CRITICAL LOADS MAPS FOR THE UNITED KINGDOM

I. SOILS

A report to the Department of the Environment by

the UK Critical Loads Advisory Group

CONTENTS

CONTRIBUTORS TO THE SOILS AND DEPOSITION MAPS

KR Bull	Institute of Terrestrial Ecology *
GW Campbell	Warren Spring Laboratory
MJ Chadwick	Stockholm Environment Institute, York
MS Cresser	University of Aberdeen
D Fowler	Institute of Terrestrial Ecology
JR Hall	Institute of Terrestrial Ecology *
M Hornung	Institute of Terrestrial Ecology
JG Irwin	Warren Spring Laboratory
RJA Jones	Soil Survey and Land Research Centre
JCI Kuylenstierna	Stockholm Environment Institute, York
SJ Langan	Heaning Consultancy
PJ Loveland	Soil Survey and Land Research Centre
MJ Wilson	Macaulay Land Use Research Institute

* UK Centre for Critical Loads Mapping

MAP 1

PROVISIONAL MAP OF CRITICAL LOADS FOR ACIDITY OF SOILS FOR GREAT BRITAIN

The map is based on 1 km squares of the UK Ordnance Survey national grid and on 1:250 000 scale soil maps, and supporting data bases. The soil maps for England and Wales were produced and published by the Soil Survey and Land Research Centre (SSLRC, 1983), and for Scotland by the Macaulay Land Use Research Institute (MLURI, 1981). Each 1 km square was assigned a critical load for total deposited acidity on the basis of the critical load of the soil map unit which occupied the largest proportion of the square. The map units were assigned a critical load following their allocation to one of five soil classes, defined at the workshop held at Skokloster in 1988 (Nilsson and Grennfelt 1988), which were based on soil mineralogy (Table A). The soil classes proposed at the Skokloster workshop were equated with a band of critical load values, eg 20-50 keq H^+ km^{-2} $year^{-1}$. In the production of this map the classes have been assigned a single critical load value, the upper limit of the band suggested at Skokloster; this has been done to facilitate the production of exceedance maps showing areas where the critical loads are exceeded.

On the soil maps covering Scotland, the map units, which are identified by number, comprise groups of soils, from a given soil association, occurring within a distinct landscape/geomorphological unit. The associations are assemblages of soil series formed on a given parent material. The map units were initially allocated to one of the five soil classes, defined at Skokloster, on the basis of available information on the mineralogy of the parent material of the relevant soil association. This initial allocation was then modified, where necessary, using modifiers based on soil depth, texture and drainage, as suggested at Skokloster. Thus, where a map unit was dominated by shallow soils on slopes, the soil class based on mineralogy was decreased by one class. Conversely, in units dominated by deep soils or soils inundated regularly the class was increased by one.

The map units on the maps covering England and Wales are soil associations, which are groups of soil series occurring within defined, distinct landscape/geomorphological units. The parent material can vary within the association, but only within narrow limits. The associations within England and Wales are named after the most widespread soil series within the association. The map units were initially allocated to a soil class on the basis of the mineralogy of the most widespread soil series within the association. This initial allocation was modified, where necessary, after making allowance for variations in soil depth, texture and drainage conditions, as with the units on the maps covering Scotland.

Organic soils cannot be allocated to one of the Skokloster classes on the basis of mineralogy. An approach developed in the Department of Plant and Soil Science, University of Aberdeen has, therefore, been used. Map units dominated by base poor peats were allocated to one of the five soils classes on the basis of the H^+ load (as H_2SO_4) which would result in a pH reduction in the surface layers of the peats, in the given location, of >0.2; it is assumed that reductions of pH of <0.2 would not have significant ecological consequences. The boundaries between classes have been set using the results of laboratory equilibration studies, and data on the relationship between changes in surface horizon pH of peats in Scotland over the last 20 years and inputs of acidic deposition over that period. The input of acidity over the last 20 years has included both nitric and sulphuric acid. In order to assign the peats to one of the five classes based on sulphur alone, it has been assumed that 70% of the input of acidity was as sulphuric acid and 30% as nitric acid. Where 30% of recent input, ie the nitric acid portion of the input, has produced a reduction in pH of >0.2, the peat unit is allocated to the most sensitive class, class 5. Where 30% of recent input would produce a reduction in surface pH of <0.2, then the critical load has been based on the 'acceptable load' of sulphuric acid, over and above the existing nitric acid load.

Finally, a land use modifier was applied to the complete map using a database developed by the Institute of Terrestrial Ecology (Bunce & Heal, 1984). For each 1km square, the critical load class of the dominant soil was decreased by one unit if the dominant land use for that area was arable or improved pasture. It was assumed that in these areas lime would be added to the soil, where necessary, to maintain the pH within the optimal range for arable crops or high yielding grass varieties. This would clearly increase the "effective critical load".

A number of points must be stressed about the map produced using the above procedures:

1. The map units portrayed on the 1:250 000 soil base maps can encompass considerable variation in soil type, although the soils within any one map unit are usually related to each other by one or more important factors. However, not all soil types within a geographical area may have been recorded at this mapping scale, and not all of the ones recorded occupy a sufficiently large area to be delineated. Thus, the most sensitive soil may have been omitted because it occupies only a very small area of land.

2. The soil properties assessed as the basis for producing the critical loads map were those of the most widespread soil (the 'dominant' soil) within the soil map unit on the 1:250 000 soil map. This may not be the most sensitive of the soils forming the association which corresponds to that map unit.

3. The 1 km squares are assigned a critical load on the basis of the most widespread soil map unit within the square - in practice, the most widespread soil type within the map unit.

4. The critical loads assigned to the soil mapping units have not been calculated using a mass balance approach, dynamic modelling or determinations of weathering rates for specific UK sites. It is a "level 0" map (UNECE, 1990).

5. The critical loads assigned to the soil mapping units are still being validated.

The resultant map is best seen as providing an indication of the regional distribution patterns of soils ranked in terms of a series of critical load/sensitivity classes.

TABLE A

Mineralogical classification of soil material and critical loads of soils:-

Class	Minerals controlling weathering	Critical load keq H^+ km^{-2} $year^{-1}$
5	Quartz *K-feldspar*	20
4	Muscovite Plagioclase Biotite (< 5%)	50
3	*Biotite* Amphibole (< 5%)	100
2	Pyroxene Epidote Olivine (< 5%)	200
1	Carbonates	400

(After Nilsson & Grennfelt, 1988)

MAP 1

Provisional Map of the Critical Loads for Acidity of Soils of Great Britain

The map is drawn by allocating each 1 km square of the national grid of Great Britain to a critical load class on the basis of mineralogy of the dominant soil unit but with modification to allow for current agricultural management.

