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PRESENTATION OF ENVIRONMENT STATISTICS: ENVIRONMENTAL DATA MAPS

PRESENTASJON AV MILJØSTATISTIKK: MILJØDATAKART

BY
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STATISTISK SENTRALBYRÅ

CENTRAL BUREAU OF STATISTICS OF NORWAY

ARTIKLER FRA STATISTISK SENTRALBYRÅ NR. 151

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STATISTISK SENTRALBYRÅ
OSLO—KONGSVINGER 1986

ISBN 82-537-2315-6
ISSN 0085-431x

EMNEGRUPPE

1 Natural resources and environment

ANDRE EMNEORD

Metoder
Miljødatakart
Miljøstatistiske metoder

PREFACE

This report is a reprint of a paper presented to the Statistical Commission and Economic Commission for Europe in December 1985 - at a Meeting on Frameworks for Environment Statistics.

The report deals with methods of presentation of environment statistics - and in special environmental data maps. - The method distinguishes between four types of environmental data maps defined at different hierarchical levels and described in Part I. - The acidification process in Southern Norway is used as an illustration of the method in Part II.

The Central Bureau of Statistics, Oslo, 19 March 1986

Arne Øien

F O R O R D

Denne rapporten er et foredrag som ble presentert for FN's økonomiske kommisjon for Europa (ECE) i desember 1985 - på et møte om miljøstatistikk.

Rapporten omhandler metoder for presentasjon av miljødata - ved bruk av miljødatakart. - Det er skilt mellom fire typer miljødatakart, som er definert for forskjellige hierarkiske nivåer. Disse er beskrevet i Del I. - Forsuringsprosessen i Sør-Norge er brukt som spesielt eksempel på fremstillingsmetoden, beskrevet i Del II.

Statistisk Sentralbyrå, Oslo, 19 mars 1986

Arne Øien

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A B S T R A C T

The purpose of this paper is to present environment statistics and analysis by use of data maps. - The maps illustrate isolated and separated situations as well as more complex ones - by being added and presented together as selected layers of information.

Basically, the paper deals with the presentation of both data on the physical environment and on human health ("human environmental parameters"), in order to illustrate possible causes and effects. Hence - synthesis of environmental data may be a useful tool in order to carry out a comprehensive and "easy to read" evaluation of possible health effects as a result of human behaviour and changes in human activities, - and thus give rise to new hypotheses for further scientific investigations.

- Four types of environmental data maps have been defined at different hierarchical levels. Each type of map might be used separately, however, each level will represent different problems and complex situations hence to be illustrated.

The acidification process in Southern Norwegian watercourses has been used as an example of environmental data maps, illustrating the main causes of acidification in Southern Norway, the actual state of the problem and possible effects of acid rain on human health. However, it is important that the synthesis example stated on the possible link between acidification and certain diseases must <u>not</u> be regarded as a final proof!

PART I

1. BACKGROUND

- The use of maps in presenting environmental data is familiar to most people working with environment statistics. - The use of maps in order to illustrate a situation within an environment is thus an accepted method of presentation. - The use of maps in Environmental Impact Assessment (EIA) or in environmental analysis is becoming more and more frequent.

Maps tend to be more simple than tables in that information presented in maps most often will be aggregated and less detailed than tables. Consequently, the use of maps may face the reader with an easier way of understanding statistics - as compared to the use of tables. By using maps the information is as well being presented within a well known and familiar geographical framework.

The purpose of introducing environmental data maps as a method of analysis and of presentation - and as a method in itself - is to present several sets of data/data series simultaneously, although the different data series might represent different levels of aggregation. Thus the final map might represent a stage of analysis or for example the end product of an Environmental Impact Assessment, implying that this map is an analysis in itself.

One pedagogic advantage of using this presentation technique is to relieve the reader/user of environment statistics by reducing the amount of maps or data series the user has to absorb. In stead the user is accompanied through different stages of information and aggregation levels - leading to the final analythical product. In fact, the process of reading and understanding the statistics will be easier - and hopefully - seem more attractive by the use of such maps.

It is important to realise, however, that environmental data maps are being used in order to illustrate hypotheses and hence must not be regarded as a somewhat final proof of co-variance between statistical measures.

2. ENVIRONMENTAL DATA MAPS - TYPES

One can distinguish between different types of environmental data maps according to the level of aggregation and of generalization to be illustrated. The following types of maps can be adopted in order to make use of thematic mapping through the process of Environmental Impact Assessment:

- Registration maps (first stage)
- Evaluation maps (intermediate stage)
- Synthesis maps (—— " —— —"—)
- Consequence maps (final stage)

Generally, the mapping process will imply that several registration maps will give origin to one or more evaluation maps - and thus make possible the presentation of a synthesis map and a consequence map as an end product (the stages are being presented in detail below). Even though the synthesis and finally the consequence stage will represent the end products, the evaluation maps and the registration maps are valuable in themselves and hence might be used separately. In fact, in most compendiums on environment statistics only registration maps are being presented.

The geographical distribution of the data is a common feature in the different maps being used, and thus opening for more commonly used ways of presentation - as for example choropleth maps and isoline maps (refer Tufte, 1983 and Spear, 1969).

3. REGISTRATION MAPS

The registration maps will represent separate data bases illustrating separate topics or situations and their geographical location and distribution. Environmental data and data on for example human health will thus be presented on separate maps, data at this stage will rarely be aggregated. However, data are usually collected and presented as registration maps resulting from detailed planning and in order to describe certain situations.

This stage of presentation represents the registration of all parameters being relevant to the final stage of analysis - being the synthesis and consequence maps. It is important to bear in mind that a uniformed classification or definition of data is necessary - to assure compatibility at later stages.

The registration maps do indeed represent useful data bases in themselves - in that for example very simple analysis might be carried out based on such maps. However, such data bases will most often be used for purely descriptive purposes.

