur, adjusted to account for the net base-cation balance. The target loads that are not feasible, given the maximum feasible reductions, are not taken into account.

Tables 8A and 8B show that the emission reduction from this scenario is 59% over the 1980 level. This is comparable with scenario 6 (2.0 times the 5 percentile of critical loads). The associated costs are 32 billion DM/year. That is 0.26% of GDP (at PPP) and 42 DM/capita. As a result of this scenario, 8% of the ecosystems would be above critical loads.

Costs per unit of GDP would be relatively high in: Kola-Karelia, Poland, Romania, the CSFR, Germany-East and Yugoslavia. Again, the percentage of ecosystems not sufficiently protected would be rather high in Norway and the Netherlands and would not be insignificant in Belgium.

3.5.2 50 percentile critical loads with Current Reduction Plans

This strategy (scenario 9) starts from the same critical loads as the previous scenario but takes the Current Reduction Plans as minimum requirements. As a result, the expected emission reduction of 64%, is slightly higher than under the previous scenario. The costs are 34 billion DM/year (Tables 9A and 9B). Costs compared to GDP are 0.27%. The percentage of ecosystems below critical loads is slightly lower (7% instead of 8%).

Under this scenario a number of countries would carry out their Current Reduction Plans: Austria, Bulgaria, Finland, Germany-East, Greece, Luxembourg, Switzerland, Turkey, Byelorussia and the Ukraine. All other countries or regions would have higher emission reductions.

Abatement costs would be high, when compared to the GDP, in Kola-Karelia, Poland, Germany-East, CSFR and Romania. Generally, the percentage of ecosystems not expected to be damaged is below 10%. Notable exceptions to this are again the Netherlands, Norway, Belgium, and to a smaller extent Sweden, the United Kingdom, CSFR and Hungary.

SCENARIO 8. 50 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	0
Austria	300	23	34	0.02	4	7
Belgium	167	80	935	0.35	95	38
Bulgaria	809	22	3	0.00	0	9
CSFR	714	77	1651	0.82	105	18
Denmark	124	72	154	0.11	30	12
Finland	131	72	493	0.37	99	9
France	600	82	924	0.06	16	2
Germany, West	279	91	6233	0.33	99	16
Germany, East	363	91	1528	0.68	94	16
Greece	907	-127	0	0.00	0	4
Hungary	541	67	279	0.28	26	21
Ireland	115	48	48	0.08	14	1
Italy	954	75	1615	0.11	28	13
Luxembourg	10	58	5	0.04	13	7
Netherlands	79	83	999	0.26	67	95
Norway	30	79	149	0.14	35	62
Poland	560	86	4410	1.84	117	5
Portugal	333	-25	0	0.00	0	3
Romania	615	66	1422	1.28	61	10

Table 8A. 50 percentile critical loads for sulfur

SCENARIO 8. 50 PERCENTILE CRITICAL LOADS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	842	74	1620	0.22	41	0
Sweden	105	80	544	0.23	64	14
Switzerland	79	37	0	0.00	0	10
Turkey	2889	-236	0	0.00	0	6
UK	544	89	3453	0.24	60	16
Yugoslavia	787	39	1233	0.62	52	3
Baltic Sea	18	75	101	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	76	76	435	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	103	84	711	3.99	364	3
St.Petersburg	91	82	248	0.33	30	3
Baltic Region	294	53	303	0.37	34	1
Byelorussia	503	32	42	0.04	4	3
Ukraine	2790	28	1368	0.29	26	3
Moldavia	306	7	47	0.12	11	3
Rem. Eur. CIS	4457	32	886	0.08	8	3
TOTAL	22707	59	32111	0.26	42	8

