Arbejdsrapport fra DMU nr. 24

Mapping effects of ozone on yield of agricultural crops and forest production in Denmark

Critical Loads

Miljø- og Energiministeriet, Danmarks Miljøundersøgelser

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Miljø- og Energiministeriet
Danmarks Miljøundersøgelser
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Data sheet

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Foreword

Mapping of yield losses due to ozone

The ongoing efforts on mapping of critical loads within the framework of UN-ECE (United Nations Economic Commission for Europe) is the background for the present project on mapping of yield losses in agriculture and forestry due to ozone.

National Focal Center

The Department of Terrestrial Ecology (TERI) at the National Environmental Research Institute (NERI) is the National Focal Center for mapping of critical loads in Denmark, and as such, represents the Danish Environmental Protection Agency (DEPA) in the Task Force on Mapping under the Convention on Long-Range Transboundary Air Pollution, which was agreed upon among the UN-ECE member states in 1979.

The present project was carried out as a co-operation between DEPA and NERI.

Acknowledgments

We are grateful for the support and comments we received from Anne Marie Bastrup-Birk, Kit Granby, Mads Hovmand, Ole Mansher and Lisbeth Mortensen, all staff members at the National Environmental Research Institute, Department of Atmospheric Environment. Niels Henrik Bastholm did the revision of the report as regards language and punctuation.

We also want to thank Teis Mikkelsen from the University of Copenhagen for an introduction to ozone problems.

Dansk sammendrag

Forhøjede ozonkoncentrationer

Emissioner af kvælstofilter (NOx) og flygtige kulbrinter (VOC) kan under indflydelse af ultraviolet lys reagere med luftens ilt, hvilket kan føre til forhøjede ozonkoncentrationer, som kan skade afgrøder og andre planter. Ozon kommer ind i planterne gennem spalteåbningerne, hvor skadevirkningen sker på grund af ozons oxiderende evne.

Langtransporteret

I Danmark er høje ozonkoncentrationer overvejende bestemt af om ozon bliver transporteret hertil; dette sker ved sydøstlige vinde fra Øst- og Centraleuropa, hvor der i sommerhalvåret både optræder høje NOx og VOC koncentrationer samtidig med at UV-indstrålingen er stor. I øvrigt henvises til Fenger (1995, på dansk) og Fenger (1996, på engelsk) fra DMU's afdeling for atmosfærisk miljø, hvor der arbejdes med problemer omkring fotokemisk luftforurening, måling af troposfærisk ozon og effekter af ozon på afgrøder og træer.

Geneve Konventionen

Det er bl.a. ozons evne til at skade afgrøder, med deraf følgende udbytteforringelse, der er årsag til at ozon er kommet på dagsordenen internationalt set. Begrænsning af luftforurening koordineres i UN-ECE regi. Geneve Konventionen, der omhandler langtrækkende grænseoverskridende luftforurening, blev vedtaget af UN-ECE landene i 1979. Under Geneve Konventionen kan der vedtages protokoller om begrænsning af udslip af de enkelte typer af luftforurening. DMU beregner og kortlægger, som Nationalt Fokuscenter for kortlægning af tålegrænser, overskridelser af tålegrænser for Miljøstyrelsen. Dette arbejde indgår i en samlet europæisk kortlægning af tålegrænseoverskridelser.

Hvede, græsdominerede arealer, løvtræ, nåletræ

Tab på op til 2 milliarder kr.

På basis af DMU's målinger af troposfæriske ozonkoncentrationer og effekterne på udvalgte afgrøder i åben-top-kamre er udbyttetabet som følge af ozonbelastningen blevet beregnet og kortlagt for hvede, græsdominerede arealer, løvtræ og nåletræ i Danmark. Kortlægningen er sket i et 5 x 5 km netværk. Denne detaljeringsgrad bestemmes af variationer i afgrødeudbyttet. Tabet kan i år med høje ozonkoncentrationer på landsplan andrage beløb i størrelsesordenen 2 milliarder kroner for de fire ovenfor omtalte produkter. Som middel vil det totale tab være i størrelsesordenen 1 milliard på landsplan, og man vil som minimum skulle regne med et totalt tab på en halv milliard kroner. Af dette tab stammer ca. 2/3 fra hvede, ca. 1/4 fra græsdominerede arealer og resten fra løv og nåleskov. Resultatet afhænger dog af i hvilken grad resultaterne fra åben-top-kamre er repræsentative for det åbne land.

Første kortlægning

De beregninger der præsenteres i rapporten er foreløbige og vil ved yderligere forskning kunne forbedres. Rapporten skal ses som en første kortlægning af ozonforårsagede udbyttetab og en bekræftelse af at troposfærisk ozon kan føre til betydelige økonomiske tab i år med høje ozonkoncentrationer. Samtidig peger rapporten på, at der er stort behov for yderligere viden inden for følgende områder:

- Ozonmålinger i afgrødehøjde og mellem afgrøder
- Forskellige sorters følsomhed over for ozon
- Effekter af ozon på andre vigtige afgrøder
- Måling eller modellering af regionale ozonkoncentrationer

Abbreviations

AOT-40	Accumulated exposure Over a Threshold of 40 ppb ozone
CL	Critical Level
CL10	Critical Level corresponding to a 10 % yield loss
CORINE	COoRdination of INformation on the Environment (from French acronym)
DEPA	Danish Environmental Protection Agency
DKK	Danish kroner
EMEP	European Monitoring and Evaluation Programme
ha	hektar = 10000 m^2,
kkr	1000 Danish kroner
NERI	National Environmental Research Institute
NOx	kvælstofoxider
OTC	Open Top Chamber
ppb	parts per billion
ppbh	ppb hours
UN-ECE	United Nations - Economic Commission for Europe
VOC	Volatile Organic Compounds

1 Introduction

Consequences

Increasing tropospheric ozone concentrations, as a result of emissions from human activities such as industrial development and traffic, have had the consequence that the biosphere is influenced due to the oxidising capacity of ozone. Since tropospheric ozone is a long range transported pollutant it is best regulated through international conventions. The United Nations Economic Commission for Europe (UN-ECE) is the forum in which reductions of air pollution are dealt with. The Geneva Convention regulates the emissions of long range transported air pollutants in the ratifying countries, by determining reductions in emissions that have to be reached within a given year. For the NOx compounds a protocol giving the reductions have been agreed upon. For the volatile organic compounds a protocol has been prepared, though it has not yet been signed by enough member states to take effect.