4. EVALUATION MAPS:

The evaluation map is a presentation of several registration maps (or data) that are added and put on top of each other. The map might be presented as for example an illustration of the assumed effect within a specific situation or the assumed importance of the same effect (by modelling). For example - the evaluation map can be used to illustrate an assumed effect on fish species resulting from hydro electric development. The mapping of an observed effect will be defined as an evaluation map, because the judgement of effect and the following (and thus resulting) state most often will be based on several separated situations and/or a way of classifying the registrations.

The evaluation map is more aggregated as compared to the registration stage, it is the essence of the data that is being utilised. A useful method of aggregation from one level to the next (both from registration to evaluation and from evaluation to synthesis) is to group the data in socalled "equivalent classes" (refer paper prepared by France to ECE meeting on methodological problems in environment statistics, 1985, - "The Presentation of Environmental Statistics"). - The distribution within quality classes in geographical units may be registered and presented as column-diagrams (bar charts). Furthermore, the units will be grouped within equivalent classes - either subjectively (but according to stated theory) or by use of a classification system. Thus the equivalent classes are being presented as for example choropleth maps using different shading or colours (refer figure 6, page 27).

5. SYNTHESIS MAPS

The synthesis maps represent the most aggregated stage for the presentation of environmental data. A synthesis map will contain either a group of evaluation maps being added together or even a group of registration maps, hence presenting a total evaluation of possible and probable causes and effects within a specific situation or an environmental problem.

The step from the evaluation stage to the synthesis stage involves as well the selection of hypotheses, based on careful weighing of the importance of the different registrations and evaluations that have been made so far - and thus which maps are going to be included at the final stage.

Evaluation maps might be supplemented with one or more diagrams in order to illustrate the principles, the assumed connections or relations that the maps are actually based upon. Such a model might illustrate a complexity that is otherwise difficult to explain verbally and will comprise synthesis in itself.

The synthesis stage is the stage where the physical environment might be treated together with for example human activities, and hence data from other disciplines (medicine, sociology and economics) can be included in the syntheses. Studies of possible relations between the physical environment and human health are for example central at this stage and will thus be presented as synthesis maps.

6. CONSEQUENCE MAPS - MAPPING OF CONCLUSIONS BASED ON SYNTHESIS

The stage of the synthesis maps will include the presentation of conclusions that might be illustrated as separate syntheses and hence the final stage of consequences. By doing so one does not aggregate the data any further, however, the data are being presented within a situation describing possible consequences of the synthesis. This type of map will be of relevance mainly to politicians and people dealing with natural resource management.

The maps presented at this stage are being based on complex situations of interconnected relationships between causes, effects and for example possible economic incentives. The maps might in this case be regarded as recommendations rather than as purely illustrations. The maps might even indicate possible recommendations for the location of specific activities, location of economic incentives in order to gain the best effect, or the location of very polluting industries in order to gain the least polluting effect. Possible effects resulting from remedial actions might as well be illustrated as consequence maps.

P A R T I I

7. USE OF ENVIRONMENTAL DATA MAPS - AN EXAMPLE OF ACIDIFICATION

Acid pollution is a reality, and is both a national and an international problem. How acids are being formed in the atmosphere is now much better understood and there is some scientific concensus emerging over the relationship between pollutive emissions and acid deposition. There is, however, much less agreement about how the acids actually damage plants, trees, crops, lakes, fish, buildings or people. How much of the observed damage is due to acid pollution, and how much to other factors, is still hotly debated.

- What is certain is that a variety of gases and particles are implicated in acid pollution and acidification; that sulphur dioxide and nitrogen oxides can be converted in the atmosphere into sulphuric and nitric acids; and that - depending on a variety of biological, chemical and meteorological factors - soils, forests, lakes, rivers, buildings, animal and plant life and human beings are susceptible in varying degrees to the direct or indirect effects of these pollutants.

In recent years acidification has become one of the most serious environmental problems in Norway. A presentation of acidification of Southern Norwegian watercourses is illustrated below by the use of environmental data maps. Some key information has been selected regarding both the registration and the evaluation stages - in order to reach a final stage of synthesis and consequences. However, the information presented on data maps is not exhaustive - meaning that there is still other information being important to the acidification that is <u>not</u> presented in this report.

Acid pollution may cause a threat to health in three ways:

(i) - in the short-term through breathing heavily polluted air;

(ii) - a long-term deterioriation through constantly breathing lower levels of polluted air;

(iii) - indirectly by exposure to heavy metals or aluminium released into soils and water as a result of acidification, the accumulation of metals in the aquatic food chain, or heavy metals dissolved in acidic tap water supplied through lead or copper piping.

Recent scientific research (Dr. Perl, University of Vermont, USA) has indicated that exposure to high aluminium (Al) levels in for example drinking water might cause serious health implications in the long run (see chapter 11). Thus at this stage registration and evaluation data on human health have been included in the synthesis of acidification because of the assumed correlation between low pH-values and high Al-concentrations in drinking water. Hypotheses needed to reach from one stage to the next are presented as well.

The example of the acidification of Southern Norwegian watercourses represents a systematic survey of well-known connections related to this problem. Hence the number of registration maps is being limited to include the subjects necessary to undertake both evaluation and synthesis of main features through the process of acidification. And finally, consequences are included in the synthesis stage.

A map of Southern Norway with a simplified coastal line and including county boundaries has been used as a basis map. Such a simplified map with major geographical information or features being left out, is part of the process of simplification (generalization) and has been used in order to make the essence of the data easier to absorb. See figures 1.A and 1.B, page 22.

8. REGISTRATION MAPS:

The annual average supply of sulphur to Norway from main sources in Europe 1978-1980, is illustrated in figure 2, page 23.

- Some basic hypotheses from previous research on problems related to acid rain might be used, as for example:

- There exist a connection between the content of acid components in air and precipitation and the acidification of watercourses.
- The chemical composition of bedrocks and soil is being causative to wheather acid rain will cause acidification of the watercourses.
- There is a connection between acidic water and fish mortality.

The presentation of acidification of watercourses as an environmental problem must be based on a registration of the main supplies of acid components from the air.

- The geographical distribution of annual precipitation is illustrated in figure 3.A, page 24.