Table 8B. 50 percentile critical loads for sulfur

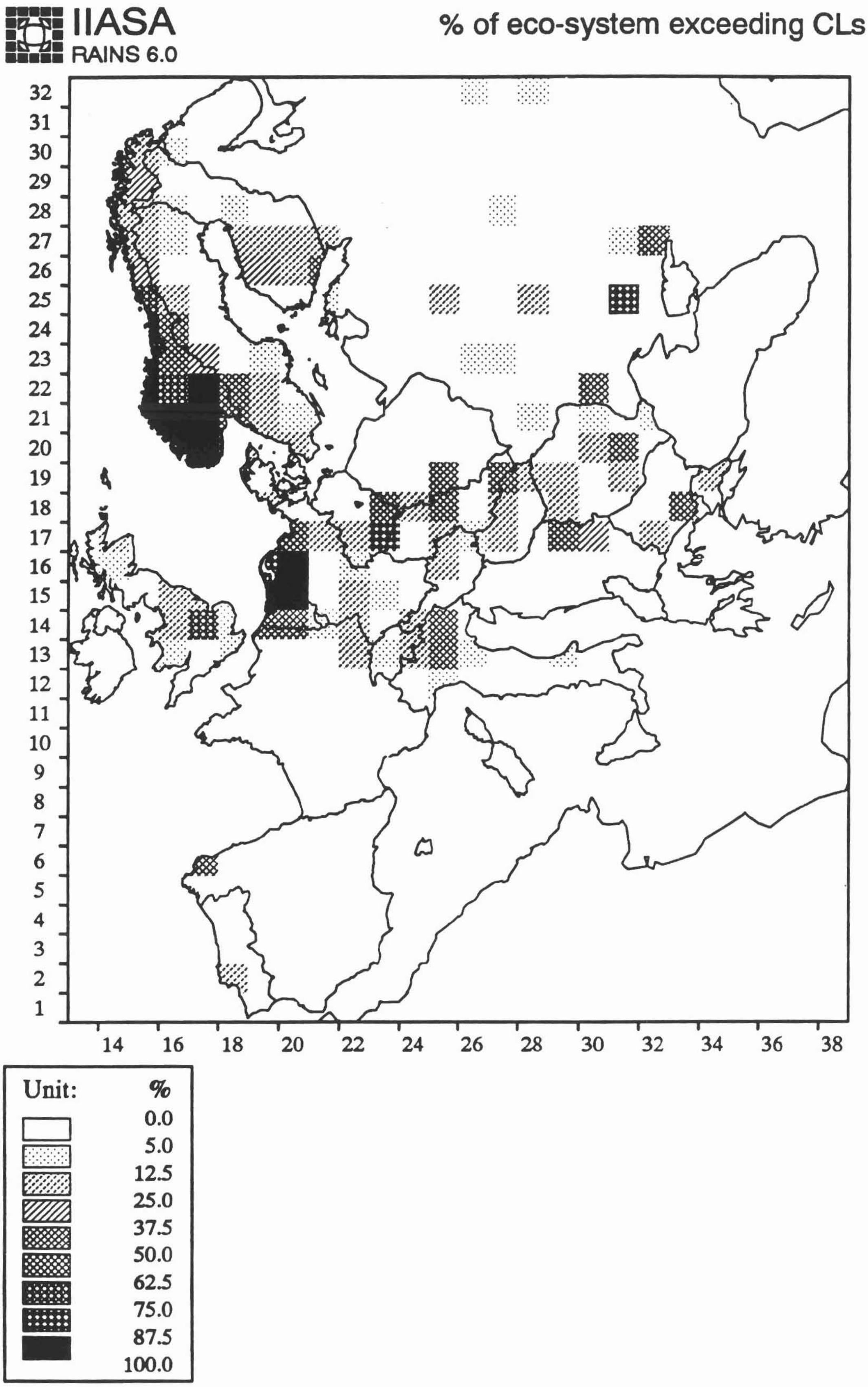


Figure 9. 50 percentile critical loads for sulfur

SCENARIO 9. 50 PERCENTILE CRITICAL LOADS PLUS CURRENT REDUCTION PLANS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	0
Austria	78	80	579	0.28	76	1
Belgium	168	80	931	0.35	95	38
Bulgaria	520	50	273	0.35	30	9
CSFR	757	76	1535	0.76	98	16
Denmark	124	72	154	0.11	30	12
Finland	116	80	603	0.45	121	9
France	600	82	924	0.06	16	2
Germany, West	298	91	6044	0.32	96	11
Germany, East	230	95	2335	1.05	144	11
Greece	595	-49	249	0.21	24	0
Hungary	541	67	279	0.28	26	15
Ireland	115	48	48	0.08	14	1
Italy	976	74	1575	0.11	27	13
Luxembourg	10	58	5	0.04	13	7
Netherlands	79	83	999	0.26	67	95
Norway	30	79	149	0.14	35	63
Poland	581	86	4290	1.79	113	5
Portugal	304	-14	23	0.02	2	2
Romania	684	62	1315	1.19	57	1

Table 9A. 50 percentile critical loads for sulfur plus Current Reduction Plans

SCENARIO 9. 50 PERCENTILE CRITICAL LOADS PLUS CURRENT REDUCTION PLANS

	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	844	74	1617	0.22	41	0
Sweden	160	69	349	0.15	41	14
Switzerland	60	52	23	0.01	3	7
Turkey	2889	-236	0	0.00	0	3
UK	544	89	3453	0.24	60	16
Yugoslavia	806	38	1200	0.61	50	3
Baltic Sea	26	64	86	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	76	76	435	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	103	84	711	3.99	364	1
St.Petersburg	121	76	184	0.24	22	1
Baltic Region	294	53	303	0.37	34	1
Byelorussia	456	38	91	0.10	9	1
Ukraine	1696	56	2071	0.44	40	1
Moldavia	231	30	97	0.24	22	1
Rem. Eur. CIS	4563	30	835	0.08	7	1
TOTAL	19867	64	34003	0.27	45	7