Critical load classes for acidification (Nilsson and Grennfelt, 1988*), expressed as keq H^+ ha^{-1} $year^{-1}$.

0.2
0.5
1.0
2.0
4.0

* Nilsson, J. and Grennfelt, P., (ed.), Critical Loads for Sulphur and Nitrogen. Report from a workshop held at Skokloster, Sweden 19–24 March, 1988. Organized by UN-ECE and the Nordic Council of Ministers.

Soil data and critical loads classification by Soil Survey and Land Research Centre, Silsoe and Macaulay Land Use Research Institute, Aberdeen. Land use data from Institute of Terrestrial Ecology (Merlewood), Grange-over-Sands. Map compilation by UK Centre for Critical Loads Mapping, Institute of Terrestrial Ecology (Monks Wood), Huntingdon.

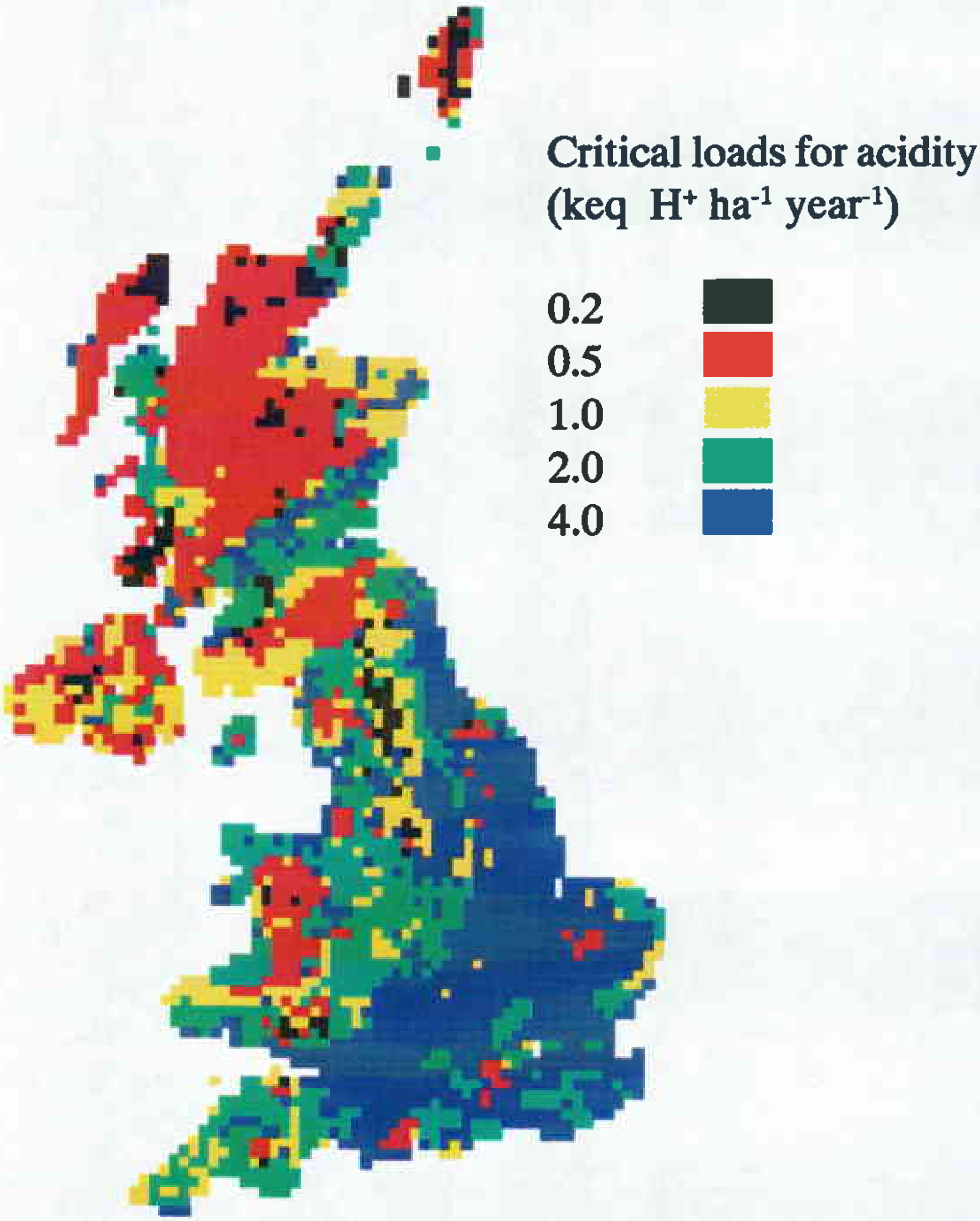
January 1991

MAP 2

CRITICAL LOADS FOR ACIDITY FOR UK SOILS

This map is based on 10km squares of the UK Ordnance Survey national grid of Great Britain. The map of critical loads for acidity of soils draws on 2 datasets. For Great Britain, the 1km map of critical loads for acidity (map 1) is summarized on the 10km grid, using the calculated dominant (modal) critical load class for each *grid square. For Northern Ireland and the Isle of Man, where comparable soil map* data are not yet available, the 1:1 000 000 Soil Map of the European Communities (CEC, 1984) has been used to identify the dominant soil in each 10x10km grid square. The approach used for allocating soils for these areas to critical loads classes was analogous to that used for the 1km critical loads for acidity map (see notes for Map 1). The land use modifier applied to these data was taken from the 1:4 000 000 European Community farming map (CEC, 1987).

