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Nitrogen FATE in European waters

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Joint Research Centre

Institute for Environment and Sustainability

Rural, Water and Ecosystem Resources Unit

TFIAM/COST729/NinE Workshop on integrated modelling of nitrogen
28-20 November 2007, Laxenburg, Austria

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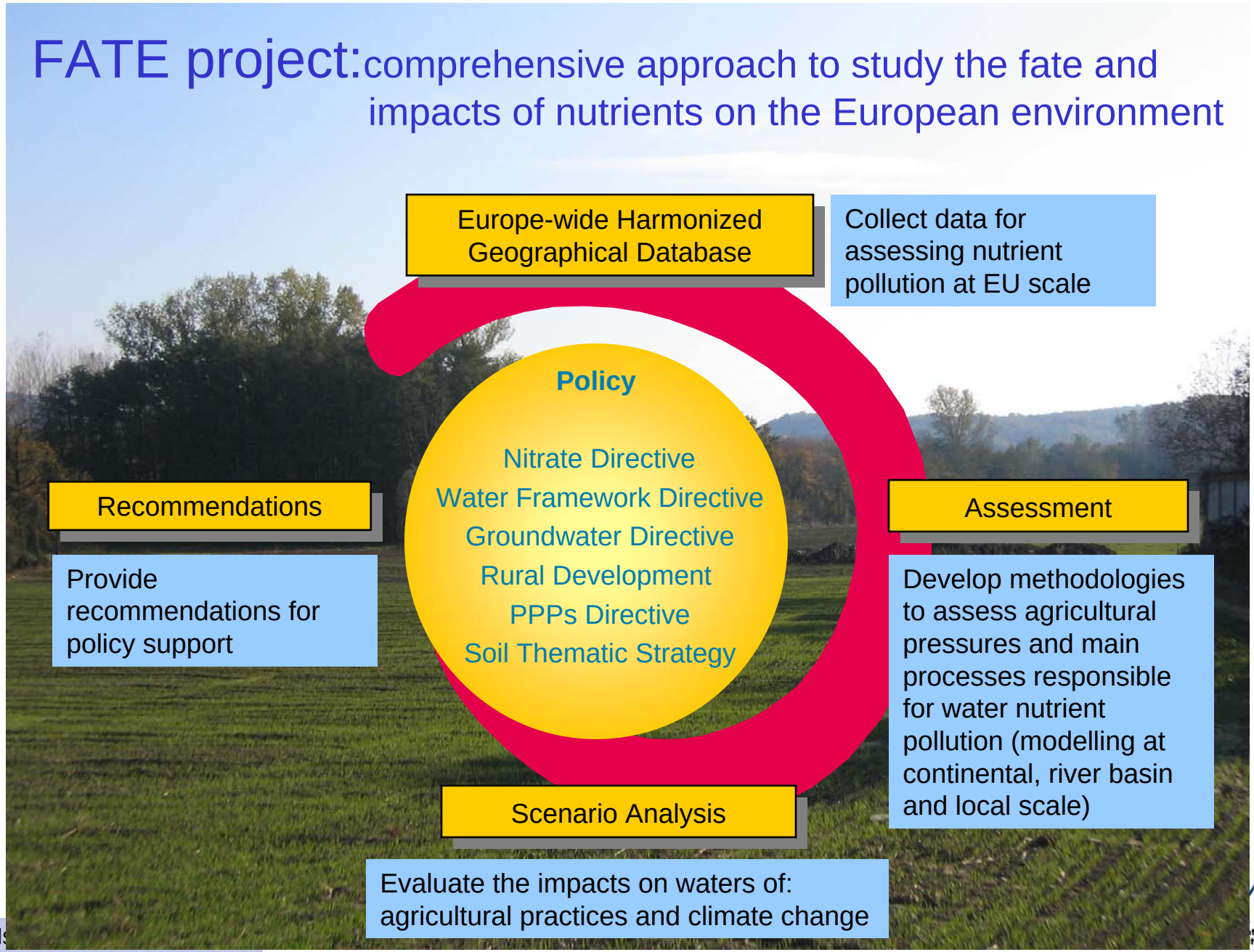
FATE project: comprehensive approach to study the fate and impacts of nutrients on the European environment



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Results of the FATE project
http://ies.jrc.ec.europa.eu

Europe-wide Harmonized Geographical Database

ATLAS collecting data available at EU27 to assess nutrient pressure

Assessment

Estimation of spatial nitrogen and phosphorus balance

Assessment of nutrient pressures (source apportionment)

Scenario Analysis

Impact of agri-environmental practices on water quality

Impact of climate changes on water and nutrient requirements in agriculture

Recommendations

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Objectives

Assess nutrient pressures on European surface water (link between agriculture and water quality)

1 Nitrogen Inputs

Nitrogen Balance

2 Nitrogen pressures on surface water quality

3 Effects of climate change

Objective 1

1 Nitrogen Inputs

Nitrogen Balance

N inputs and balance

Challenges:

1. Estimate the input from agriculture spatially
2. Data covering the whole Europe

Available data :