- The content of sulphate, nitrate and ammonium are some of the most essential indicators on chemical components in air causing acid reaction when being in contact with water, - being registered as annual mean concentrations in precipitation. See figures 3.B, 3.C and 3.D, page 24.

The degree of acidity or alkalinity of a liquid is measured on the pH scale. This ranges from 0 to 14, with 0 being the most acid, 7 being neutral (the pH of distilled water) and 14 the most alkaline. The scale is logarithmic, which means that a step of a single number increases or decreases acidity by a factor of 10.

All rain is slightly acidic because of the natural carbon dioxide (CO_2) content of air. Dissolved in water, CO_2 forms carbonic acid - a weak acid. So while distilled "pure" water has a pH of 7, "normal" or unpolluted rainwater (i.e. water in equilibrium with atmospheric carbon dioxide) has a pH of about 5.6, although the presence of naturally occuring sulphur dioxide, ammonia, organic compounds or dust can cause "normal" pH values of between 4.9 and 6.5 (NATURE, 295, 1982). - pH measured in precipitation in Southern Norway is presented in figure 4.A, page 25.

Aluminium (Al) plays a key role in several chemical and biological processes provoked by an excess of sulphur and nitrogen compounds. Aluminium is normally tied to soil particles or to humus substances in water, and causes no harm to living organisms as long as it is immobile. But in heavily weathered soils and bedrocks with a high input of hydrogen ions and low buffering capacity, aluminium ions can be released and washed deeper down into the soil, eventually reaching the groundwater (also refer chapter 11). - Figures 4.B and 4.C, page 25, show areas in Southern Norway with Al-concentrations in 1974 and 1981. Concentration of Al in drinking water, 1982-83, is illustrated in figure 4.D, page 25.

9. EVALUATION MAPS

Evaluation maps that can be based on the registrations above will illustrate a general survey of the deposition of for example the amounts of sulphate, ammonium and nitrate to certain areas in Norway. In principle, these maps will contain information on both the precipitation and on concentrations of substances in the precipitation. Figure 5.A (page 26) shows the amount of sulphate supply to Southern Norway being expressed as annual wet deposition of sulphur (gS/m^2). The same type of map might be constructed in order to illustrate the supply of nitrate and ammonium.

The chemical composition of the local soil will mainly be reflected by the composition of the bedrocks, - and hence in this case an evaluation map has been constructed only for bedrocks, see figure 5.B (page 26). The map is simplified and thus illustrates only acidic and heavily weathering bedrocks, as this type of bedrock represents the poorest natural buffer against acid rain.

In Norway's four southernmost counties, fish stocks have been halved since 1940. Lakes and rivers covering an area of more than 13 000 sq km (5 000 sq miles) contain no fish, and fish stocks have been reduced in a further 20 000 sq km (7 700 sq miles). - In total, approximately 33 000 sq km of Southern Norway is affected by acidification and 1 700 fish stocks are lost (SNSF-project, 1980).

- Areas in Southern Norway with heavily affected or totally destroyed fish populations are illustrated in figure 5.C (page 26). Such a map might comprise a synthesis map, if being constructed by using the registrations and evaluations in order to predict what areas might be affected. - The map might on the other hand represent a registration map if the effects were widely recognized purely as measured effects of acid rain.

A special type of evaluation map might be constructed by adding registration maps on the same parameter, however - referring to different periods of time. Such a map will illustrate the change in different parameters over time, and hence might be a useful tool in the process of presenting for example predictions or a registration of different development patterns (refer the French method on registration of evolution rythms, ECE, 1985).

As an example of an evaluation map illustrating development over time the two maps on Al-concentrations in lakes in 1974 and 1981 (figures 4.B and 4.C) are being added and presented in figure 5.D (page 26). - The areas that have definitely experienced a worsening situation as regards an increasing content of Al in drinking water within the time period, are the south-eastern parts of Norway.

10. SYNTHESIS MAPS

- Figure 6 (page 27) illustrates a survey of the acidfication situation in Southern Norway, based on data on pH and alkalinity and by using a system for evaluation of water quality (developed by The Norwegian Institute for Water Research, 1984). The counties in the map are grouped according to the distribution of selected monitoring stations in Norwegian counties within water quality classes. The actual grouping is similar to the French method being referred to in chapter 4 (ECE, 1985). The map (figure 6) is supplemented with a diagram illustrating the distribution of counties within equivalent classes - and hence comprises a synthesis map.

This synthesis map is not based solely upon several registration and evaluation maps, corresponding maps might easily be drawn based on registrations of pH-values and concentrations of bicarbonate (HCO_3^-).

A synthesis map on the subject of acidification will in principle be constructed by adding all relevant registration maps and evaluation maps. Thus areas with a multiple of unfavourable factors are also the areas being most exposed to acidification. Such a synthesis map may most easily be constructed by the use of special electronic equipment for image processing - or photographically - based on specially established data bases.

Alternatively, in lack of sufficient equipment, several registration maps and evaluation maps might be presented next to each other and comprising a somewhat "logic order", so that the synthesis map will consist of several "sub-sets". The synthesis stage will thus illustrate - logically - causes of acidification, the acidification situation in itself and effects of acidification - partly as illustrated in figures 3, 4 and 5 in this report.

A simple and different synthesis map is shown in <u>figure 7</u> (page 28) - presenting the distribution of populations exceeding 5 000 inhabitants in Norway, the location of main polluting industries and areas being specially exposed to problems of environmental toxins. The map simply illustrates that the heavily polluted areas in Norway are located close to densely populated areas - which, however, is a common feature in most industrialized countries!

11. SYNTHESIS AND CONSEQUENCES: AN EXAMPLE OF ACIDIFICATION AND EFFECTS ON HUMAN HEALTH

At this stage an example of synthesis will be to test a hypothesis on the relationship between Al-concentrations in drinking water and the mortality rate resulting from certain diseases in

Norway.