Critical loads for acidity of UK soils



MAP 3

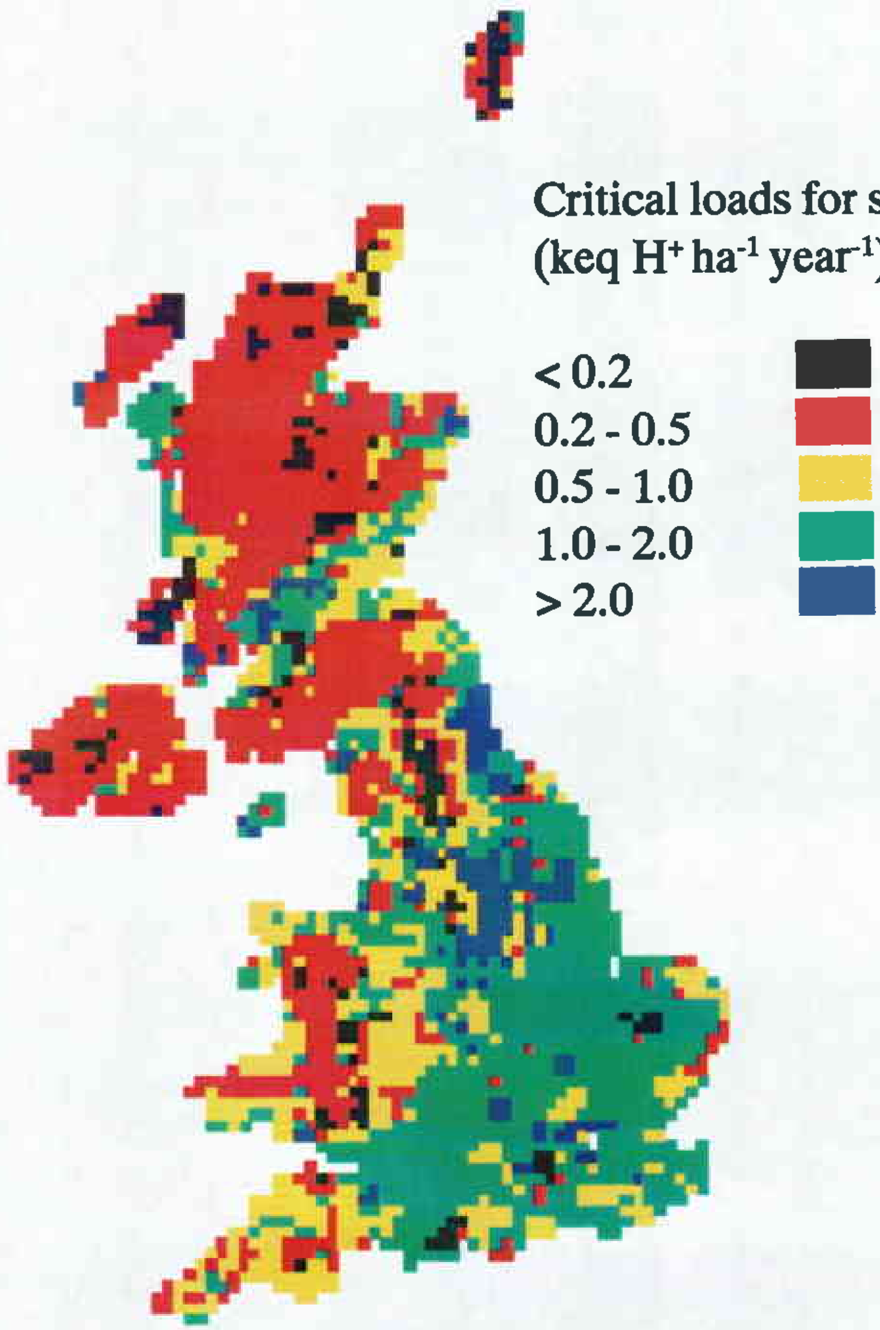
ESTIMATED CRITICAL LOADS FOR SULPHUR FOR THE UK

Critical loads for sulphur have been estimated from the critical loads for acidity, using a methodology recommended by the UNECE Task Force on Mapping. The method partitions each critical load for acidity into a critical load for sulphur and a critical load for nitrogen on the basis of the "current" regional deposition of the 2 elements.

For the UK, the 10km critical loads for acidity map (Map 2) has been partitioned using the calculated ratio of the total sulphur deposition to total (sulphur+nitrogen) deposition (Map 7).

Such maps of critical loads for sulphur can only be considered simple estimates, since partitioning critical loads on the basis of deposition assumes sulphur and nitrogen are identical environmentally and economically. The approach, therefore, ignores any chemical interactions of deposited nitrogen with the terrestrial environment. Also, it takes no account of the different abatement strategies for reducing the deposition of the two elements, or of the relative costs of abatement of any of the components of the two pollutants.

Estimated critical loads for sulphur for UK soils



January 1991

MAP 4

TOTAL NON-MARINE SULPHUR DEPOSITION IN THE UK

Sulphur deposition for the UK has been calculated from the sum of:-

1. data interpolated from measured wet deposited sulphur, including estimated seeder-feeder scavenging;

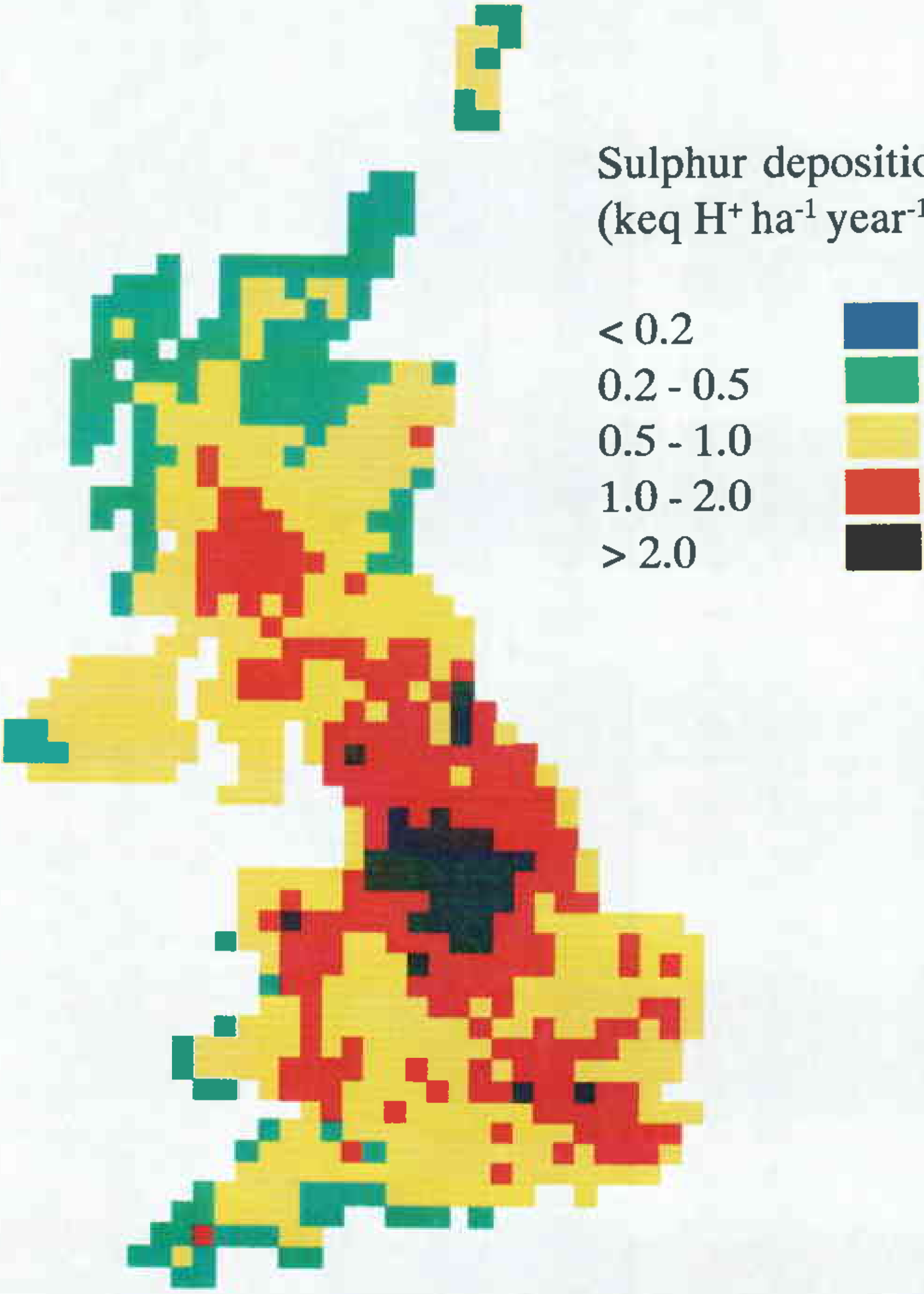
2. dry deposited sulphur modelled from measurements of the gaseous concentration of SO_2, allowing for different deposition rates to different vegetation types;