Denmark have ratified the Geneva Convention and is through the different organs under UN-ECE an active participant in the international efforts to reduce air pollution.

Regulation

The regulation of ozone is very complicated because the formation of ozone is a function of the two primary pollutants (NOx and VOC's) and climatic conditions. Even with a 95% reduction of the man made contribution of both primary pollutants, the ozone pollution may in some parts of Europe reach levels which are harmful to vegetation (Fenger, 1995).

Purpose

The purpose of this report has been to calculate and map yield losses in agricultural crops due to the harmful effects of ozone. Measurements of Danish ozone concentrations from three stations carried out by the department of atmospheric environment at NERI (Hovmand & Mansher, unpublished) combined with results from Eupopean open top chambers (OTC) were used for this calculation.

1.1 Ozone

Doubling of the ozone concentration

The increased use of fossil fuels have implied more than a doubling of the ozone concentration in the air over Europe, since the start of the century. A more thorough treatment of the processes leading to ozone formation and degradation can be found in Fenger (1995, Danish) or Fenger (1996, English).

The conditions necessary for a critically increased concentration of ozone in the air over Denmark are a combination of the following factors:

- Transport of ozone and ozone precursors from central and eastern Denmark
- High influx of ultraviolet light

1.2 Yield losses

Open top chambers

From experiments in open top chambers (OTC), relations between ozone concentration and yield losses have been calculated. The problem has been to establish a relation between the ozone levels used in the experiments and the highly varying concentrations seen in the open land. From a compilation of available data it has been found that measurement of accumulated concentrations over 40 ppb ozone for a given period gives the best agreement between ozone level and effects on crops (Fuhrer, 1994). This value is referred to as

AOT-40

the AOT-40 (Accumulated exposure Over a Threshold of 40 ppb ozone) which is defined as the Critical Level (CL) for ozone. The relation between AOT-40 and the yield loss has been found to be linear (Fuhrer and Achermann, 1994). In cereal crops, experience from OTC experiments suggests a loss in the order of 10% in years with high ozone concentrations. Though the sensitivity to ozone seen on a yearly base is somewhat less in trees compared to wheat, the corresponding yield loss percentage from forest production is not necessarily smaller, because the sensitivity period for trees is longer (Fuhrer and Achermann, 1994).

1.3 Critical Level for ozone

Critical level

For exposures causing a yield reduction, a threshold of 40 ppb should be applied for the calculation of the CL. By calculating the accumulated exceedance of this threshold during the growing season corresponding yield reductions can be obtained. To exclude uncertainties from the determination of the relationship between yield reduction and ozone exposure, due to the statistical significance of OTC-obtained results, it is suggested that AOT-40 values causing a 10% yield reduction are applied as the long term CL for yield reduction (Fuhrer and Achermann, 1994) (Tab. 1). The CL corresponding to a 10% yield loss is termed CL10.

'Level One'

Application of the AOT-40 value without modifying factors is normally referred to as a 'Level One' approach and is most suited for assessing the risk of damage in terms of exceedances of a critical level. For the assessment of actual yield losses a 'Level Two' approach

Modifying factors

should be applied taking into account factors which modify the sensitivity of the plant according to local environmental factors:

- light influx
- the atmospheric conductivity
- water availability and water vapour deficit
- temperature
- phenological stage, adaptation to ozone
- species and subspecies characteristics
- local conditions as regards climate and soil

Episodic events

It should also be considered, that events of increased ozone concentrations in Denmark are highly episodic, which might lead to increased plant sensitivity compared to the vegetation adapted to the

higher concentration in Middle Europe. Finally, it should be taken into account, that the ozone concentration is measured in different heights above ground ranging from 2 meters *in 'Lille Valby'* to 10 meters or more in *'Frederiksborg'* and *'Ulborg'* .

However, there are not sufficient data available, for applying a 'Level Two' approach, so a 'Level One' approach has been applied for estimating yield losses. Hence the calculated figures (Table 1) should be considered as a risk assessment giving a possible maximum magnitude of the yield losses.

Research aimed at applying a "Level Two" approach is carried out within the Nordic framework (NMR) and the department of Atmospheric Environment at NERI participates in the development of further knowledge.

Table 1. OTC based AOT-40 (ppbh) relation from linear regression between growth season AOT-40 value and yield loss. The 10% yield reduction AOT-40 value should be applied as the long term CL for ozone

AOT-40 (ppbtimer) værdier for udbyttetab i %

Yield loss *Udbyttetab %*	*Pasture* *Clover* *Kløver*	*Beans* *Bønner*	*Wheat* *Hvede*[1]	*Beech,* *Oak* *Bøg, Eg*	*Deciduous*	*Pine, spuce* *Skovfyr,* *Rødgran*	*Silver fir* *Ædelgran* *Abies alba*
5	3.000 b		2.600 a				
10	6.300 b	1.700 b	5.300 a	6.000-7.000 a	9.000 a	12.000 a	12.000 a
15	9.600	2.700	7.900 a				
20	12.900	3.600	10.500 a				

1. Calculation include May, June and July
a. Fuhrer & Achermann, 1994
b. Fuhrer, 1994
c. Skärby, 1994

Relations

Table 1 shows relations between OTC based AOT-40 values and yield losses. Wheat values are for spring wheat, whereas the mainpart of the Danish wheat production is winter wheat - it has not been proven that spring wheat values can represent winter wheat. This is obviously a field that needs further research. Clover has been used to represent pasture (Fuhrer, 1994) - this approach may be problematic, but it is the only one available. For deciduous and coniferous trees, respective AOT-40 values of 9000 ppbh and 12000 ppbh were chosen.

2 Methods

Aim of the report

The aim of the present report has been to calculate 'Level One' yield losses in Danish crops and relate the losses to the infrastructure of agriculture and forestry. This purpose has been pursued by use of monthly AOT-40 data from three Danish stations from 1991 - 1994 calculated by Hovmand & Manscher (unpublished) and local variations in the structure of land use. On the basis of the above-mentioned calculations minimum, average with one standard deviation, and maximum AOT-40 values were calculated for crops and forests separately. For crops the period May - July was applied, whereas for forest trees the period was April - September. The values calculated are presented in Table 2.