- A report in Science (1984) states that acid rain has been tentatively implicated in several brain disorders including Alzheimer's disease, senile dementia, Parkinson's disease and amyotrophic lateral sclerosis (Lou Gehrig's disease). Drawing on research conducted by a bevy of scientists, the key factor in these diseases may be aluminium. Unusually high levels of aluminium have been found in the brain lesions of those who suffered from these disorders, although a cause and effect relationship has not been finally proved. Recent studies in Japan and Guam, however, suggest that aluminium may indeed play a causative role in the diseases.

The possible link with acid rain is as follows: Alùminium is abundant in the earth, comprising about 5 per cent of the planet's crust. Aluminium is insoluble in water that is either neutral or alkaline. But when the acidity of water - rain, snow, sleet, fog, - increases, it begins dissolving aluminium in lake-bottom sediments, soil, metal pipes used to transport water, and soldering materials used to join sections of pipe (also refer chapter 8).

The same phenomenon goes for other metals as well: lead, cadmium, and mercury - all dissolve much more readily as the acidity of water increases.

Humans can absorb aluminium directly through drinking water from acidified areas. There may also be some uptake of aluminium in grain and other plants cultivated on acidified ploughed land. - Figure 4.D showed a registration of Al in drinking water in Southern Norway, based on a sample survey in 1983 (The Norwegian Geological Survey, 1984). Furthermore, an evaluation of Southern Norway based on concentrations of Al in surface waters in lakes, is illustrated in figure 8 (page 29). The Southern Norwegian municipalities have been grouped within 5 different zones, according to Al-concentrations - and with increasing concentrations from zone 1 to zone 4. In zone 5 the municipalities with highest acid depositions out of zone 4, were grouped.

- The concentrations of Al are highest in the coastal zones of South-Eastern Norway in both drinking water and in surface waters of lakes (figures 4.D and 8) - as have been commented on in chapter 8.

Based on a study of the possible relationship between mortality rates (age-adjusted) from presenile dementia and senile dementia in Norway and concentrations of Al in lakes and drinking water (Vogt et. al., report in prep.), mortality rates from these diseases during the period 1969-83, increase from zone 1 to zone 5, refer figure 8. - This may suggest that there exist a relationship between Al-concentrations and mortality from senile dementia in Norway, and hence a co-variance between acid rain and the occurrence/deaths from these diseases. The number of people with a medical diagnosis of senile dementia or presenile dementia will indicate the occurrence of Alzheimer's disease within the population, as between 50 and 70 per cent of people with the dementia diagnosis are suffering specifically from Alzheimer's disease.

In the study referred to above, mortality rates from other diseases were checked as well - within the 5 different zones. The trend for other diseases was not as for senile dementia - and thus did not increase from zone 1 to zone 5. The mortality rates from senile dementia and presenile dementia were studied within age-groups, as the diseases are mainly present within the older age-groups. - The development in age structure (meaning more elderly people) over time was less in zone 5 than in the other zones, and recent patterns of people's movement in Norway do not suggest that zone 5 is being "favoured" by the older age-groups.

It is important to point out that the co-variance referred above must not be regarded as a proof of an existing linkage between acid rain and senile dementia. However, the study suggests a co-variance that may cause further scientific studies to be undertaken - and indeed indicating potential areas of action for the Norwegian politicians!

THE MAPS

FIG.1 SIMPLIFICATION OF A BASE MAP TO FIT THE PURPOSE OF ENVIRONMENTAL DATA MAPPING, SOUTHERN NORWAY. A - TRADITIONAL GEOGRAPHICAL MAP, B - SIMPLIFIED MAP.

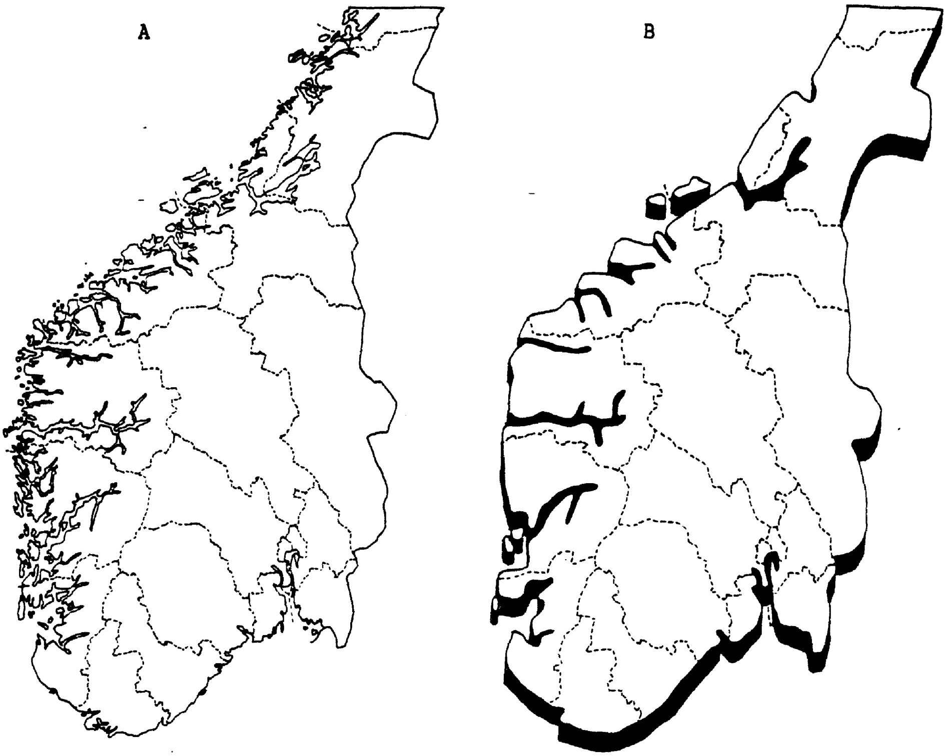


FIG.2 ANNUAL AVERAGE SUPPLY OF SULPHUR TO NORWAY FROM MAIN SOURCES IN EUROPE (1.OCT. 1978 - 1.OCT. 1980). 1 000 TONS SULPHUR.