3. estimated deposition of sulphur from cloud and mist (occult deposition).

These data for Great Britain have been described elsewhere (UKRGAR, 1990). For Northern Ireland simple estimates of dry deposited sulphur have been used in conjunction with the total wet deposited sulphur.

The data are mapped on 20km squares of the Ordnance Survey national grid of Great Britain. This level of resolution is considered appropriate for mapping the interpolated pollutant data. Consequently, when the data are considered for 10x10km squares, the 4 squares within each 20x20km square are given the same pollutant value. The pollutant ranges used for the map are those recommended by the UNECE Task Force on Mapping (UNECE, 1990).

Total non-marine sulphur deposition



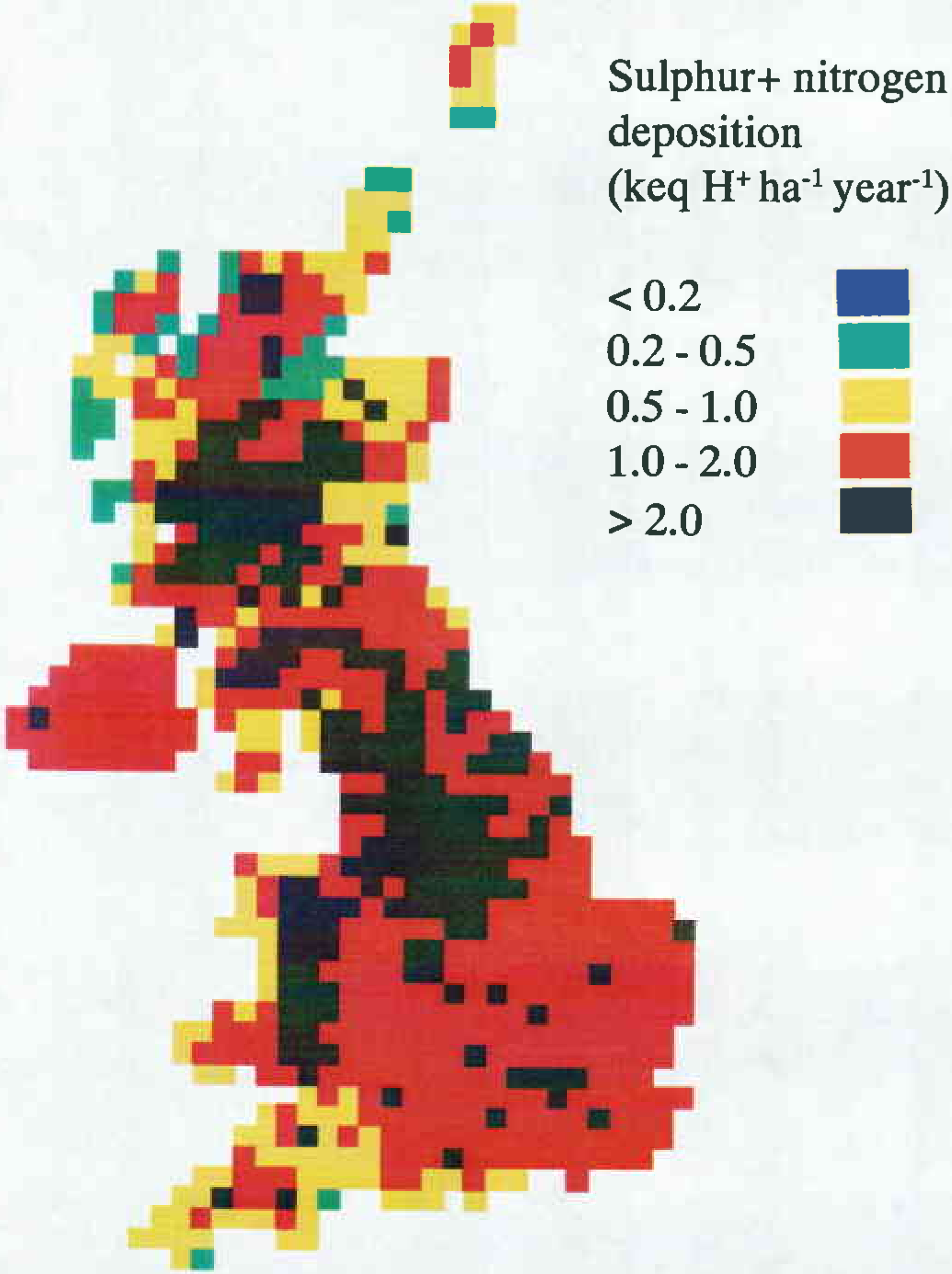
January 1991

MAP 5

TOTAL NON-MARINE SULPHUR AND NITROGEN DEPOSITION IN THE UK

The sum of the total non-marine sulphur (map 4) and nitrogen provides a convenient estimate of deposited acidity. This may be used for comparison with the critical loads for acidity maps. Pollutant data is mapped on a 20km grid as for the sulphur deposition map (Map 4) using the same colour coding and ranges. The methods used for measuring and interpolating the data are described elsewhere (UKRGAR, 1990). Inputs of NH_x to managed land were not considered previously (UKRGAR, 1990) so only estimates for unmanaged land are included here.