Table 2. Range of annual growth seasonal AOT-40 values for crops and forests in Denmark for the years 1991-94.

Størrelsesordenen af danske AOT-40 værdier for landbrugsafgrøder og skove.

AOT-40	min.	average and (sd)*	max.
Crops	3381	7029 (3600)	11899
Trees	5994	9926 (3649)	14496

*sd = Standard Deviation

Maximum values

The maximum values can be considered as representing years with a high ozone concentration e.g. 1992, whereas the minimum values similarly represents years with a low ozone concentration.

CORINE

The spatial distribution of forests and agricultural crops has been adapted from a digitalisation of the CORINE landuse database. The species selected were the crops, wheat and grass (pasture), and the forest tree groups; deciduous and coniferous trees. The relations between AOT-40 values and yield losses (Table 1) were obtained from Fuhrer & Achermann (1994). In the case of pasture it was decided to use an AOT-40 value of 6300 ppbh corresponding to an yield loss equal to 10% (Fuhrer, 1994). This may not be the best estimate, because Fuhrer uses the yield loss in clover to express the yieldloss in pasture, it is, however, the best estimate available because it is the only one that has been calculated.

5 x 5 km grid

A 5 x 5 km grid has been used for mapping of yield losses. For the calculation of the percentage losses, the AOT-40 values presented in Table 1 have been used. They are average values of diurnal measurements carried out by the National Environmental Research Institute, department of Atmospheric Environment. This may represent a minor overestimation for crops because diurnal values are used, however, by comparison with modelled AOT-40 values (Posch *et al.*, 1995) it is seen that the 1992 values are in the same range as the max. values in Table 2. Bearing in mind that most plant species never totally close their stomata the chosen approach should be viewed as a principle of precaution.

Economic calculations

The economic calculations are based on constant rates of production per hectare throughout the country, and a constant price on the product throughout the year and the country. The values used are stated below (Table 3).

Table 3. Area based yield in DKK (Danish kroner)

Areal baseret udbytte

Product	Average value/ha	Average value/kg
Wheat	9033.5 kr/ha	1.45 kr/kg
Pasture	5980 kr/ha	1.00 kr/kg
Deciduous trees	1350 kr/ha	
Coniferous trees	1560 kr/ha	

Pasture

The value of pasture is problematic because the products from pasture include a great variety of different products - the price of 1 DKK represents a simplification. Probably the value of 1 DKK represents an overestimation in the order of max 50%.

2.1 Land use mappings

Two mappings

There are two land use mappings, from which a nation wide spatial distribution can be made: The nation wide soil Classification (Landbrugsministeriet (Ministry of Agriculture), 1976) and the - CORINE mapping (European Commission, 1994) (see App. 2).

The nation wide soil classification is a result of mapping made by the agricultural advisers in 1975. This mapping contains the total farmland and total forest areas in scale 1:25.000. Due to the age, this mapping is of no interest for this project.

Based on satellite data

The CORINE land use mapping is a land use mapping mainly based on satellite data (Landsat) from the period 1987-1993. This mapping contains mapping units with minimum size of 25 ha. The mapping units consist of similar areas seen from satellite, which means that the mapping units can not simply be referred to the above mentioned area classes; farm land, coniferous and deciduous. In stead the classes consist of for instance mixtures of coniferous and deciduous, or farm land with max 25% of coniferous and deciduous etc. (App. 2.).

Interpretation

Due to the fact that the CORINE mapping is the only existing and relevant land use database, it is necessary to make an interpretation of the mapping units. In this interpretation each mapping unit have been given a certain percentage for each land use category of interest.

The spatial land use distribution within the major CORINE land use classes is considered constant during the period.

2.2 Distribution within the land use categories

The distribution of farmland, grass, coniferous and deciduous within the land use categories is achieved by an interpretation of the de-

scription of each land use category combined with the estimated total distribution in Denmark.

The estimates of the total distribution within the CORINE classes are found in:

- community countings from Danish Statistics (Danmarks Statistik, 1994)
- county sample countings from Danish Statistics (Danmarks Statistik, 1994)

Country data

County data is collected every year. Unfortunately, data based on community level stopped in 1989. Therefore a percentage based extrapolation is used for farmland from 1989 to 1994 within each community using the information of the county.

For wheat, this distribution is made by using the distribution within farmland in rotation. For grass, this distribution is made for grass in rotation (within farmland in rotation) and for grass outside rotation.

Coniferous data and deciduous data are not extrapolated.

Nation-wide area

Based on these assumptions, the nation wide area have been calculated and shown in appendice 1. The difference between the calculated figures, and the figures from Danish Statistics should be referred to the method in which the distribution of each mapping unit is based on the development in the county.

3 Results

Overall country results on losses due to ozone are presented in Table 4 and the Figures 1- 5.

3.1 Calculated yield losses

Losses

The losses are calculated from yield per ha as mentioned earlier. The losses are calculated as the percentage loss of the calculated yields. The yields and prices used for the calculation are listed below in Table 3.

The price per kg for pasture is not based on literature values, it is a common price for grass. The price for wheat is the 1991 price from the agricultural statistics (Danmarks Statistik, 1994). For trees no price per kg is obtainable, hence the area based income is simply the 1992 ratio between the total income and the area (Danmarks Statistik, 1994).

The losses for the 4 categories and the total sum are shown in Table 4 and in the Figures 1 - 5.

The statistical data material behind the calculations has been obtained from Danmarks Statistik (1994). As mentioned in the 'Methods section' the price for grass was set to one DKK per kg.

Table 4. Annual Danish average yield losses given in millions of DKK for the products wheat, pasture, deciduous trees and coniferous trees.

Årligt middeludbyttetab som følge af ozonbelastningen.

	Total	Wheat	Pasture	Deciduous	Coniferous
Loss (mio DKK)	1.094	724	307	16	46

4 Discussion

The largest losses

From the maps (Fig. 1-5) it is seen that the areas with the most fertile soils are the areas suffering the largest total losses from ozone. This is because the losses are calculated on a percentage of the yield scale and that the ozone levels used are considered equal within Denmark.