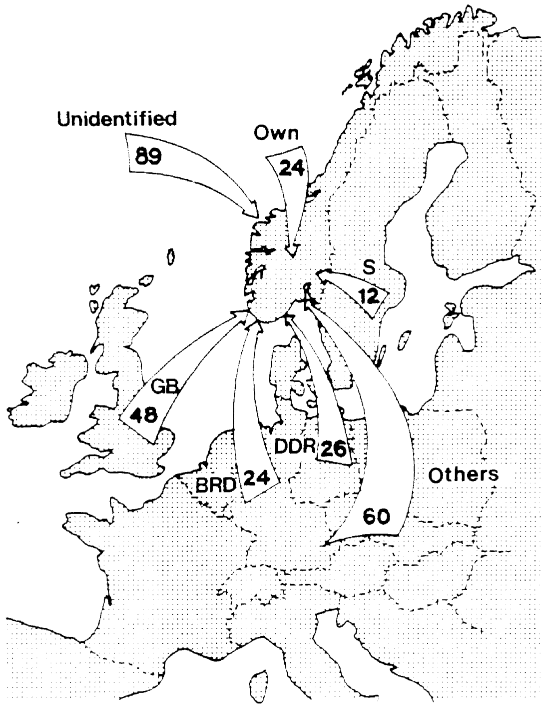


FIG.3 MEAN ANNUAL SUPPLIES OF COMPONENTS SIGNIFICANT FOR THE ACIDIFICATION OF SOUTHERN NORWAY.

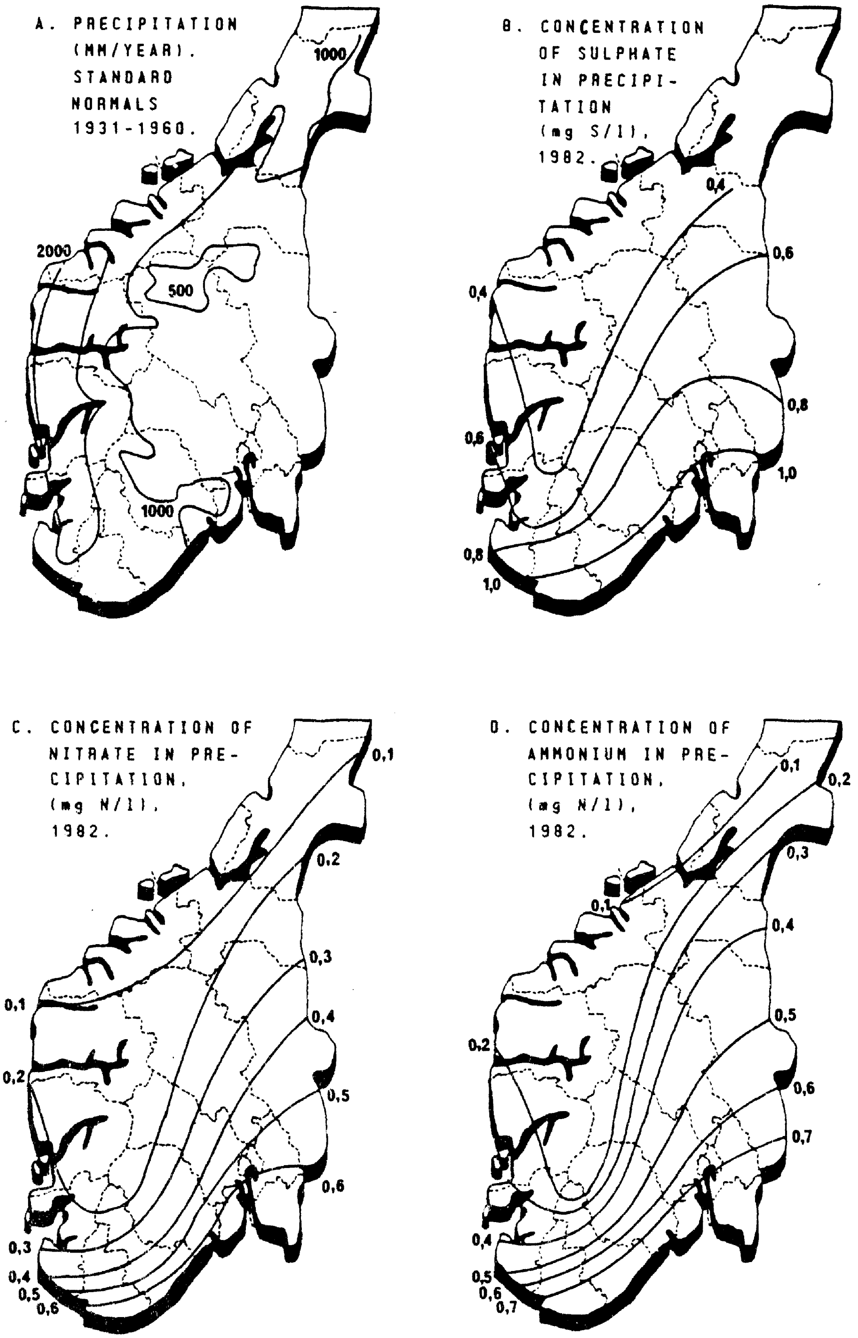


FIG.4 pH IN PRECIPITATION (A) AND MAIN EFFECTS OF THE ACIDIFICATION IN SOUTHERN NORWAY (B-D).