Total non-marine sulphur and nitrogen deposition



January 1991

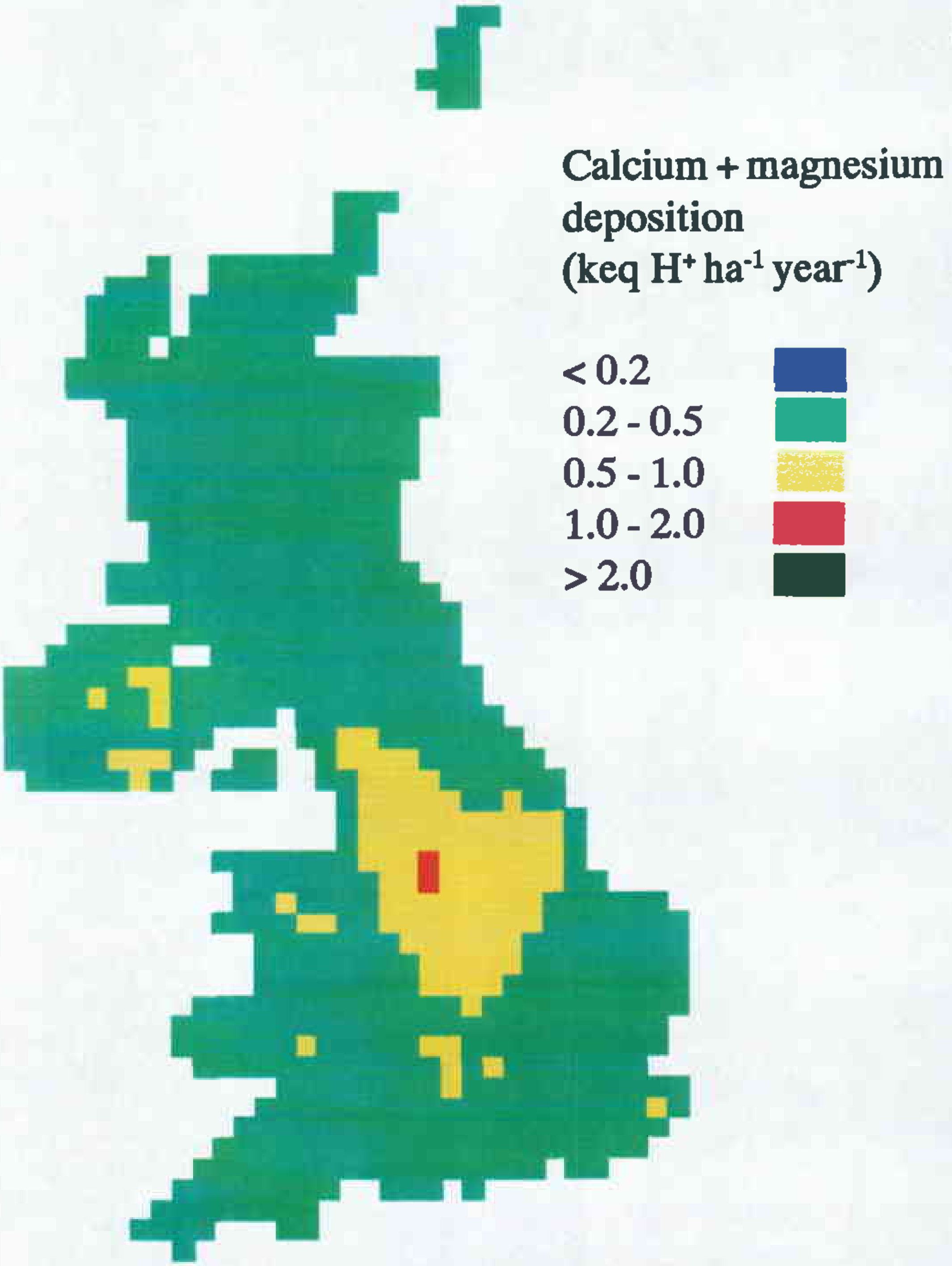
MAP 6

NON-MARINE CALCIUM AND MAGNESIUM DEPOSITION IN THE UK

These elements neutralize the acidity of deposited sulphur and nitrogen. Their deposition values are therefore subtracted from the values of deposited pollutants before these are compared with the maps of critical loads.

The grids, colours and ranges used for the map are the same as those used for the pollutant maps.