Forest areas

Other aspects equal, forested areas will result in a smaller yield loss than arable areas. Two main causes exist for the observed pattern; according to Fuhrer and Achermann forest trees are less sensitive to ozone than are wheat and pasture (Table 1), and the area based yields are the smallest in the forest areas.

Figures

Figure 1-5 (following pages). Ozone caused average yield-losses for areas with wheat (hvede), pasture (græsdominerede arealer), deciduous forest (løvskov), coniferous forest (nåleskov) and total (hvede+græs+løv+ nål) in 1000 DKK for Denmark, presented in a 5 x 5 km grid. The loss is presented per square (25 km^2), therefore the loss is smaller in the squares where the sea area makes up a part of the square. The white colour indicates a loss between 0 and 50,000 DKK per 25 km^2, whereas the darkest colour similarly indicates a loss between 700,000 and 900.000 DKK per 25 km^2.

Figur 1 - 5 (følgende sider). Middeludbyttetab i kkr som følge af skadevirkninger fra ozon for arealer med hvede, græsdominerede arealer, løvskov, nåleskov og total. Udbyttetabet er præsenteret i et 5 x 5 km (25 km^2) netværk dækkende hele Danmark. Den hvide farve viser at tabet i kvadratet ligger mellem 0 og 50.000 kr. På samme måde er tabet i de mørkeste kvadrater på mellem 700.000 og 900.000 kr pr kvadrat (25 km^2).

The methods used in the calculations above may be criticised from the following reasons:

OTC

- The use of results obtained in a similated natural environment like the OTC for the calculation of yield losses in the field situation may be problematic. In the OTC the mixing of air differs from the situation in nature. Growing conditions may be optimised in OTC chambers, implying that stomata are open when ozone levels are high which is not necessarily the case in the field.

Field measurements

- Field measurements of ozone does not necessarily represent the ozone concentrations to which the crops are exposed, because vertical concentration gradients may exist from the boundary layer near the leaf to the air over the field.

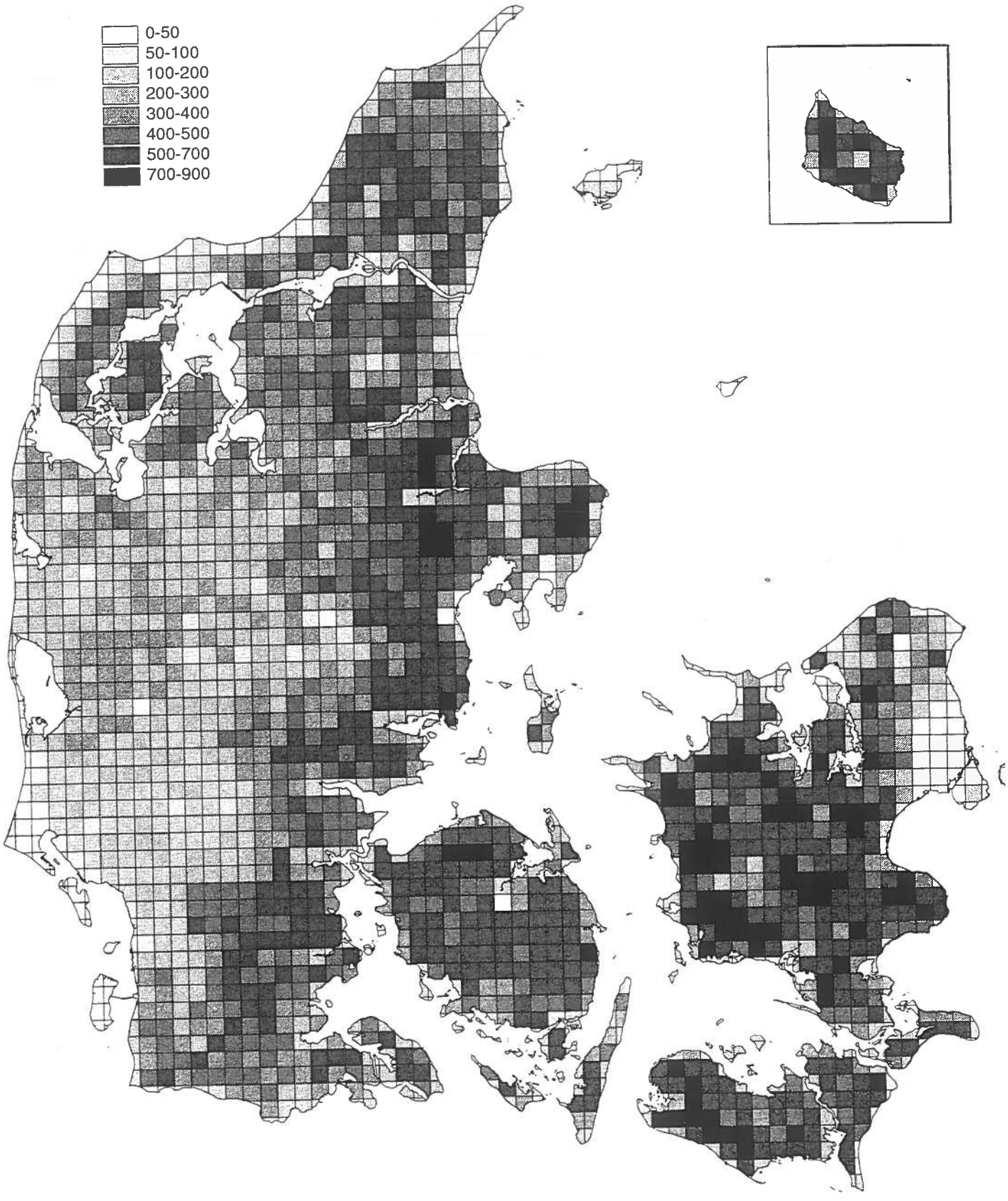
Prices

- The use of one price on the product may overestimate the loss economically, because prices may rise when production decreases.

The category pasture include all types of land use where grass is grown. The category 'wheat' includes spring wheat and winter wheat.