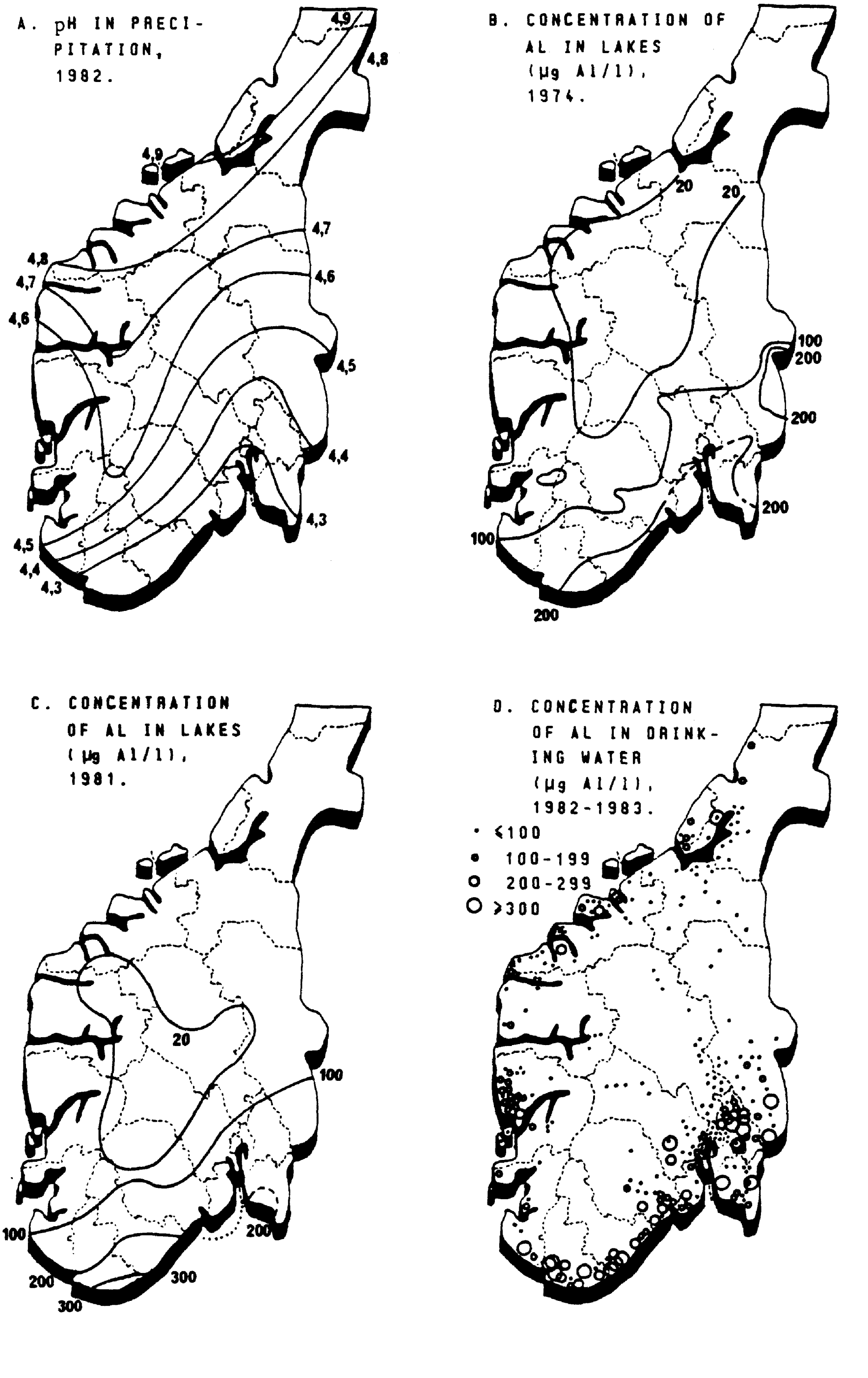


FIG.5 SUPPLY OF SULPHATE (A), BEDROCKS OF POOR BUFFERING CAPASITY (B), AND EFFECTS OF THE ACIDIFICATION IN SOUTHERN NORWAY (C AND D)