Non-marine calcium and magnesium deposition

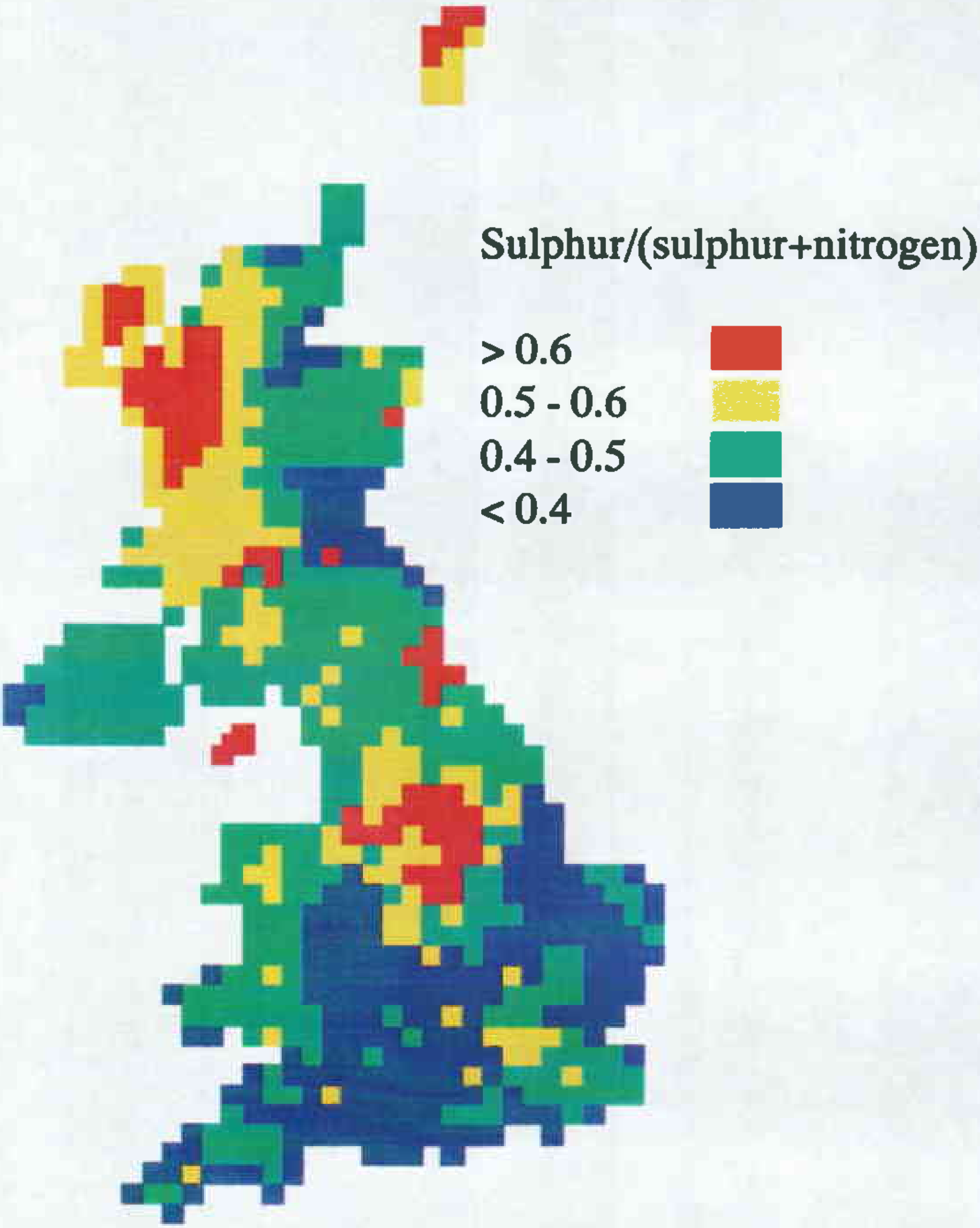


MAP 7

THE RATIO OF TOTAL SULPHUR DEPOSITION TO TOTAL SULPHUR PLUS NITROGEN

This ratio is used for deriving a critical loads map for sulphur (map 3) from the critical loads map for acidity (map 2) according to the methodology recommended by the UNECE Task Force on Mapping. It is also used to calculate a "sulphur component" of the calcium and magnesium deposition for deriving the map showing areas where the critical loads for sulphur are exceeded (Map 9).

Total sulphur/(total sulphur+nitrogen)

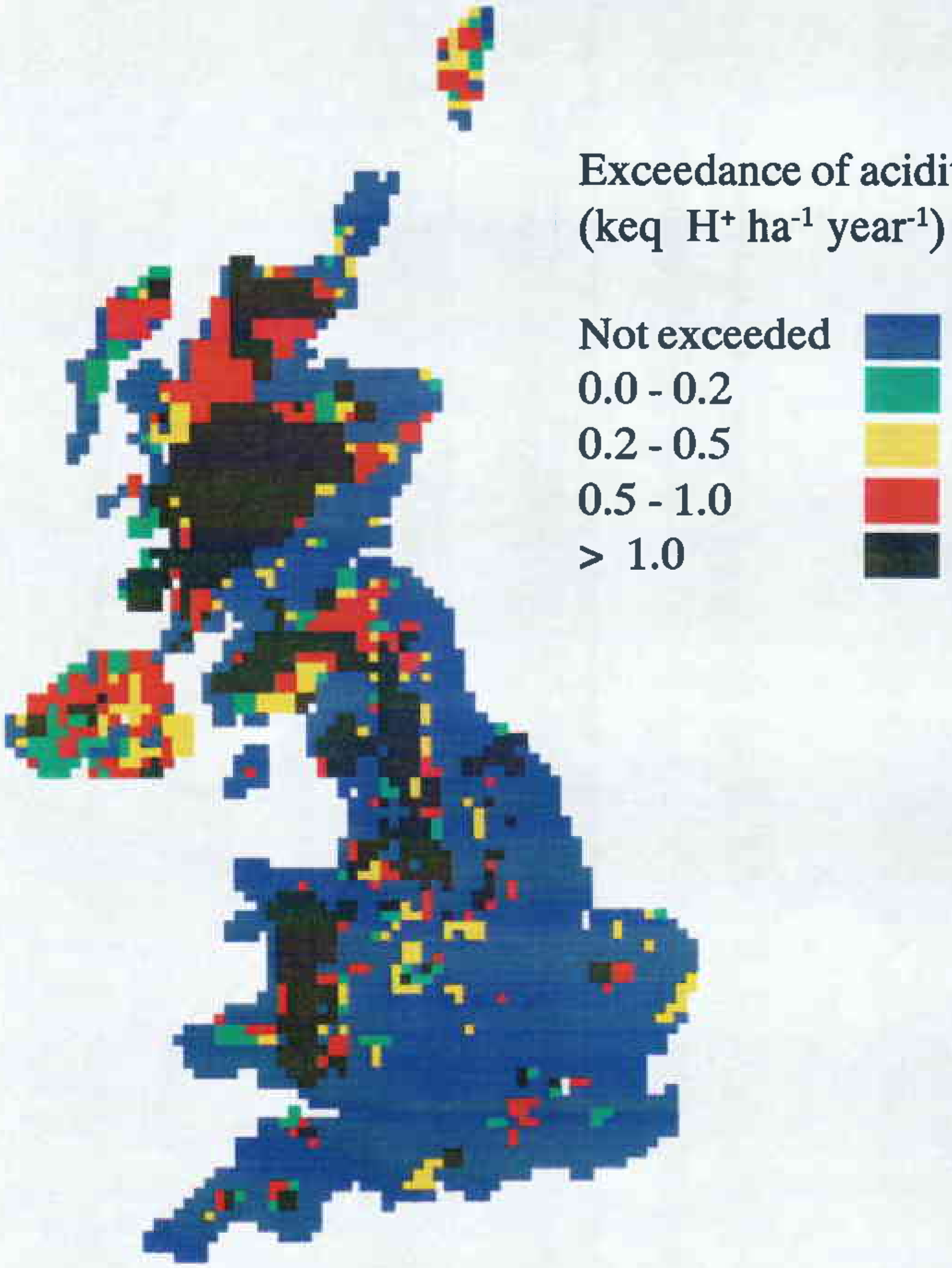


MAP 8

AREAS OF THE UK WHERE CRITICAL LOADS FOR ACIDITY ARE EXCEEDED

The amounts by which critical loads are exceeded are calculated as the difference between the 10km critical loads map for acidity (map 2) and the total sulphur and nitrogen deposition (map 5). As the deposition data are for 20km squares, all four 10km squares within each 20km area are assumed to have the same pollutant value. The pollutant deposition is reduced by the neutralizing non-marine calcium and magnesium deposition (map 6). The ranges displayed on the map are those recommended by the UNECE Task Force on Mapping (UNECE, 1990).