Table 9B. 50 percentile critical loads for sulfur plus Current Reduction Plans

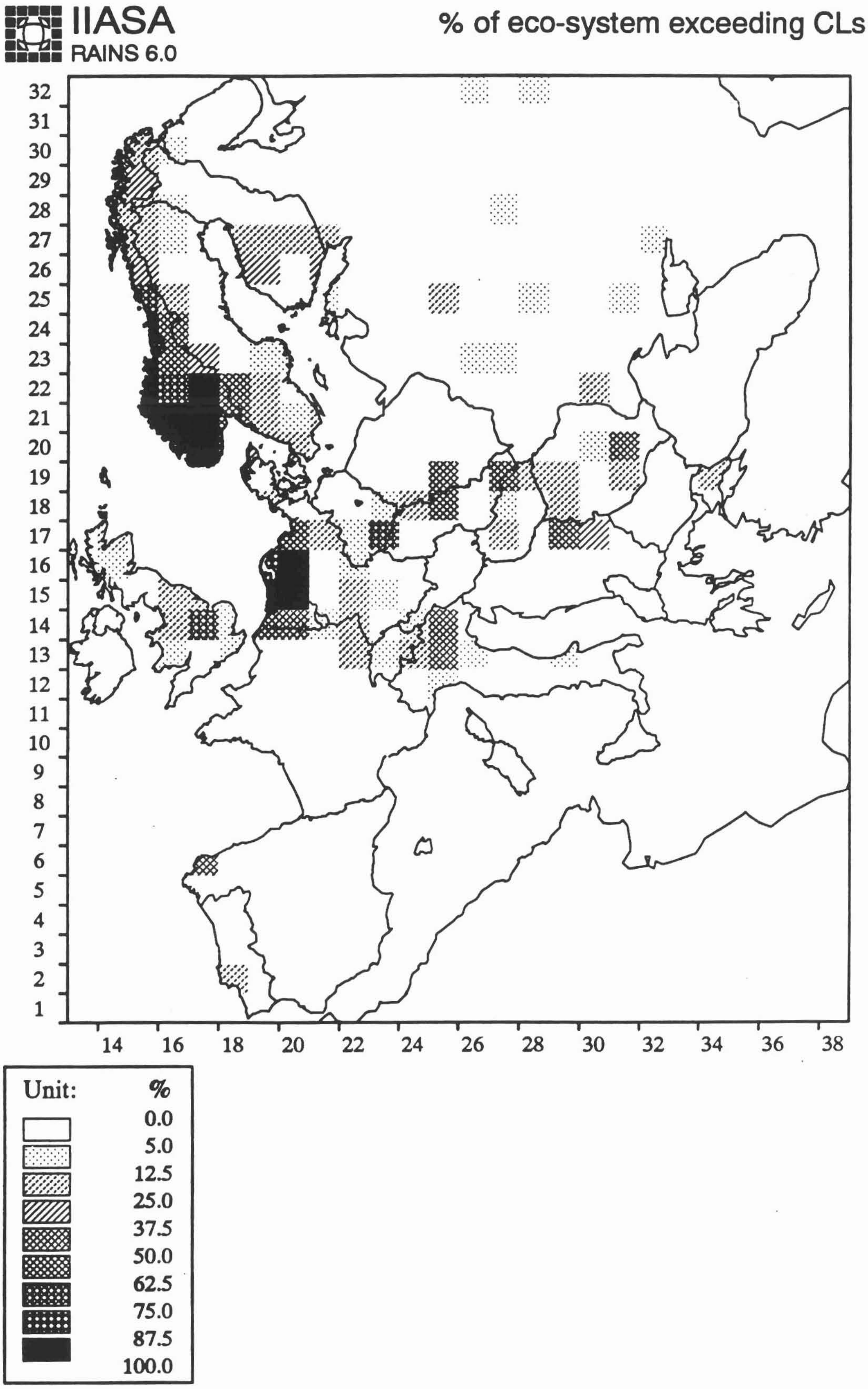


Figure 10. 50 percentile critical loads for sulfur plus Current Reduction Plans

3.6 Reductions up to marginal costs of 2500 DM/TON SO_2, 0.2% of GDP and Current Reduction Plans

This scenario is based on a minimum reduction requirement that would follow from emission reduction up to marginal costs of 2500 DM/ton SO_2. Furthermore, the remaining money of 0.2% of GDP (not reflecting purchasing power parity), taking Current Reduction Plans as minimum constraints, is put into an international fund. The contributions of this fund are allocated such that, given the limited budget, emission removal is maximized. Stated differently, countries pay the costs of either reductions up to 2500 DM/ton SO_2 removed, costs of 0.2% of GDP or Current Reduction Plans. Whatever leads to the highest costs (or alternatively leads to the highest emission reductions) has to be paid. As a result of these conditions, the following countries reduce emission up to 2500 DM/ton SO_2: Albania, Bulgaria, CSFR, Greece, Poland, Portugal, Romania, Spain, Turkey, Yugoslavia, the Baltic Sea, the North Sea, the Atlantic Ocean, the Mediterranean Sea, Kola-Karelia, the Baltic region, Byelorussia, the Ukraine, and Moldavia. The following countries will spend money on the basis of 0.2% of their GDP: Belgium, Denmark, France, Germany-W, Ireland, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, Yugoslavia, St. Petersburg and the remainder of CIS within EMEP. Costs on the basis of their Current Reduction Plans are spent by: Austria, Finland and Germany-East. If a country's abatement costs exceed the costs of the 2500 DM/ton SO_2, the surplus is put into a fund and allocated so that the emissions abated are maximized. The total surplus allocated in this way is 15800 million DM per year. This corresponds to the difference between the costs of this scenario (51838 million DM/year) and the costs of 2500 DM/ton SO_2 abated (36038 million DM/year).

Tables 10A and 10B present the results of this strategy. The reduction in emission achieved is 84% over the 1980 level. Emissions come down to 8520 kton SO_2 in 1990, close to the maximum feasible reduction. The associated costs are 51.8 billion DM/year, which corresponds to 0.41% of GDP (at purchasing power parity). In this case 4.8% of all ecosystems will have sulfur deposition above critical loads.

Costs compared to GDP for all countries are, per definition, at least 0.2% of GDP (not reflecting purchasing power parity) in this scenario. They are, however, much higher in: Kola-Karelia, Yugoslavia, Poland, Romania, Germany-East, Bulgaria and Albania. Note that the costs in this case consist of pollution control costs plus the contribution to the fund. The environmental impacts are favorable for most countries with the exception of the Netherlands, Norway, Belgium and the UK.

SCENARIO 10. 2500 DM/TON, 0.2% GDP AND CURRENT REDUCTION PLANS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	35	65	92	.	28	0
Austria	58	85	557	0.27	73	0
Belgium	172	79	708	0.27	72	26
Bulgaria	88	91	796	1.01	88	1
CSFR	700	77	1382	0.69	88	4
Denmark	42	91	522	0.37	101	7
Finland	131	78	583	0.44	117	6
France	350	90	4884	0.31	87	1
Germany, West	502	84	5282	0.28	84	14
Germany, East	237	94	2239	1.00	138	14
Greece	105	74	721	0.60	71	0
Hungary	414	75	428	0.42	41	3
Ireland	29	87	164	0.27	47	0
Italy	300	92	3722	0.25	65	2
Luxembourg	7	71	30	0.25	80	6
Netherlands	79	83	1142	0.30	76	95
Norway	34	76	476	0.44	112	60
Poland	567	86	4056	1.70	107	3
Portugal	60	77	301	0.23	29	0
Romania	381	79	1612	1.45	69	0

Table 10A. 2500 DM/ton $S0_2$, 0.2% of GDP plus Current Reduction Plans

SCENARIO 10. 2500 DM/TON, 0.2% GDP AND CURRENT REDUCTION PLANS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	378	88	2262	0.30	58	0
Sweden	105	80	810	0.35	95	11
Switzerland	44	65	740	0.32	111	1
Turkey	947	-10	1484	0.48	27	0
UK	544	89	3744	0.26	65	16
Yugoslavia	226	83	2097	1.06	88	0
Baltic Sea	18	75	17	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	76	434	434	.	.	.
Mediter. Sea	12	16	16	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	111	83	561	3.14	288	0
St.Petersburg	46	91	356	0.47	43	0
Baltic Region	86	86	623	0.77	70	0
Byelorussia	66	91	571	0.61	56	0
Ukraine	715	81	2918	0.62	56	0
Moldavia	47	86	240	0.60	55	0
Rem. Eur. CIS	766	88	5030	0.47	43	0
TOTAL	8520	84	51838	0.41	68	5