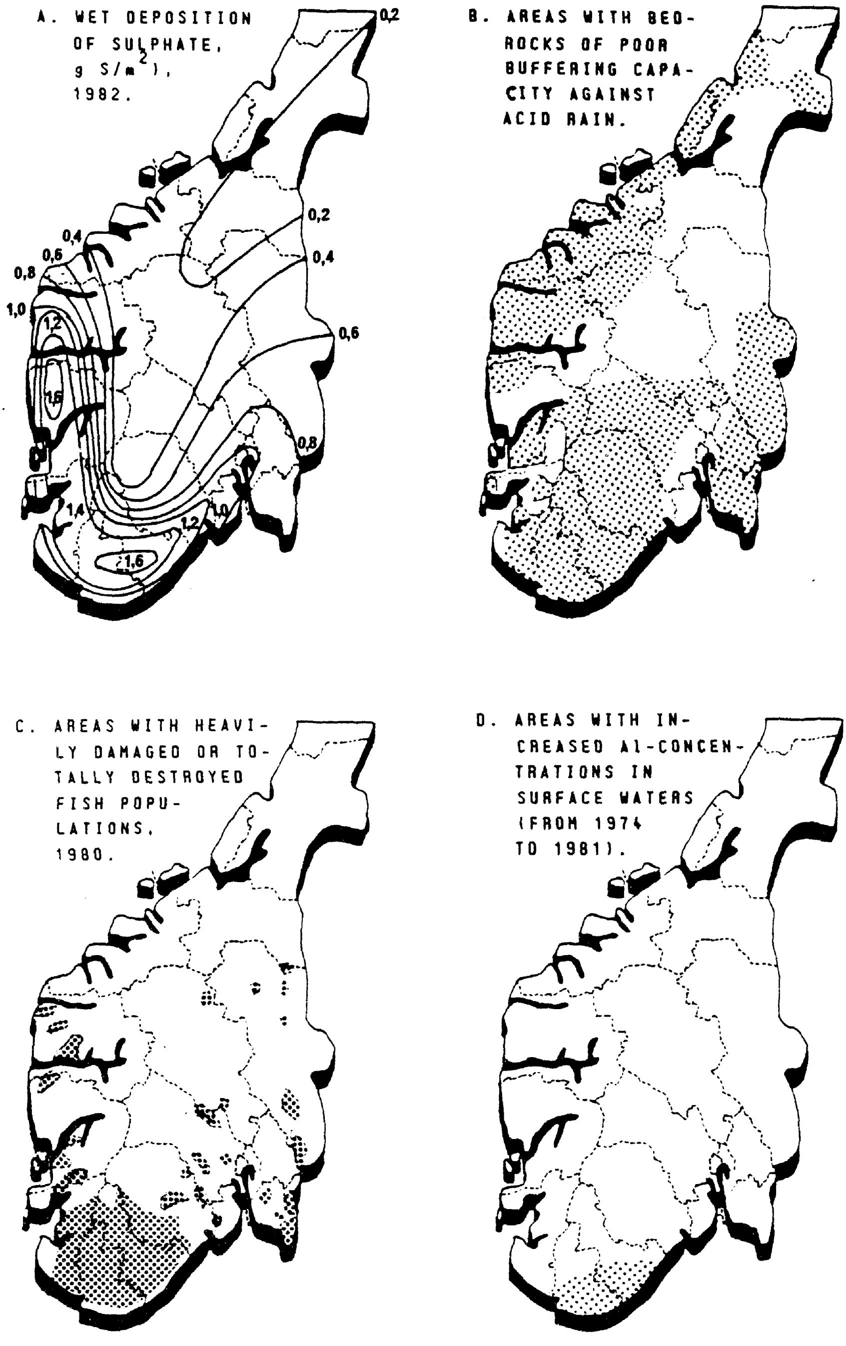
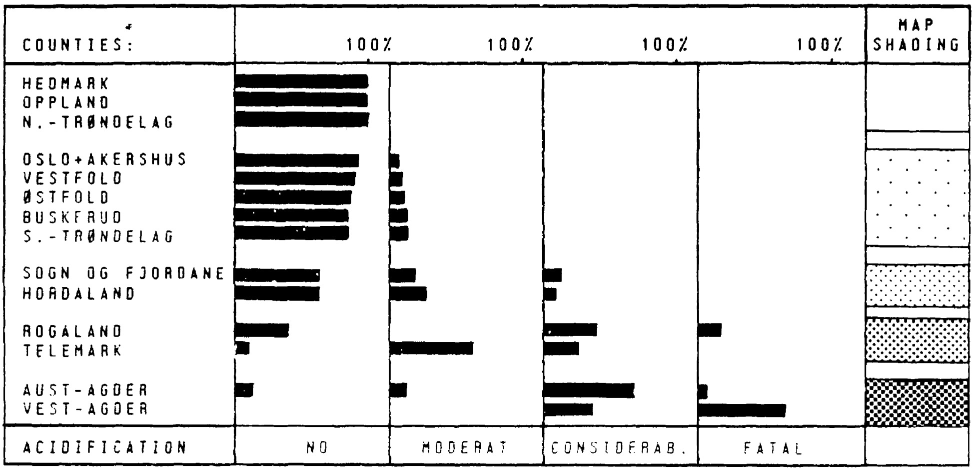


FIG.6 ACIDIFICATION IN SOUTHERN NORWAY EXPRESSED AS THE DISTRIBUTION OF SELECTED MONITORING STATIONS WITHIN WATER QUALITY CLASSES IN COUNTIES. SOUTHERN NORWAY, 1982.



* No data from the county of Møre og Romsdal

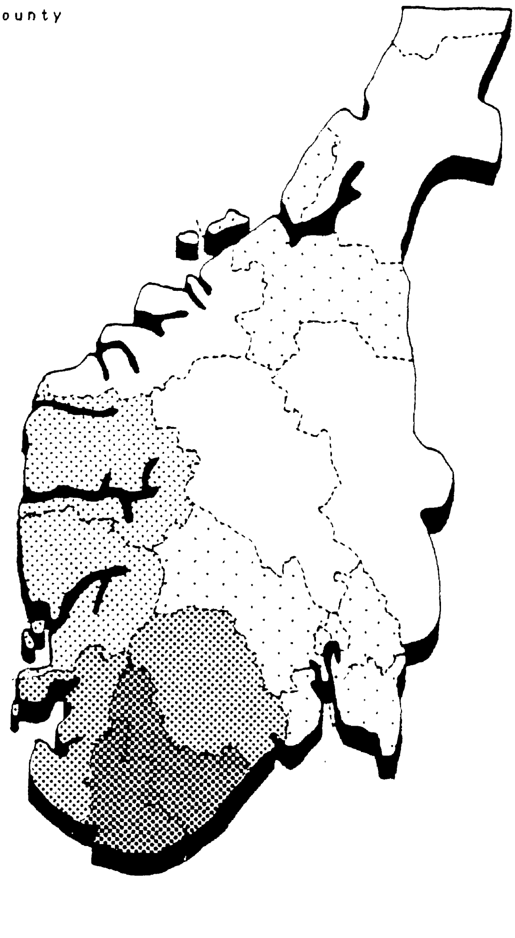


FIG.7 DISTRIBUTION OF SETTLEMENTS EXCEEDING 5 000 INHABITANTS, LOCATION OF MAIN POLLUTING INDUSTRIES AND AREAS SPECIALLY EXPOSED TO PROBLEMS OF ENVIRONMENTAL TOXINS. SOUTHERN NORWAY, 1980.