Areas where critical loads for acidity of soils are exceeded

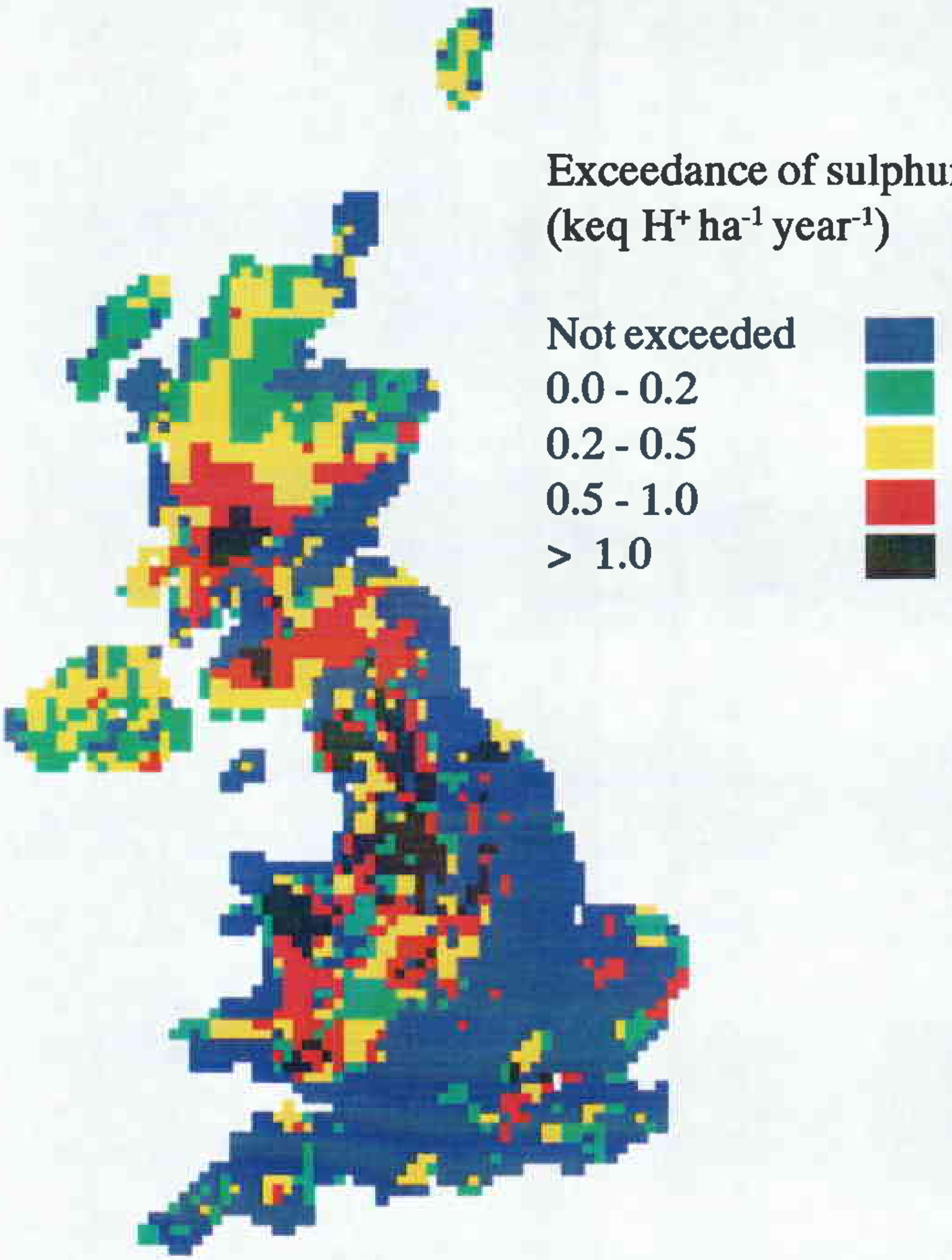


MAP 9

AREAS OF THE UK WHERE THE CRITICAL LOADS FOR SULPHUR ARE EXCEEDED

The amounts by which critical loads for sulphur are exceeded are calculated by subtracting the critical load displayed on the 10km critical loads map for sulphur (map 3) from the total sulphur deposition (map 4). As for map 8, the calcium and magnesium deposition is subtracted from the pollutant load. However, these elements neutralize the deposition of both sulphur and nitrogen, and only sulphur is considered here. Therefore, the calcium and magnesium deposition values for this calculation (for sulphur) are estimated using the sulphur:(sulphur + nitrogen) ratio (map 7) in an analogous fashion to the calculation of the critical loads for sulphur. The ranges displayed on the map are those recommended by the UNECE Task Force on Mapping (UNECE, 1990).