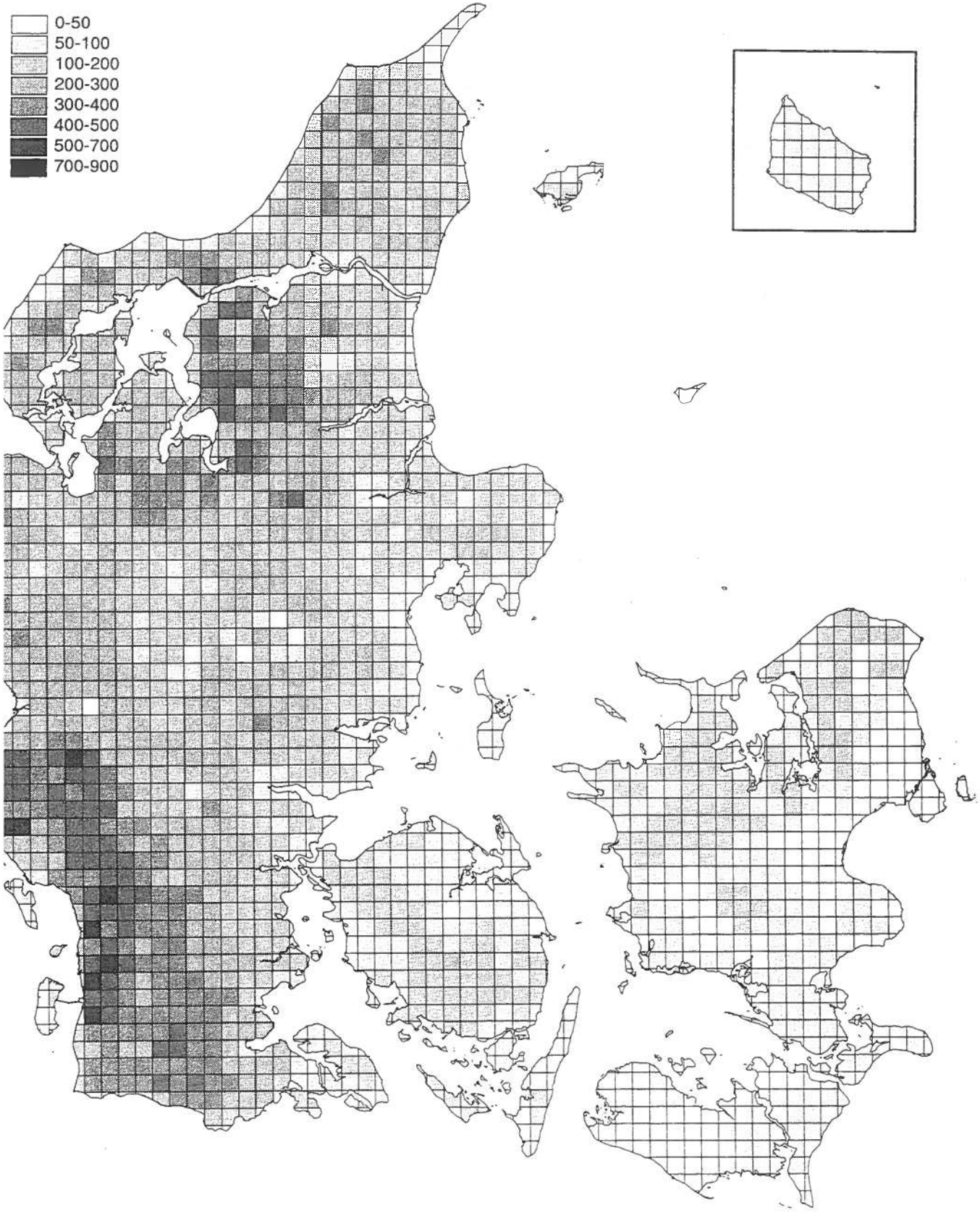
WHEAT

Average Yield Loss in 1000 DKk/25 km*2



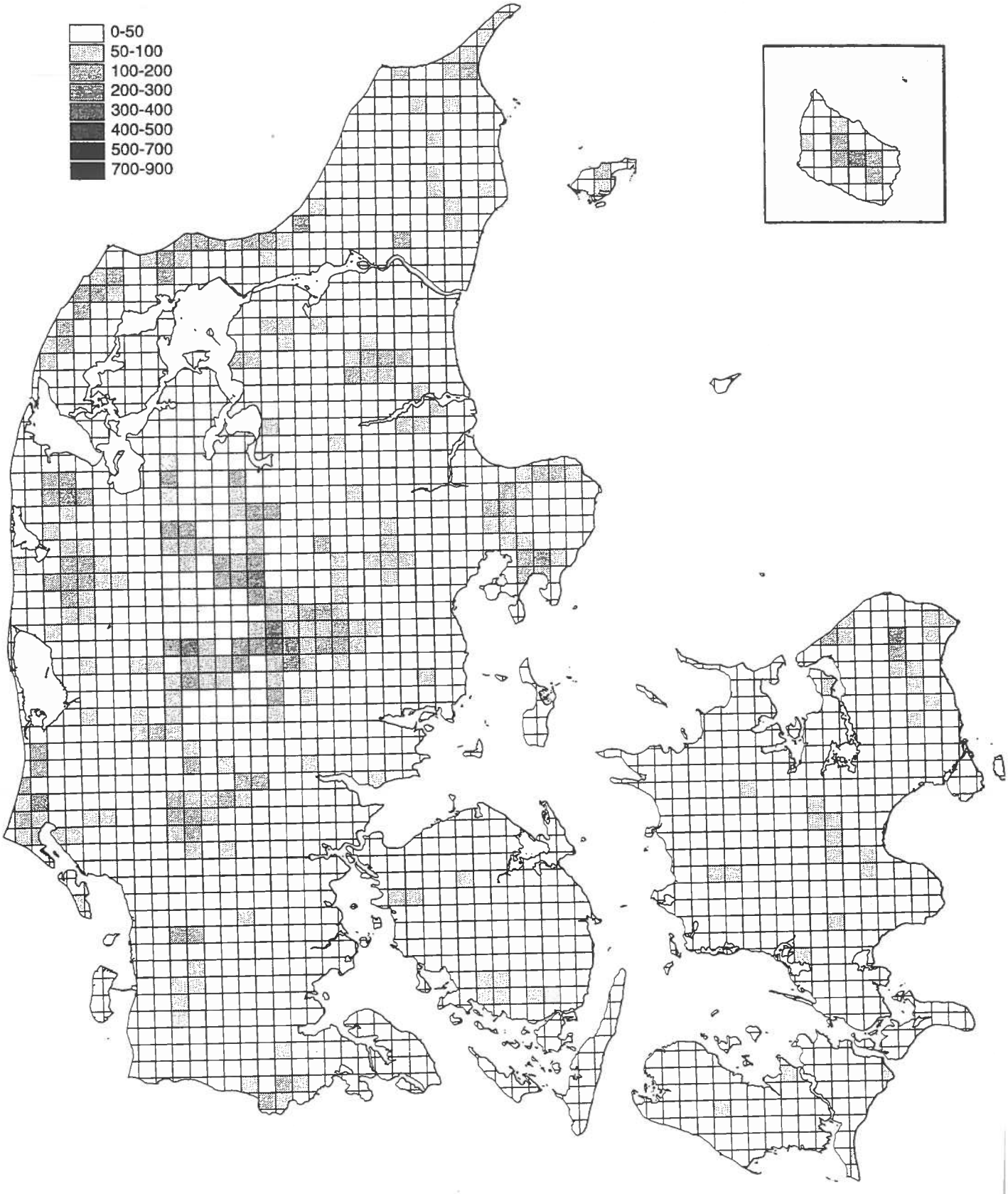
GRASS

Average Yield Loss in 1000 DKk/25 km*2



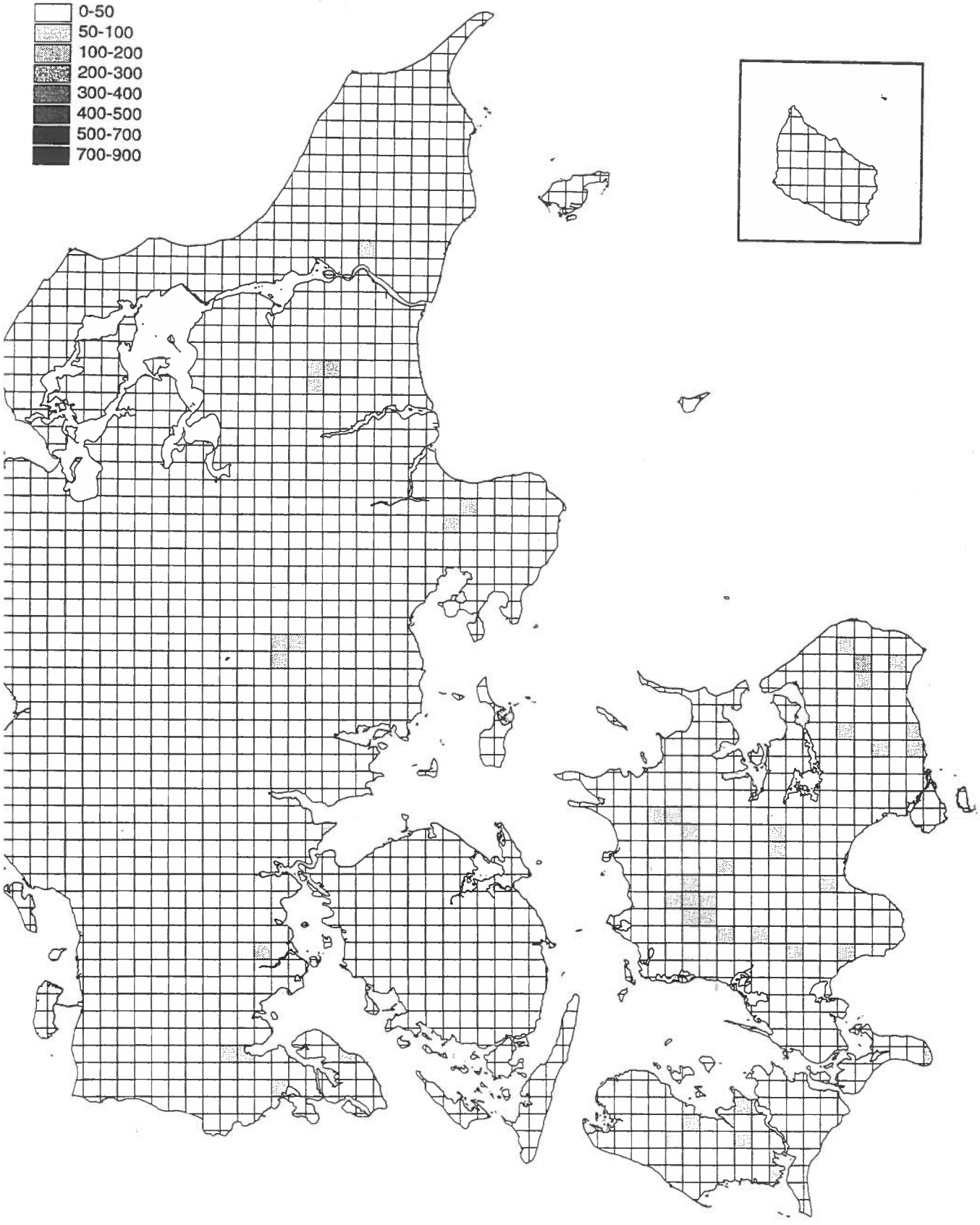
CONIFEREOUS FOREST

Average Yield Loss in 1000 DKk/25 km*2



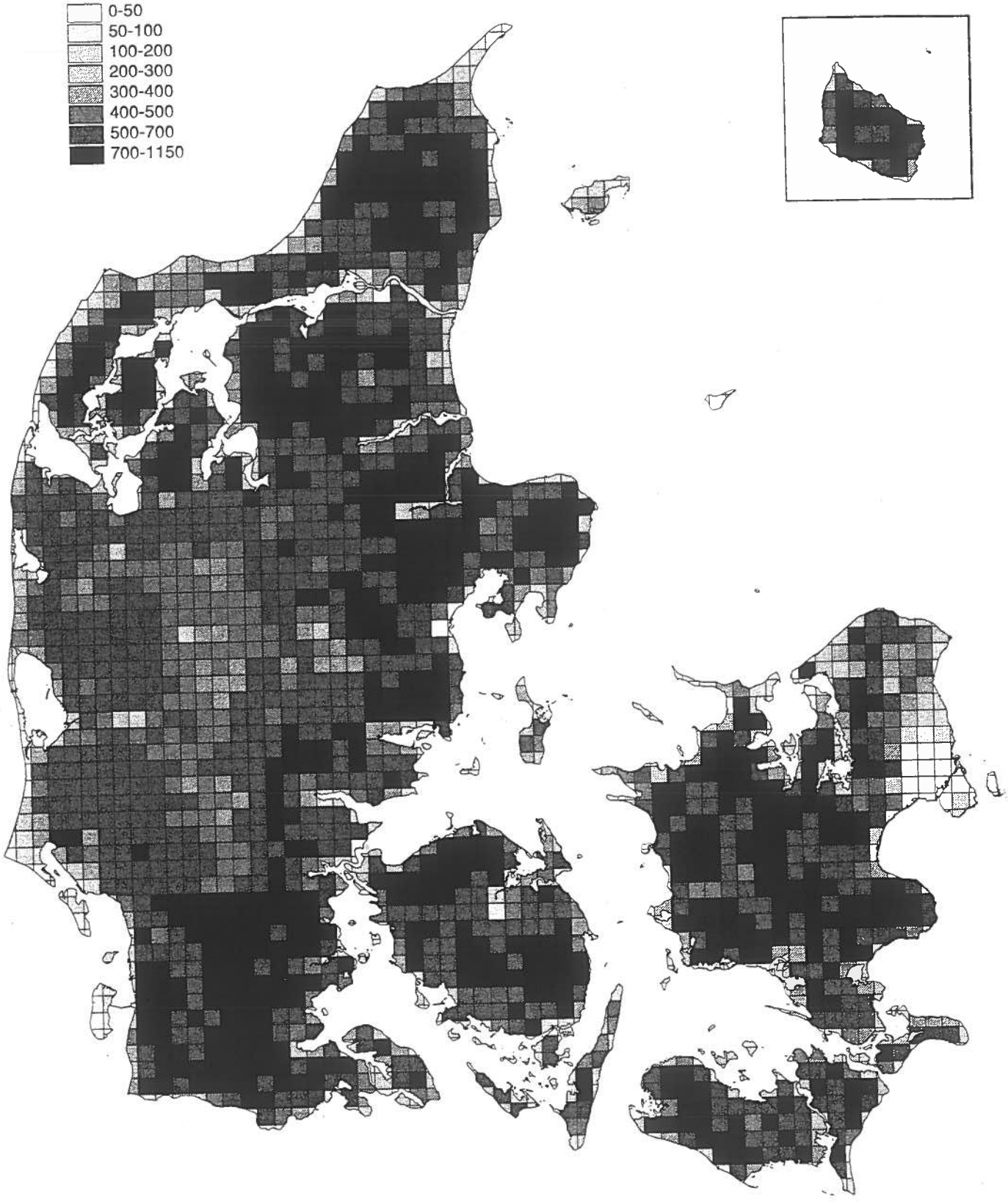
DECIDUOUS FOREST

Average Yield Loss in 1000 DKk/25 km*2



Average total loss from:
Wheat, Grass, Deciduous and Coniferous

in 1000 DKk/ 25 km*2



5 Conclusion

A national scale economic problem

The losses calculated were in the range of billions of DKK for the four selected products. Although they should be considered with some caution, they indicate that tropospheric ozone consists a national scale economic problem. Because of the nature of ozone as a long range transported pollutant it is obvious that the problem should be dealt with in an international forum, as it is the case today in the framework of UN-ECE.

Ozone formation

The most important factor in ozone formation controllable by man is the emission of NOx hence this is the field where a reduction in the load of ozone can be obtained. Regulation of the emission of VOC's is another field where a reduction can be obtained.

Nationally there may be a need for support of the Danish contribution of data and other efforts within the international framework.