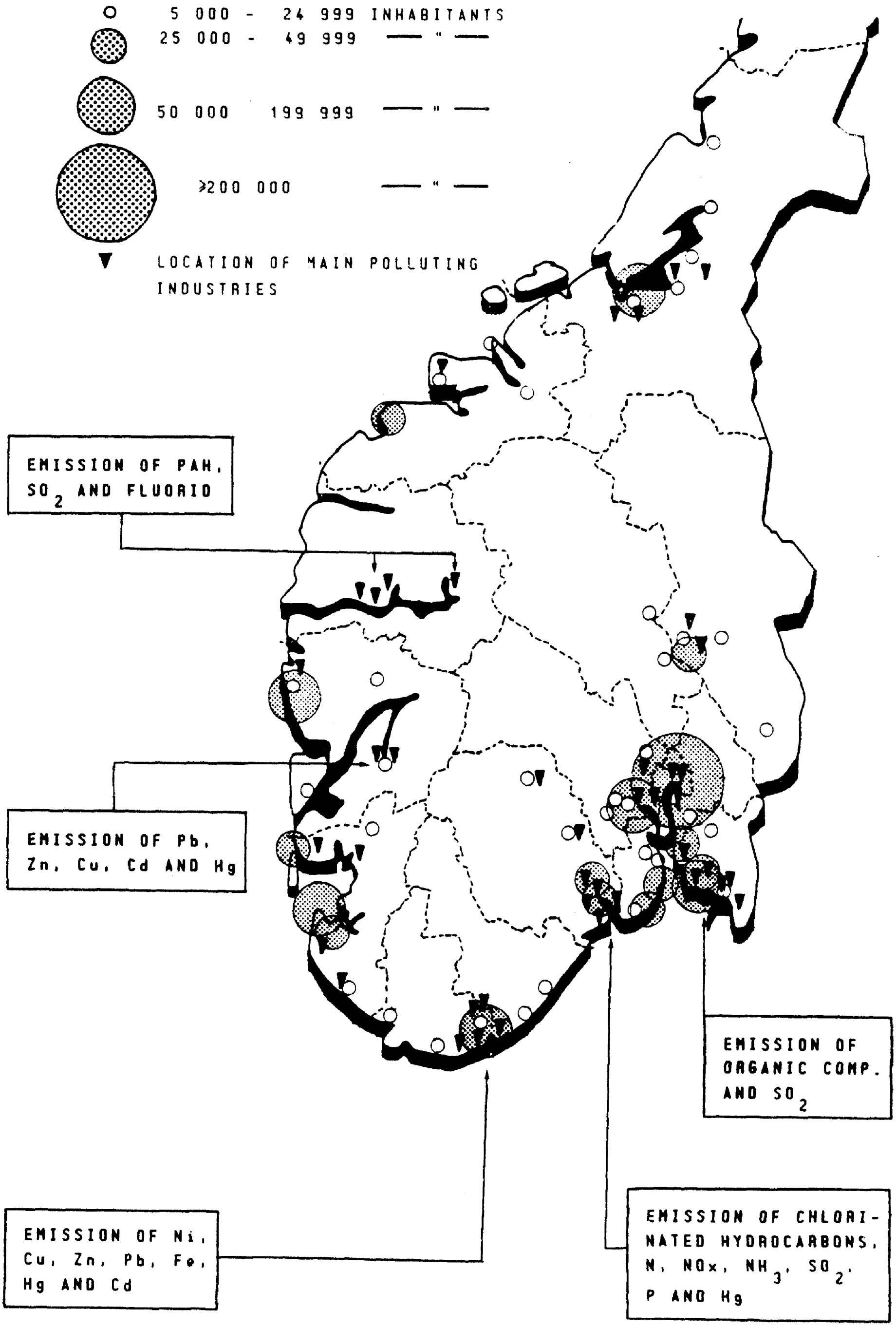
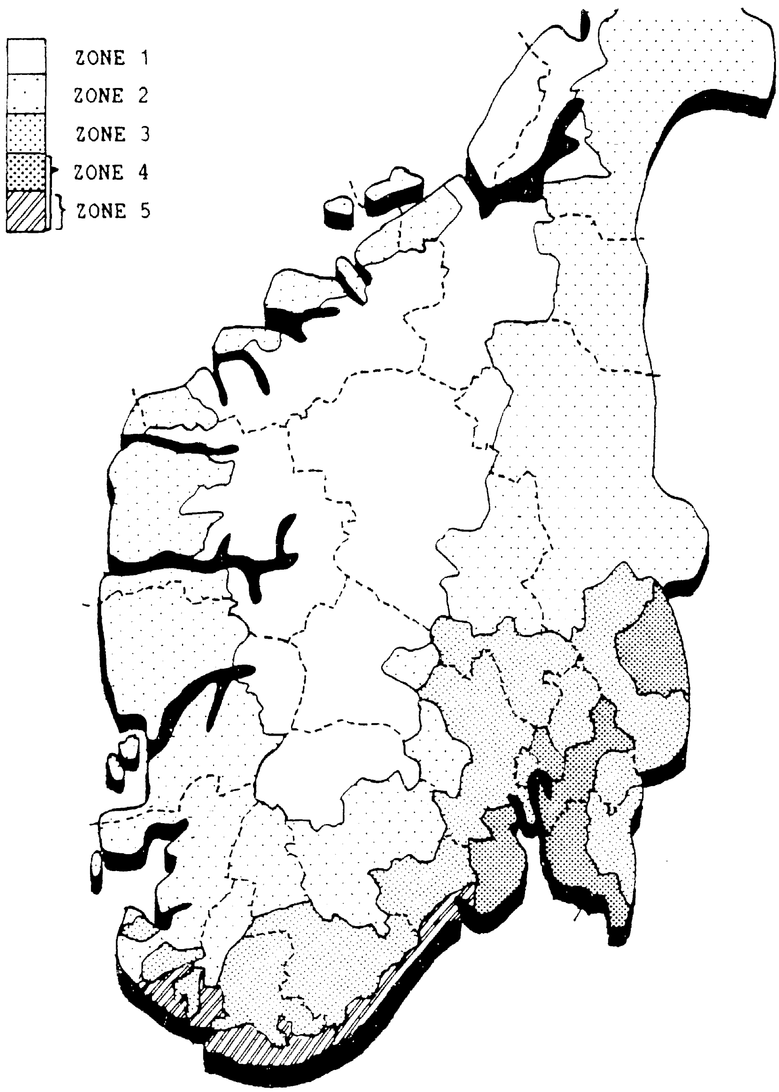


FIG.8 CONCENTRATION OF ALUMINIUM IN SURFACE WATERS OF LAKES. DIVISION INTO ZONES. SOUTHERN NORWAY.



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Publikasjonen utgis i kommisjon hos
H. Aschehoug & Co. og Universitetsforlaget, Oslo,
og er til salgs hos alle bokhandlere
Pris kr 20,00

Omslag trykt hos Grøndahl & Søn Trykkeri, Oslo

ISBN 82-537-2315-6
ISSN 0085-431x