Areas where critical loads for sulphur of soils are exceeded



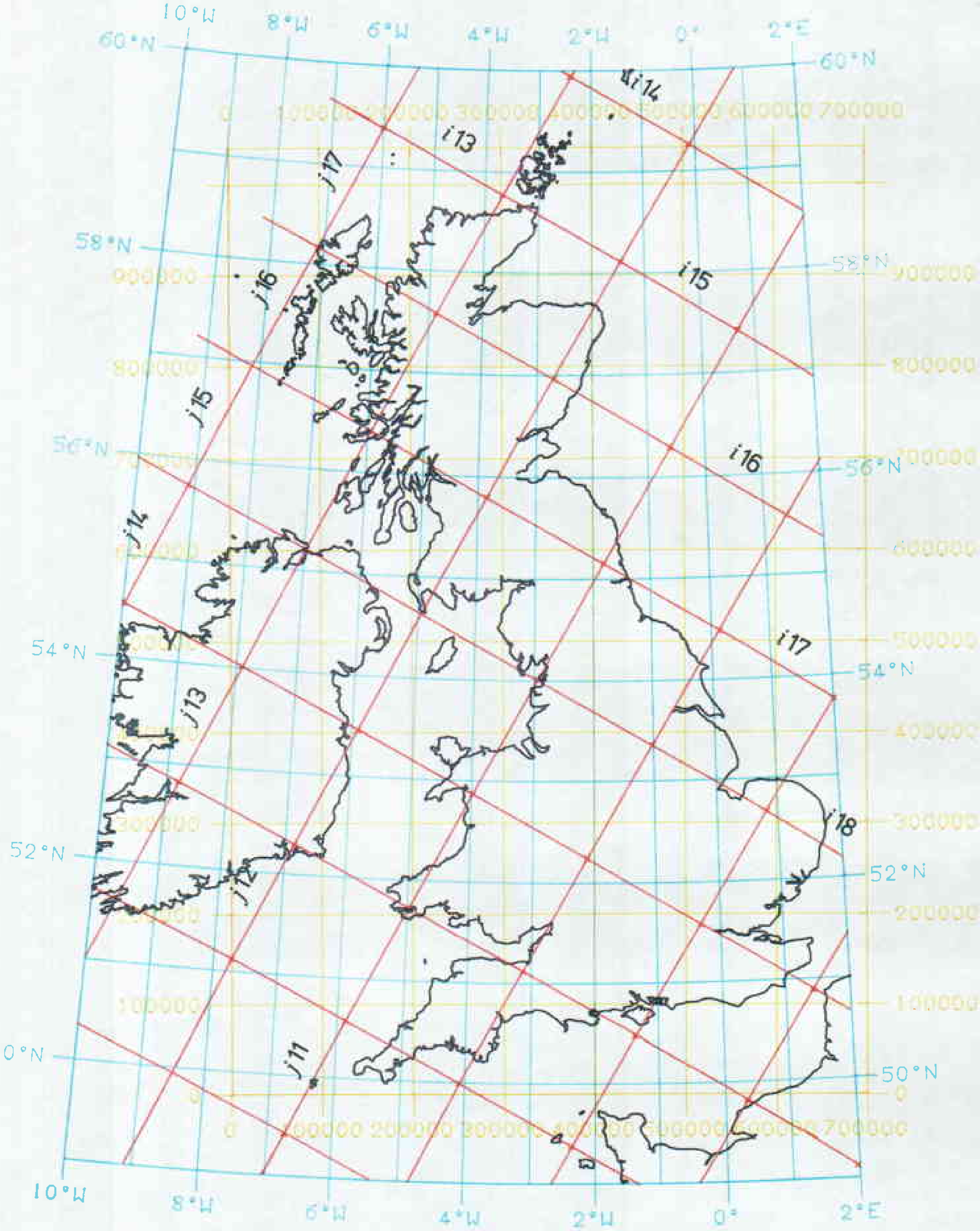
January 1991

MAP 10

THE EMEP GRID FOR THE UK

The EMEP (European Monitoring and Evaluation Programme) grid is to be used for abatement strategy modelling within the UNECE Convention on Long Range Transboundary Air Pollution. The 150x150km grid squares (red) are shown in relation to the UK coastline, the national grid of Great Britain (yellow) and lines of longitude and latitude (blue).

The EMEP grid for the area of the UK



January 1991

TABLE 1

THE PERCENTILE DISTRIBUTIONS OF THE VALUES OF CRITICAL LOADS FOR ACIDITY OF SOILS IN EMEP SQUARES OF THE UK

The base data for the Great Britain and Northern Ireland maps of critical loads for acidity of soils (Maps 1 & 2) have been used to derive the areas covered by each critical loads class. These are expressed in terms of percentage area cover within each EMEP square. It should be noted that some squares are the summation of areas in Northern Ireland and parts of Great Britain, they are therefore based on 2 different data sets. Further, some EMEP squares include the national boundary between Northern Ireland and Eire. For these, only the Northern Ireland areas have been measured. In compiling the European map of critical loads, the additional areas from Eire must be added to this table.

TABLE 1

EMEP		Area cover (%) of critical loads values (CL) +					
i	j	CL=4.0	CL=2.0	CL=1.0	CL=0.5	CL=0.2	sea*
13	14	0.0	0.040	4.90	3.50	0.0	91.56
13	15	0.178	0.500	0.044	0.460	0.071	98.75
13	16	1.01	6.57	1.05	22.5	1.94	66.93
13	17	0.449	0.067	0.124	22.2	7.08	70.08
14	14	2.30	8.00	21.2	16.3	3.1	49.10
14	15	6.29	11.8	10.2	10.8	5.36	55.55
14	16	7.53	8.61	8.93	55.0	11.5	8.43
14	17	4.28	6.39	13.3	20.9	8.48	46.65
14	18	0.200	1.67	1.59	0.347	0.698	95.50
14	19	0.040	0.502	0.613	2.41	2.65	93.79
15	12	0.088	0.551	0.093	0.0	0.0	99.27
15	13	0.916	2.42	2.56	0.333	0.031	93.74
15	14	3.70	4.17	1.36	3.10	0.289	87.38
15	15	5.37	16.8	23.3	22.3	6.66	25.57
15	16	8.64	19.1	8.65	7.59	1.44	54.58
15	17	2.8	1.4	3.94	0.649	10.2	81.01
16	11	0.413	2.51	2.33	0.013	0.0	94.73
16	12	5.58	19.2	9.71	3.63	1.06	60.82
16	13	10.7	28.6	15.9	15.9	4.92	23.98
16	14	18.2	32.9	16.1	11.7	3.08	18.02
16	15	34.9	16.9	16.3	4.49	6.64	20.77
16	16	1.41	0.351	0.008	0.0	0.0	98.23
17	12	6.10	7.25	2.13	1.48	0.004	83.04
17	13	58.2	18.3	4.38	4.32	0.0	14.80
17	14	65.2	14.6	7.21	2.04	0.0	10.95
17	15	22.3	2.13	3.56	1.32	0.0	70.69
18	13	16.1	10.7	1.15	2.38	0.0	69.67
18	14	35.3	8.98	3.35	2.19	0.0	50.18
18	15	5.31	3.63	1.26	1.00	0.0	88.80

+ Critical loads values are in keq H^+ ha^{-1} $year^{-1}$

* For some areas "sea" includes areas of Ireland (Eire)

REFERENCES

Bunce, R.G.H. & Heal, O.W. 1984. Landscape evaluation and the impact of changing land-use on the rural environment: the problem and an approach. In: Planning and Ecology, edited by R.D. Roberts and T.M. Roberts. 164-188. Chapman and Hall: London.

CEC 1984. 1:1 000 000 soil map of the European Communities. Office for the Official Publications of the European Communities: Luxembourg.

CEC 1987. 1:4 000 000 European Community farming map. Office for the Official Publications of the European Communities: Luxembourg.

Nilsson, J. & Grennfelt, P. 1988. Eds. Critical loads for Sulphur and Nitrogen. UNECE/Nordic Council workshop report, Skokloster, Sweden. March 1988. Nordic Council of Ministers: Copenhagen.

UKRGAR 1990. Acid deposition in the United Kingdom 1986-1988. Third report of the United Kingdom Review Group on Acid Rain. Warren Spring Laboratory: Stevenage, UK.

UNECE 1990. Draft manual on methodologies and criteria for mapping of critical levels/loads and geographical areas where they are exceeded. Report prepared by the Task Force on Mapping under the Convention on Long-Range Transboundary Air Pollution of the United Nations Economic Commission for Europe.