Table 10B. 2500 DM/ton SO_2, 0.2% of GDP plus Current Reduction Plans

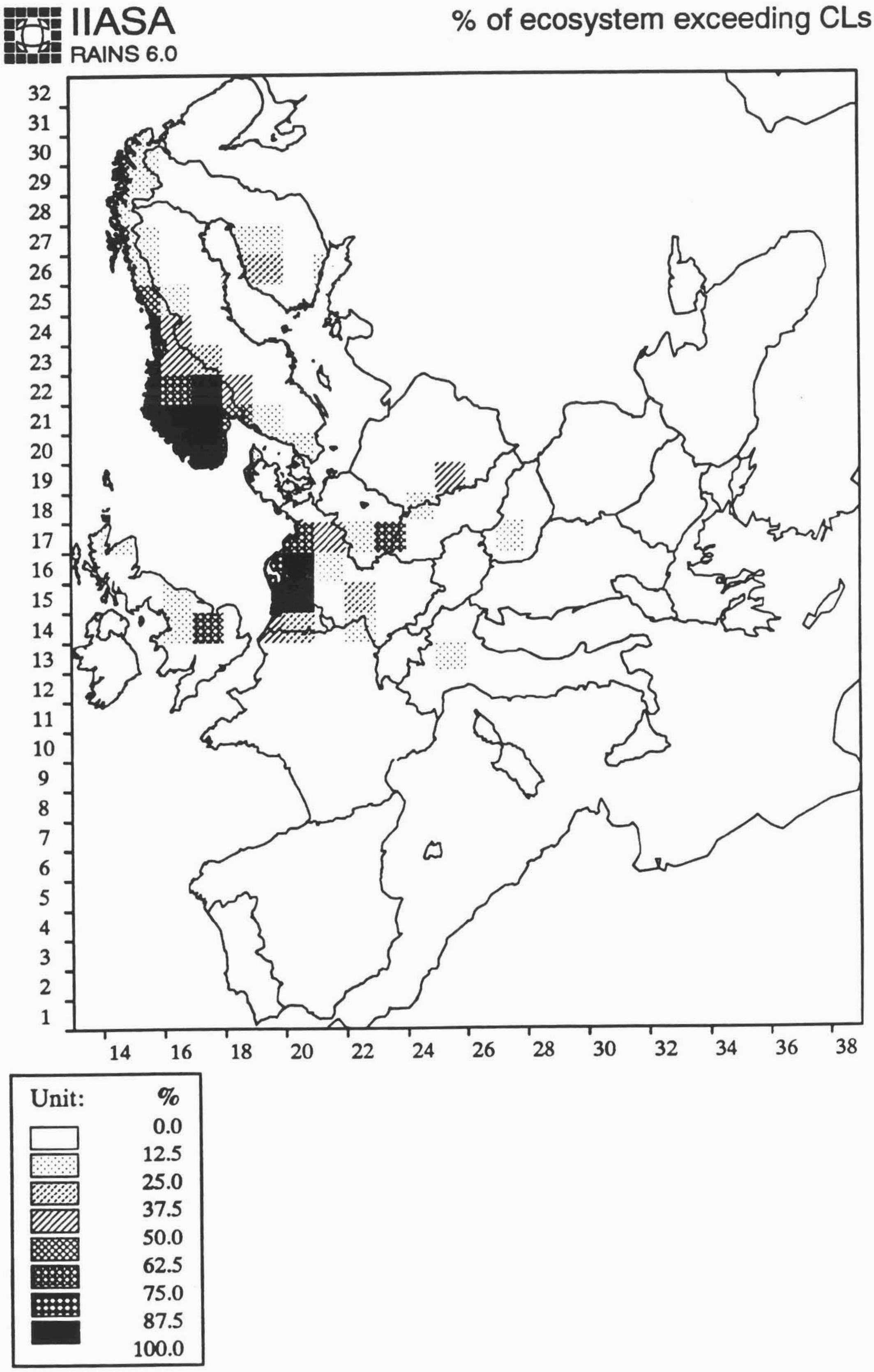


Figure 11. 2500 DM/ton SO_2, 0.2% of GDP plus Current Reduction Plans

3.7 National target loads plus Current Reduction Plans

Eleven countries have submitted (preliminary and sometimes unofficial) national target loads for sulfur: Finland, Sweden, Norway, Denmark, the United Kingdom, the Netherlands, Germany (East and West), France, Switzerland, Austria and the former USSR. These target loads include the revised target loads submitted by Finland at the end of May 1992. The target loads are partly based on critical loads information but also reflect socio-economic considerations. The data have been collected by the CCE, Figure 12 depicts the map of target loads used in this paper. For this scenario the Current Reduction Plans are taken as minimum constraints.

Tables 11A and 11B show the major results of this strategy. The emission reduction of this scenario boils down to 61% over the 1980 level. Annual costs are 33.2 billion DM/year. This is 0.18% of GDP (at purchasing power parity) and 42 DM/capita per year. 8% of all ecosystems would be exceeding critical loads levels in the year 2000.

Costs would be relatively high in Kola-Karelia (3.76% of GDP), CSFR, Germany-East and Romania. The percent of ecosystems still not protected would be high in Norway and the Netherlands, but also in the United Kingdom, Poland, CSFR, Sweden, Hungary and Belgium (Figure 13).