EUROSTAT
Farm Structure Survey
(FSS)

crops statistics on
administrative
boundaries

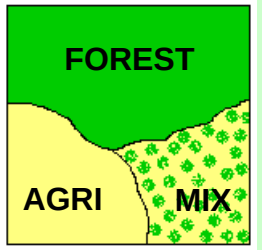
FSS crop data

CROP	AREA
Forest	50
Agriculture	50

CORINE Land Cover 2000
(CLC)

geographical
information

Corine Land Cover



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FATE land-cover map including crop distribution

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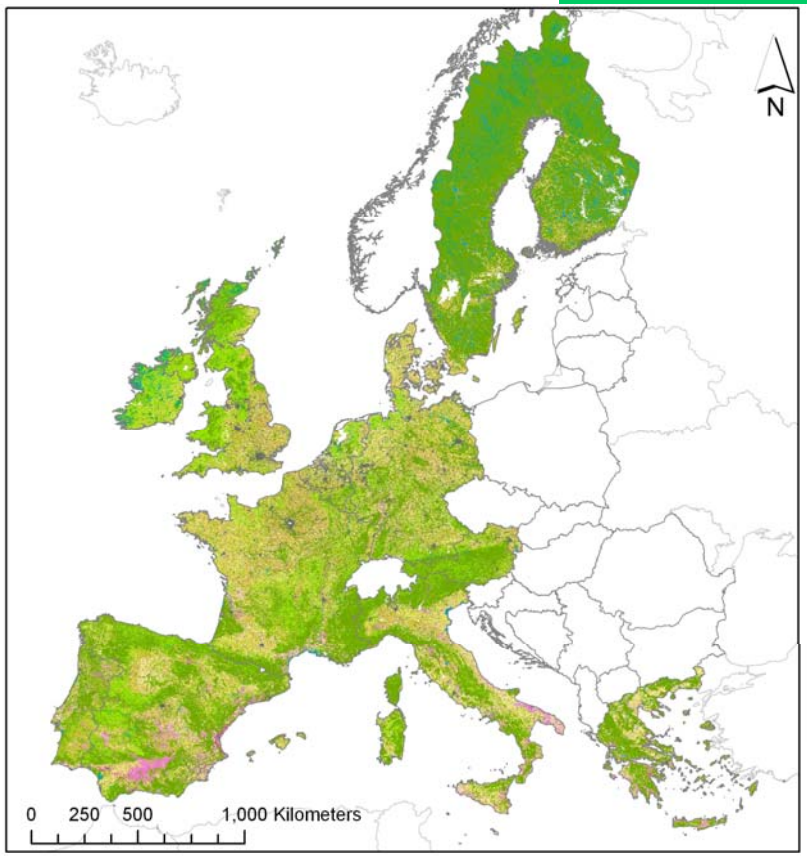

1.1.1 Continuous urban fabric
1.1.2 Discontinuous urban fabric
1.2.1 Industrial or commercial units
1.2.2 Road and rail networks and associated land
1.2.3 Port areas
1.2.4 Airports
1.3.1 Mineral extraction sites
1.3.2 Dump sites
1.3.3 Construction sites
1.4.1Green urban areas
1.4.2 Sport and leisure facilities
2.4.1 Annual crops associated with permanent crops
2.4.2 Complex cultivation patterns
2.4.3 Land principally occupied by agriculture with sig
2.4.4 Agro-forestry areas
3.1.1 Broad-leaved forest
3.1.2 Coniferous forest
3.1.3 Mixed forest
3.2.1 Natural grasslands
3.2.2 Moors and heathland
3.2.3 Sclerophyllous vegetation
3.2.4Transitional woodland-shrub
3.3.1 Beaches, dunes, sands
3.3.2 Bare rocks
3.3.3 Sparsely vegetated areas
3.3.4 Burnt areas
3.3.5 Glaciers and perpetual snow
4.1.1 Inland marshes
4.1.2 Peat bogs
4.2.1 Salt marshes
4.2.2 Salines
4.2.3 Intertidal flats
5.1.1 Water courses
5.1.2 Water bodies
5.2.1 Coastal lagoons
5.2.2 Estuaries

D01 - Common wheat and spelt
D02 - Durum wheat
D03 - Rye
D04 - Barley
D05 - Oats
D06 - Grain maize
D07 - Rice
D08 - Other cereals
D09 - Pulses - total
D10 - Potatoes
D11 - Sugar beet
D12 - Fodder roots and brassicas
D13A - Tobacco
D13B - Hops
D13C - Cotton
D13D1A - Rape and turnip:Other oil-seed or fibre plants
D13D1B - Sunflower:Other oil-seed or fibre plants
D13D1C - Soya:Other oil-seed or fibre plants
D13D1D - Others:Other oil-seed or fibre plants
D13D2 - Aromatic-; medicinal and culinary plants
D13D3 - Industrial plants - Others
D14 - Outdoor:Fresh vegetables; melons; strawberries
D15 - Under glass:Fresh vegetables; melons; strawberries
D16 - Outdoor:Flowers and ornemental plants
D17 - Under glass:Flowers and ornemental plants
D18A - Forage plants - temporary grass
D18B1 - Green maize:Other green fodder:Forage plants
D18B2 - Leguminous plants:Other green fodder:Forage plants
D18B3_2000 - age plants - other green fodder - others
D20 - Other crops
D21 - Fallow land without subsidies
F01 - Pasture and meadow:Permanent grassland and meadow
F02 - Rough grazings:Permanent grassland and meadow
G01 - Fruit and berry plantations - total
G02 - Citrus plantations
G03A - Olive plantations - table olives
G03B - Olive plantations - oil production
G04A - Vineyards - quality wine
G04B - Vineyards - other wines
G04C - Vineyards - table grapes
G04D - Vineyards - raisins
G05 - Nurseries
G06 - Other permanent crops
G07 - Permanent crops under glass
general agricultural land
general permanent crops
I08AD22 - Fallow land with no economic use:Set-aside