Fields of research that need to be promoted

Fields of research that need to be promoted could be:

- validation in field (if possible) of results obtained in open top chambers
- measurement of the ozone concentrations to which different crops are subjected, and development of correlations to overall ozone measurements.
- further knowledge regarding crop sensitivity to ozone
- further mapping and socio-economic modelling
- further knowledge on the area based use of farmland

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Appendice 1

DANMARKS MILJØUNDERSØGELSER
GIS-gruppen
Steen Wessel Platou

Beregning af arealer:

Sammenlægning af kommunearealer:

Metode 1.A: DS (-visse bykommuner)	: 4.297.122 Ha
Metode 1.B: Ckom (Arc/info)	: 4.555.501 Ha
Metode 2 : Grid	: 4.360.687 Ha

hvor der ved 1.A og 1.B beregnes arealer ved brug af afgrødernes fordeling udfra kommunearealerne i 1.B (og 1.A), og der ved 2 beregnes arealer ved brug af afgrødernes fordeling i Grid.

De beregnede arealer inden for de to metoder er

Hvede:

Areal 1:	572.552 ha
Areal 2:	605.097 ha

Græs:

	Areal 1	Areal 2
I omdrift:	243.552 ha	254.234 ha
Udenfor omdrift:	189.635 ha	218.734 ha
Totalt græs:	433.187 ha	472.968 ha

Løvskov:

Areal 1:	143.000 ha
Areal 2:	147.098 ha

Nåleskov:

Areal 1:	268.000 ha
Areal 2:	268.000 ha

Table 2.2 – **CORINE land cover nomenclature**

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units 1.2.2. Road and rail networks and associated land 1.2.3. Port areas 1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas 1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1. Arable land	2.1.1. Non-irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards 2.2.2. Fruit trees and berry plantations 2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation patterns 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4. Agro-forestry areas
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniferous forest 3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation associations	3.2.1. Natural grassland 3.2.2. Moors and heathland 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional woodland shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains 3.3.2. Bare rock 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. Inland wetlands	4.1.1. Inland marshes 4.1.2. Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes 4.2.2. Salines 4.2.3. Intertidal flats
5. Water bodies	5.1. Inland waters	5.1.1. Water courses 5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons 5.2.2. Estuaries 5.2.3. Sea and ocean

Appendice 2

From *European Commision* (1993): CORINE Land Cover, Technical guide - European Commision, Luxembourg 1993. ISBN 92-826-2578-8.