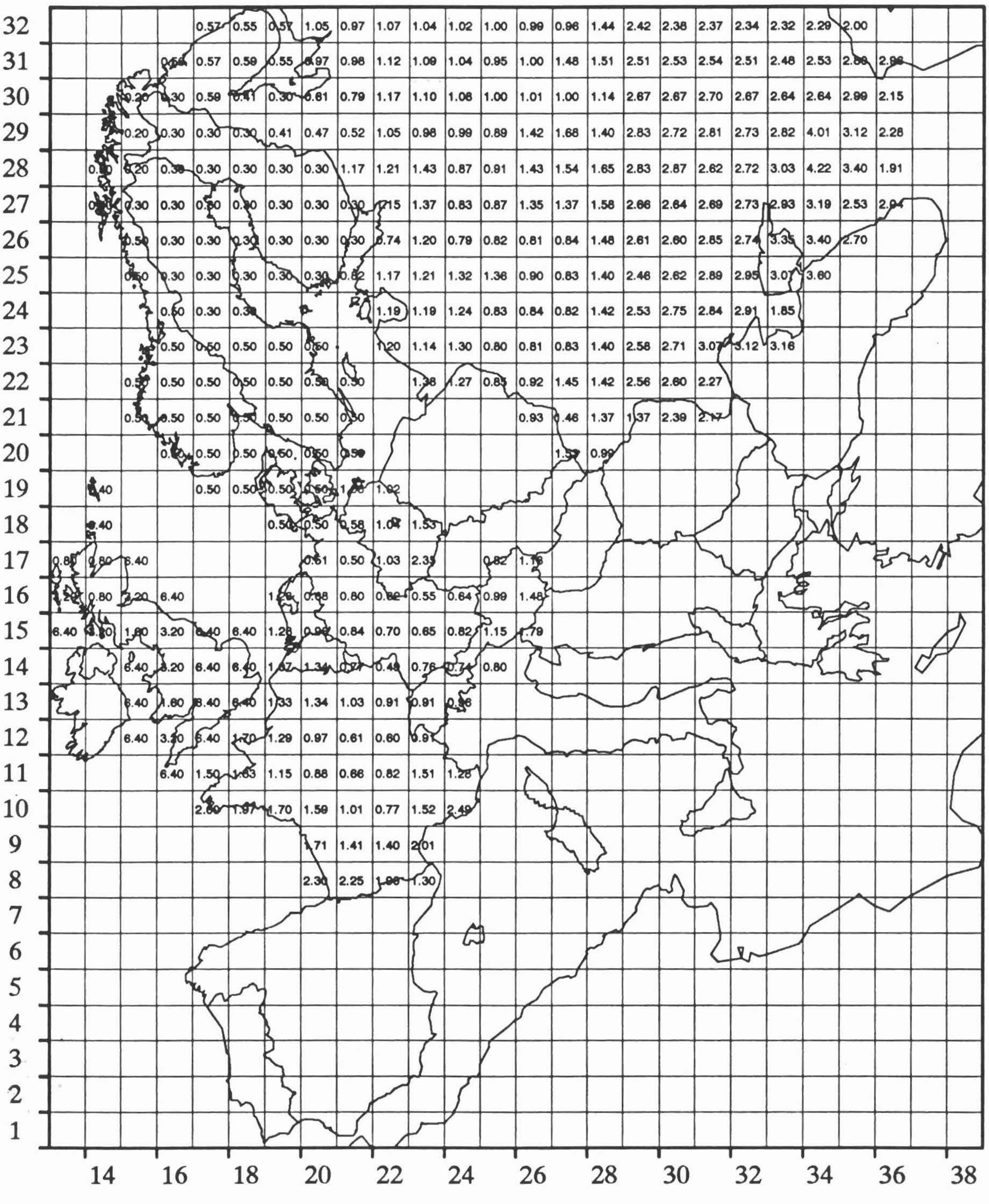


Figure 12. Provisional National Target Loads for the year 2000.

SCENARIO 11. NATIONAL TARGET LOADS AND CURRENT REDUCTION PLANS						
	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Albania	138	-37	0	.	0	0
Austria	78	80	579	0.28	76	2
Belgium	72	91	1763	0.67	180	15
Bulgaria	520	50	273	0.35	30	6
CSFR	777	75	1481	0.74	95	21
Denmark	49	89	474	0.33	90	11
Finland	57	90	603	0.78	208	11
France	350	90	1970	0.12	35	1
Germany, West	231	93	6707	0.36	107	12
Germany, East	230	95	2335	1.05	144	12
Greece	595	-49	249	0.21	24	0
Hungary	467	71	399	0.40	38	16
Ireland	171	23	0	0.00	0	7
Italy	704	81	2190	0.15	38	7
Luxembourg	7	71	19	0.12	37	6
Netherlands	79	83	999	0.26	67	95
Norway	70	51	29	0.03	7	67
Poland	1456	64	2179	0.89	56	31
Portugal	304	-14	23	0.02	2	2
Romania	556	69	1550	1.36	65	1

Table 11A. National target loads

SCENARIO 11. NATIONAL TARGET LOADS AND CURRENT REDUCTION PLANS

	Emissions		Abatement costs			Deposition
Country	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
Spain	2145	34	242	0.03	6	0
Sweden	182	65	306	0.13	36	16
Switzerland	51	60	47	0.02	7	5
Turkey	2889	-236	0	0.00	0	3
UK	1505	69	1536	0.10	27	26
Yugoslavia	1547	-19	20	0.01	1	8
Baltic Sea	18	75	101	.	.	.
North Sea	42	76	238	.	.	.
Atlantic Ocean	316	0	0	.	.	.
Mediter. Sea	12	0	0	.	.	.
Black Sea	0	0	0	.	.	.
Kola Karelia	194	70	421	3.76	343	1
St.Petersburg	102	79	224	0.55	50	1
Baltic Region	294	53	303	0.90	83	2
Byelorussia	367	50	194	0.55	51	1
Ukraine	715	81	3037	0.64	59	1
Moldavia	231	30	97	0.24	22	1
Rem. Eur. CIS	4091	37	1158	0.10	9	1
TOTAL	21621	61	31748	0.27	44	9

Table 11B. National target loads

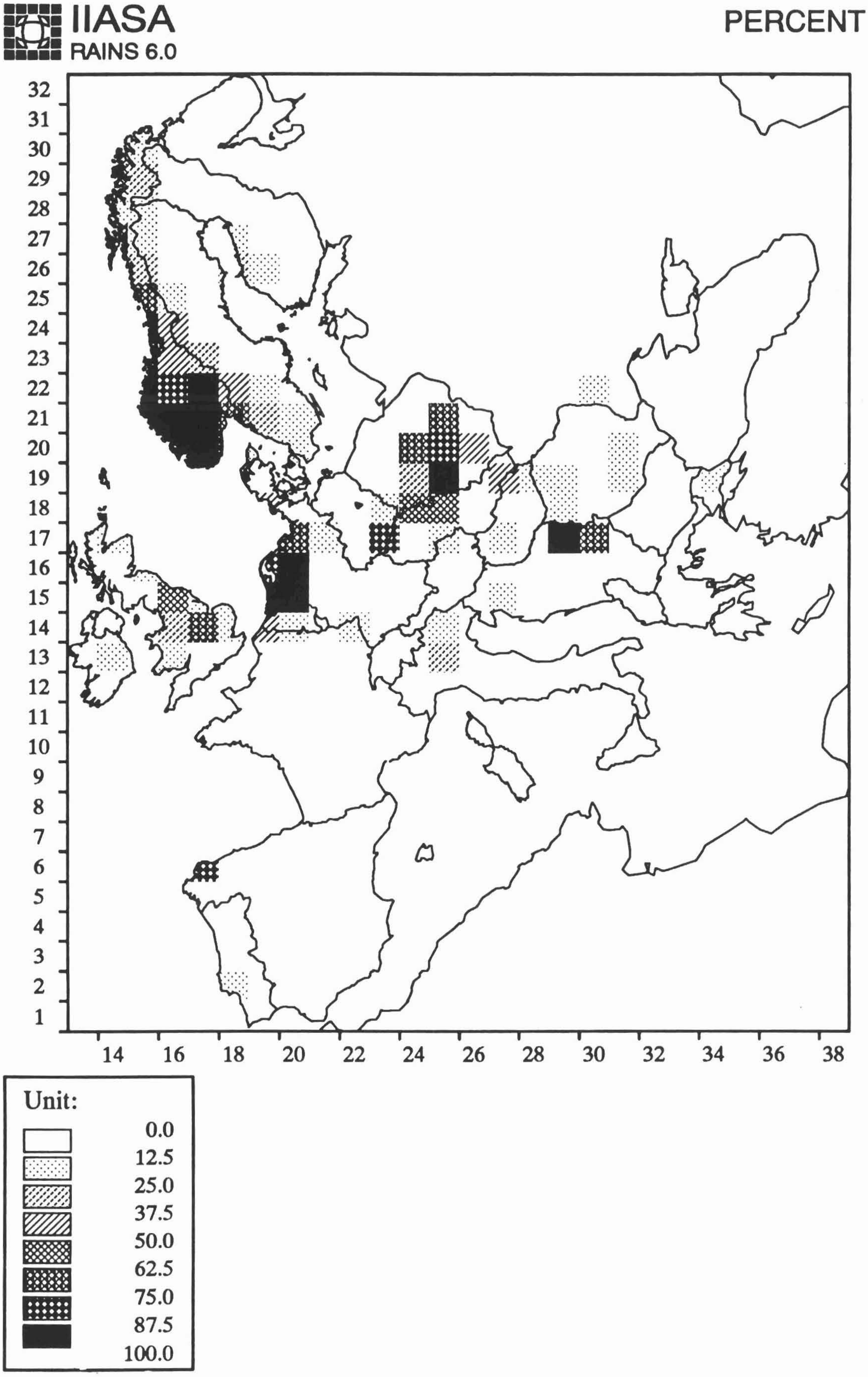


Figure 13. Target loads plus Current Reduction Plans.

4 COMPARISON OF SCENARIOS

Table 12 compares the major results of the abatement strategies. The emission reduction achieved by the different scenarios ranges from 31% (scenario 3) to 88% (scenario 2, Maximum Feasible Reductions). Costs vary between 8.2 billion DM/year (scenario 3) and 84.4 billion DM/year (scenario 2). The percentage of ecosystems exceeding critical loads varies between 28 and 4%.

Remarkably, scenarios 3 and 4, reducing the difference between 1990 deposition and the 5 percentile critical loads by 30%, do not lead to emission reductions higher than, and environmental impacts significantly better than, the Current Reduction Plans. Higher percentage reductions (50%) would be necessary for that purpose.

Regarding the environmental impacts, several scenarios are comparable. Scenario 2 (Maximum Feasible Reductions), scenario 5 (1.5 times the 5 percentile critical loads) and scenario 10 (2500 DM/ton SO_2, 0.2% of GDP and Current Reduction Plans) lead to comparable percentages of ecosystems not protected (4 to 5%). Scenario 5, however, is much more cost-effective; annual emission control costs are only 45.5 billion DM. The annual costs of scenario 10 are 51. 8 billion DM and the costs of scenario 2 are 84.4 billion DM. The costs of scenario 2 (Maximum Technically Feasible Reductions) and scenario 10 (2500 DM/ton SO_2, 0.2% of GDP and Current Reduction Plans) are higher because both scenarios ignore the location of the sources in relation to the sensitivity of ecosystems. In conclusion, accounting for the critical loads, as in scenario 5, is more cost-effective; the same overall percentage of ecosystems is protected at less costs.

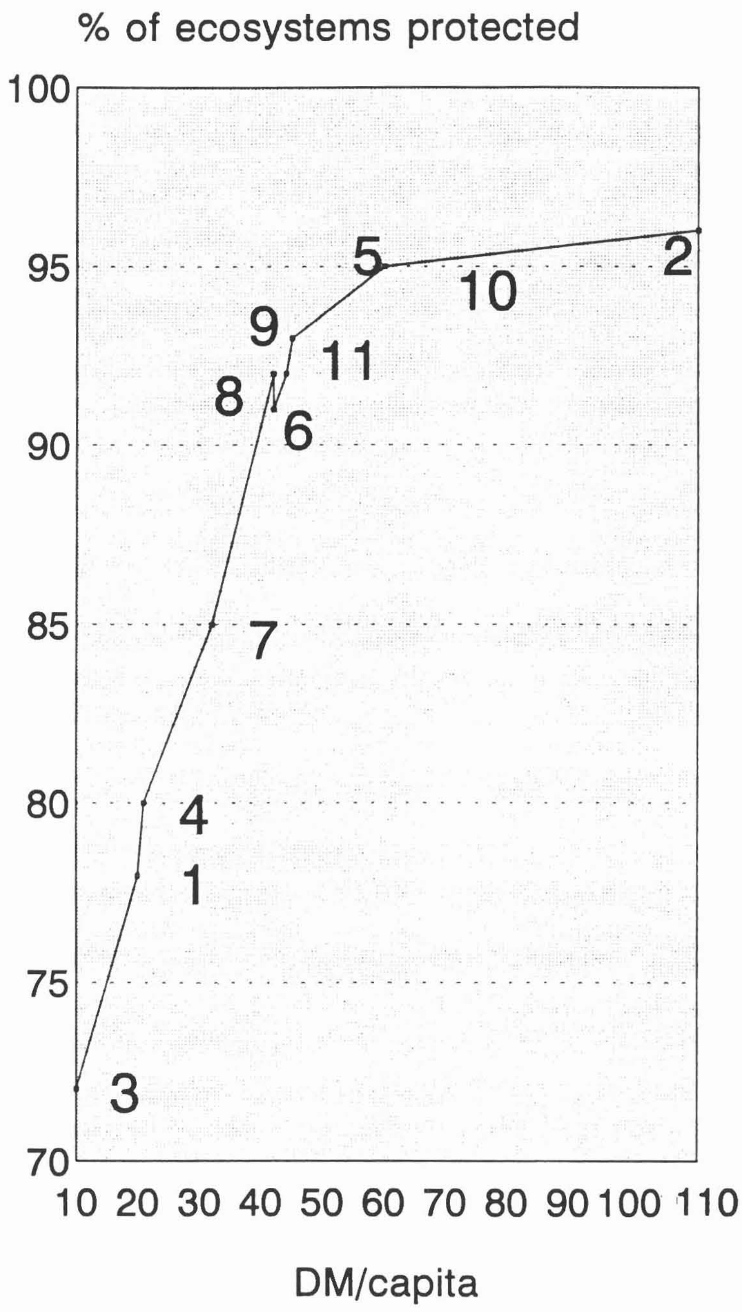
Scenarios 6, 8, 9 and 11 have comparable impacts in terms of ecosystems still exceeding critical loads (7 to 9%) and comparable costs (0.26 to 0.27% of GDP at purchasing power parity). The cost-effectiveness of the scenarios (in terms of billion DM percent of ecosystem not exceeding critical loads) is also comparable.