Nomenclature definitions

1. Artificial surfaces

1.1. Urban fabric

1.1.1. Continuous urban fabric

Most of the land is covered by structures. Buildings, roads and artificially surfaced areas cover almost all the ground. Non-linear areas of vegetation and bare soil are exceptional.

1.1.2. Discontinuous urban fabric

Most of the land is covered by structures. Buildings, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces.

1.2. Industrial, commercial and transport units

1.2.1. Industrial or commercial units

Artificially surfaced areas (with concrete, asphalt, tarmacadam, or stabilized, e.g. beaten earth) devoid of vegetation, occupy most of the area in question, which also contains buildings and/or vegetated areas.

1.2.2. Road and rail networks and associated land

Motorways, railways, including associated installations (stations, platforms, embankments). Minimum width to include: 100 m.

1.2.3. Port areas

Infrastructure of port areas, including quays, dockyards and marinas.

1.2.4. Airports

Airport installations: runways, buildings and associated land.

1.3. Mine, dump and construction sites

1.3.1. Mineral extraction sites

Areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for river-bed extraction.

1.3.2. Dump sites

Landfill or mine dump sites, industrial or public.

1.3.3. Construction sites

Spaces under construction development, soil or bedrock excavations, earthworks.

1.4. Artificial, non-agricultural vegetated areas

1.4.1. Green urban areas

Areas with vegetation within urban fabric. Includes parks and cemeteries with vegetation.

1.4.2. Sport and leisure facilities

Camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc. Includes formal parks not surrounded by urban zones.

2. Agricultural areas

2.1. Arable land

Cultivated areas regularly ploughed and generally under a rotation system.

2.1.1. Non-irrigated arable land

Cereals, legumes, fodder crops, root crops and fallow land. Includes flower and tree (nurseries) cultivation and vegetables, whether open field, under plastic or glass (includes market gardening). Includes aromatic, medicinal and culinary plants. Excludes permanent pastures.

2.1.2. Permanently irrigated land

Crops irrigated permanently and periodically, using a permanent infrastructure (irrigation channels, drainage network). Most of these crops could not be cultivated without an artificial water supply. Does not include sporadically irrigated land.

2.1.3. Rice fields

Land developed for rice cultivation. Flat surfaces with irrigation channels. Surfaces regularly flooded.

2.2. Permanent crops

Crops not under a rotation system which provide repeated harvests and occupy the land for a long period before it is ploughed and replanted: mainly plantations of woody crops. Excludes pastures, grazing lands and forests.

2.2.1. Vineyards

Areas planted with vines.

2.2.2. Fruit trees and berry plantations

Parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces. Includes chestnut and walnut groves.

2.2.3. Olive groves

Areas planted with olive trees, including mixed occurrence of olive trees and vines on the same parcel.

2.3. Pastures

2.3.1. Pastures

Dense, predominantly graminoid grass cover, of floral composition, not under a rotation system. Mainly used for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).

2.4. Heterogeneous agricultural areas

2.4.1. Annual crops associated with permanent crops

Non-permanent crops (arable lands or pasture) associated with permanent crops on the same parcel.

2.4.2. Complex cultivation patterns

Juxtaposition of small parcels of diverse annual crops, pasture and/or permanent crops.

2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation

Areas principally occupied by agriculture, interspersed with significant natural areas.

2.4.4. Agro-forestry areas

Annual crops or grazing land under the wooded cover of forestry species.

3. Forests and semi-natural areas

3.1. Forests

3.1.1. Broad-leaved forest

Vegetation formation composed principally of trees, including shrub and bush understories, where broad-leaved species predominate.

3.1.2. Coniferous forest

Vegetation formation composed principally of trees, including shrub and bush understories, where coniferous species predominate.

3.1.3. Mixed forest

Vegetation formation composed principally of trees, including shrub and bush understories, where broad-leaved and coniferous species co-dominate.

3.2. Shrub and/or herbaceous vegetation associations

3.2.1. Natural grassland

Low productivity grassland. Often situated in areas of rough uneven ground. Frequently includes rocky areas, briars, and heathland.

3.2.2. Moors and heathland

Vegetation with low and closed cover, dominated by bushes, shrubs and herbaceous plants (heath, briars, broom, gorse, laburnum, etc.).

3.2.3. Sclerophyllous vegetation

Bushy sclerophyllous vegetation. Includes *maquis* and *garrigue*.
Maquis: a dense vegetation association composed of numerous shrubs associated with siliceous soils in the Mediterranean environment.
Garrigue: discontinuous bushy associations of Mediterranean calcareous plateaus. Generally composed of kermes oak, arbutus, lavender, thyme, cistus, etc. May include a few isolated trees.

3.2.4. Transitional woodland/shrub

Bushy or herbaceous vegetation with scattered trees. Can represent either woodland degradation or forest regeneration/colonization.

3.3. Open spaces with little or no vegetation

3.3.1. Beaches, dunes, and sand plains

Beaches, dunes and expanses of sand or pebbles in coastal or continental locations, including beds of stream channels with torrential regime.

3.3.2. Bare rock

Scree, cliffs, rocks and outcrops.

3.3.3. Sparsely vegetated areas

Includes steppes, tundra and badlands. Scattered high-attitude vegetation.

3.3.4. Burnt areas

Areas affected by recent fires, still mainly black.

3.3.5. Glaciers and perpetual snow

Land covered by glaciers or permanent snowfields.

4. Wetlands

4.1. Inland wetlands

Non-forested areas either partially, seasonally or permanently waterlogged. The water may be stagnant or circulating.

4.1.1. Inland marshes

Low-lying land usually flooded in winter, and more or less saturated by water all year round.

4.1.2. Peatbogs

Peatland consisting mainly of decomposed moss and vegetable matter. May or may not be exploited.

National Environmental Research Institute

The National Environmental Research Institute - NERI - is a research institute of the Ministry of the Environment and Energy. NERI's tasks are primarily to do research, collect data and give advice on problems related to the environment and nature.

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