Figure 14 depicts the percentage of ecosystems protected (that is, where deposition is above the 5 percentile critical loads) as a function of the cost per capita. Figure 14 shows that for increasing the percentage of ecosystems a proportionally larger sum per capita has to be spent. In other words, marginal costs (in terms of percentage ecosystems protected) increase. Scenarios 6, 8, 9, 11 have comparable costs per capita and a comparable percentage of ecosystems protected. Scenario 2 (MFR) is nearly twice as expensive as Scenario 5, but does not result in a significant environmental improvement in terms of percentage of ecosystems protected.

CROSS SCENARIO COMPARISON						
	Emissions		Abatement costs			Deposition
Scenario	kton SO_2	Reduction compared to 1980(%)	10^6 DM/ year	% of GDP	DM/ capita/ year	% of ecosystems above CL
1. CRP	33520	39	15428	0.12	20	22
2. MFR	6643	88	84434	0.68	111	4
3. GAP30%	37929	31	8286	0.07	11	28
4. GAP30%CRP	32204	41	16269	0.13	21	20
5. 1.5*5%CLS	14782	73	45500	0.36	60	5
6. 2.0*5%CLS	21777	60	31941	0.26	42	9
7. 2.5*5%CLS	26157	52	24352	0.19	32	15
8. 50%CLS	22707	59	32111	0.26	42	8
9. 50%+CRP	19867	64	34003	0.27	45	7
10. 2500DM	8520	84	51838	0.41	68	5
11. TARGET	21135	61	33165	0.27	44	8

Scenarios:
1. Current Reduction Plans
2. Maximum Feasible Reductions
3. Reduce the difference between 1990 deposition and 5% critical loads by 30%
4. Reduce the difference between 1990 deposition and 5% critical loads by 30% plus Current Reduction Plans
5. 1.5 times the 5 percentile critical loads
6. 2.0 times the 5 percentile critical loads
7. 2.5 times the 5 percentile critical loads
8. 50 percentile critical loads
9. 50 percentile critical loads plus Current Reduction Plans
10. 2500 DM/ton, 0.2% of GDP and Current Reduction Plans
11. National target loads plus Current Reduction Plans.

Table 12. Comparison of scenarios



		% red.
1.	CRP 2000	39
2.	MFR	88
3.	30% GAP	31
4.	30% GAP + CRP	41
5.	1.5 x 5 percentile	73
6.	2 x 5 percentile	60
7.	2.5 x 5 percentile	52
8.	50 percentile	59
9.	50 percentile + CRP	64
10.	2,500 DM/tonne	84
11.	TL + CRP	61

Figure 14. Effectiveness of scenarios

Not only are the European-wide costs and environmental impacts important but also their distributional impacts. In order to keep an overview, the impacts for the various regions and countries are presented for a selection of what appear to be the most interesting scenarios. Tables 13A and 13B present the emission reductions required, Tables 14A and 14B show the costs as a percent of GDP and Tables 15A and 15B present the percentage of ecosystems exceeding critical loads.

Tables 13A and 13B show that under scenario 5 every country would reduce emissions further than currently planned. This is not the case with scenarios 6, 7 9 and 11 where several countries would have to do less than currently planned.

Tables 14A and 14B indicate that, quite irrespective of the scenario, the costs as percentage of GDP will be fairly high (exceeding 0.5%) in the CSFR, Poland, Romania and Kola-Karelia. Depending on the scenario, some other countries also make significant contributions in terms of their GDP; FRG-E (scenario 5, 9 and 11), Hungary (scenario 5) and Yugoslavia (scenario 5 and 9).

Tables 15A and 15B show that scenario 5 implies an improvement in the percentage of ecosystems protected for every country when compared to the current plans. The exception is Portugal. Scenarios 6 and 7 improve the percent of ecosystems not exceeded in every region except for the Netherlands, Greece and Portugal where the situation remains the same as under currently planned reductions. Under scenario 9, the environmental situation is better everywhere than currently planned, except again in Portugal and the Netherlands where the environment does not improve compared to the current plans. The same is true for scenario 11, target loads. With the exception of the Netherlands and Portugal, the percent of ecosystems exceeding critical loads under scenario 11 is much lower in every region.

EMISSION REDUCTIONS OF VARIOUS SCENARIOS COMPARED TO 1980 (%)						
	Scenario					
Country	1. CRP	5. 1.5*CLS	6. 2.0*CLS	7. 2.5*CLS	9. 50%CLS +CRP	11. Target loads
Albania	-37	-29	-37	-37	-37	-37
Austria	80	88	64	36	80	80
Belgium	48	92	79	79	80	91
Bulgaria	50	57	21	21	50	50
CSFR	30	79	72	72	76	75
Denmark	61	95	92	91	72	89
Finland	80	86	85	78	80	80
France	67	92	90	86	82	90
Germany, West	84	93	92	87	91	93
Germany, East	95	94	90	90	95	95
Greece	-49	-127	-127	-127	-49	-49
Hungary	33	76	74	67	67	71
Ireland	-8	74	48	48	48	23
Italy	48	91	88	85	74	81
Luxembourg	58	83	71	71	58	71
Netherlands	77	83	59	59	83	83
Norway	51	76	54	54	79	51
Poland	29	86	75	68	86	64
Portugal	-14	-25	-25	-25	-14	-14
Romania	-44	75	63	51	62	69

Table 13A. Emission reductions of various scenarios

EMISSION REDUCTIONS OF VARIOUS SCENARIOS COMPARED TO 1980 (%)						
	Scenario					
Country	1. CRP	5. 1.5*CLS	6. 2.0*CLS	7. 2.5*CLS	9. 50%CLS +CRP	11. Target loads
Spain	34	61	47	33	74	34
Sweden	65	82	78	68	69	65
Switzerland	52	65	60	60	52	60
Turkey	-236	-236	-236	-236	-236	-236
UK	47	91	89	80	89	69
Yugoslavia	-21	87	7	-17	38	-19
Baltic Sea	0	75	75	75	64	75
North Sea	0	76	76	76	76	76
Atlantic Ocean	0	0	0	0	76	0
Mediter. Sea	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0
Kola Karelia	30	75	56	27	84	83
St.Petersburg	30	76	76	76	76	91
Baltic Region	30	82	53	52	53	84
Byelorussia	38	85	24	24	38	85
Ukraine	56	73	21	0	56	81
Moldavia	30	66	52	38	30	30
Rem. Eur. CIS	30	62	55	41	30	36
TOTAL	39	73	60	52	64	61

Table 13B. Emission reductions of various scenarios.

ANNUAL COSTS OF VARIOUS SCENARIOS IN 2000 (% OF GDP)						
	Scenario					
Country	1. CRP	5. 1.5*CLS	6. 2.0*CLS	7. 2.5*CLS	9. 50%CLS +CRP	11. Target loads
Albania	.	.	.	.	.	.
Austria	0.28	0.40	0.15	0.05	0.28	0.28
Belgium	0.10	0.69	0.34	0.34	0.35	0.67
Bulgaria	0.35	0.45	0.00	0.00	0.35	0.35
CSFR	0.06	0.99	0.61	0.61	0.76	0.74
Denmark	0.05	0.55	0.41	0.35	0.11	0.33
Finland	0.46	0.65	0.62	0.37	0.45	0.78
France	0.02	0.17	0.12	0.10	0.06	0.12
Germany, West	0.21	0.36	0.35	0.27	0.32	0.36
Germany, East	1.05	0.94	0.62	0.61	1.05	1.05
Greece	0.21	0.00	0.00	0.00	0.21	0.21
Hungary	0.00	0.90	0.53	0.28	0.28	0.40
Ireland	0.00	0.22	0.08	0.08	0.08	0.00
Italy	0.05	0.23	0.21	0.17	0.11	0.15
Luxembourg	0.04	0.33	0.16	0.16	0.04	0.12
Netherlands	0.23	0.26	0.12	0.12	0.26	0.26
Norway	0.03	0.11	0.03	0.03	0.14	0.03
Poland	0.24	1.81	1.33	1.02	1.79	0.89
Portugal	0.02	0.00	0.00	0.00	0.02	0.02
Romania	0.00	1.50	1.21	0.98	1.19	1.36

Table 14A. Annual costs of various scenarios

ANNUAL COSTS OF VARIOUS SCENARIOS IN 2000 (% OF GDP)						
	Scenario					
Country	1. CRP	5. 1.5*CLS	6. 2.0*CLS	7. 2.5*CLS	9. 50%CLS +CRP	11. Target loads
Spain	0.03	0.11	0.07	0.03	0.22	0.03
Sweden	0.13	0.31	0.22	0.14	0.15	0.13
Switzerland	0.01	0.04	0.02	0.02	0.01	0.02
Turkey	0.00	0.00	0.00	0.00	0.00	0.00
UK	0.04	0.28	0.24	0.17	0.24	0.10
Yugoslavia	0.00	1.34	0.26	0.02	0.61	0.01
Baltic Sea	.	.	.	.	.	.
North Sea	.	.	.	.	.	.
Atlantic Ocean	.	.	.	.	.	.
Mediter. Sea	.	.	.	.	.	.
Black Sea	.	.	.	.	.	.
Kola Karelia	1.04	2.71	1.75	0.96	3.99	3.76
St.Petersburg	0.00	0.24	0.24	0.24	0.24	0.55
Baltic Region	0.20	0.80	0.37	0.37	0.37	0.90
Byelorussia	0.10	0.55	0.00	0.00	0.10	0.55
Ukraine	0.44	0.52	0.25	0.15	0.44	0.64
Moldavia	0.24	0.45	0.37	0.29	0.24	0.24
Rem. Eur. CIS	0.08	0.22	0.19	0.12	0.08	0.10
TOTAL	0.12	0.36	0.26	0.19	0.27	0.27

Table 14B. Annual costs of various scenarios

PERCENT OF ECOSYSTEMS EXCEEDING CRITICAL LOADS						
	Scenario					
Country	1. CRP	5. 1.5*CLS	6. 2.0*CLS	7. 2.5*CLS	9. 50%CLS +CRP	11. Target loads
Albania	0	0	0	0	0	0
Austria	29	0	2	7	1	2
Belgium	94	7	29	40	38	15
Bulgaria	79	2	18	31	9	6
CSFR	85	4	31	35	16	21
Denmark	35	5	7	11	12	11
Finland	23	5	9	17	9	5
France	15	1	1	2	2	1
Germany, West	56	7	16	24	11	12
Germany, East	56	7	16	24	11	12
Greece	2	0	5	5	0	0
Hungary	66	3	6	23	15	16
Ireland	14	1	1	2	1	7
Italy	36	2	3	7	13	7
Luxembourg	95	3	6	7	7	6
Netherlands	95	68	95	95	95	95
Norway	72	60	66	69	63	66
Poland	82	3	19	36	5	31
Portugal	2	3	3	3	2	2
Romania	14	0	2	14	1	1

Table 15A. Percent of ecosystems exceeding critical loads

PERCENT OF ECOSYSTEMS EXCEEDING CRITICAL LOADS						
	Scenario					
Country	1. CRP	5. 1.5*CLS	6. 2.0*CLS	7. 2.5*CLS	9. 50%CLS +CRP	11. Target loads
Spain	0	0	0	0	0	0
Sweden	25	10	14	17	14	15
Switzerland	35	0	4	7	7	5
Turkey	5	2	7	8	3	3
UK	43	15	16	22	16	26
Yugoslavia	18	0	5	10	3	8
Baltic Sea	.	.	.	.	.	.
North Sea	.	.	.	.	.	.
Atlantic Ocean	.	.	.	.	.	.
Mediter. Sea	.	.	.	.	.	.
Black Sea	.	.	.	.	.	.
Kola Karelia	8	0	3	8	1	1
St.Petersburg	8	0	3	8	1	1
Baltic Region	12	0	2	2	1	0
Byelorussia	8	0	3	8	1	1
Ukraine	8	0	3	8	1	1
Moldavia	8	0	3	8	1	1
Rem. Eur. CIS	8	0	3	8	1	1
TOTAL	22	5	9	15	7	8

Table 15B. Percent of ecosystems exceeding critical loads.

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