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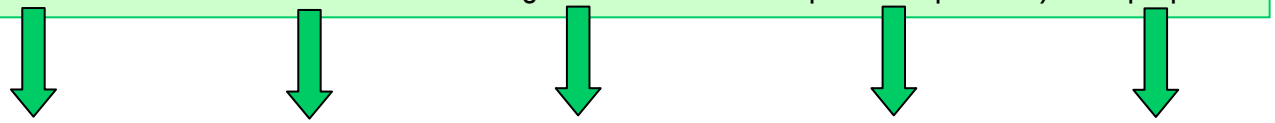
Gross Nitrogen Balance

The **gross nutrient balance** includes all residual emissions of nutrient compounds from agriculture into soil, water and air. This means that the nutrient losses by leaching, runoff, N denitrification are included in the balance as well as the ammonia (NH3) volatilisation during manure accumulation, storage and spreading (OECD, 2007).

Gross nitrogen balance = (mineral fertilisers + livestock manure + biological fixation + atmospheric deposition) – crop uptake



EUROSTAT, from the Theme on “Agriculture and Fisheries”. http://epp.eurostat.ec.europa.eu/portal/

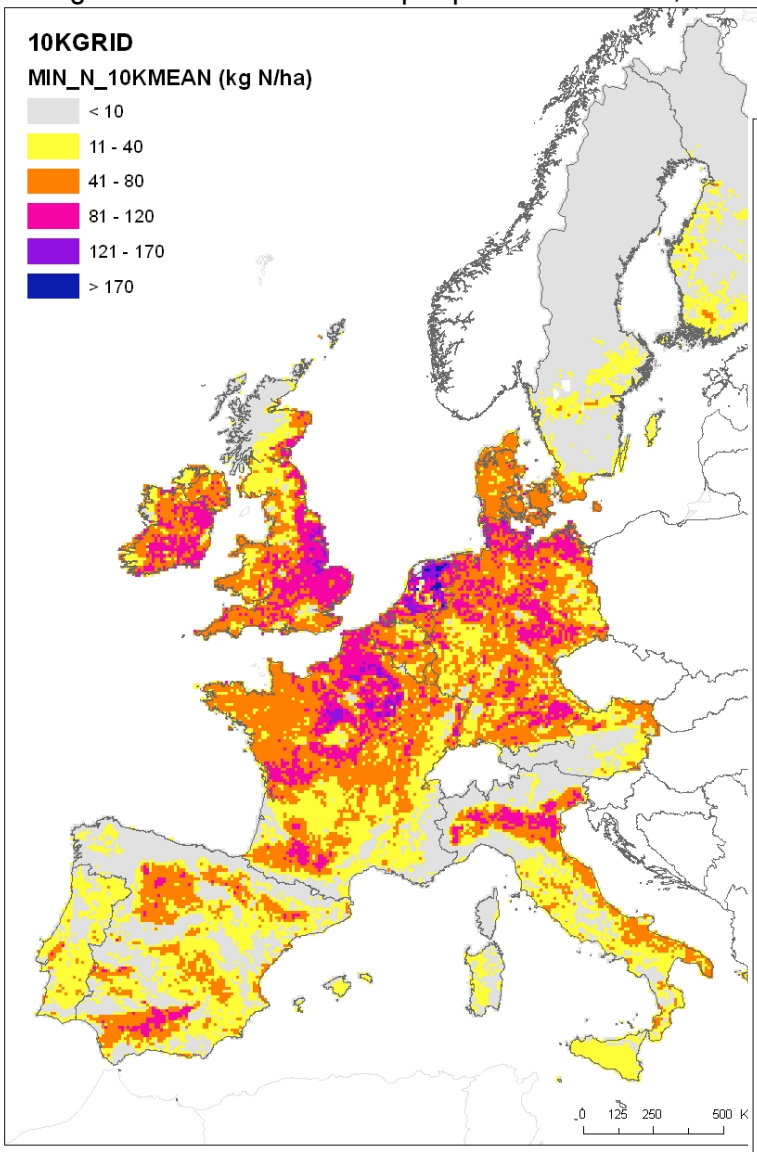
EMEP (The Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe), 2001. EMEP measurement database. Available online from http://www.emep.int/

IFA (International Fertiliser Association), 2006. www.IFA.org

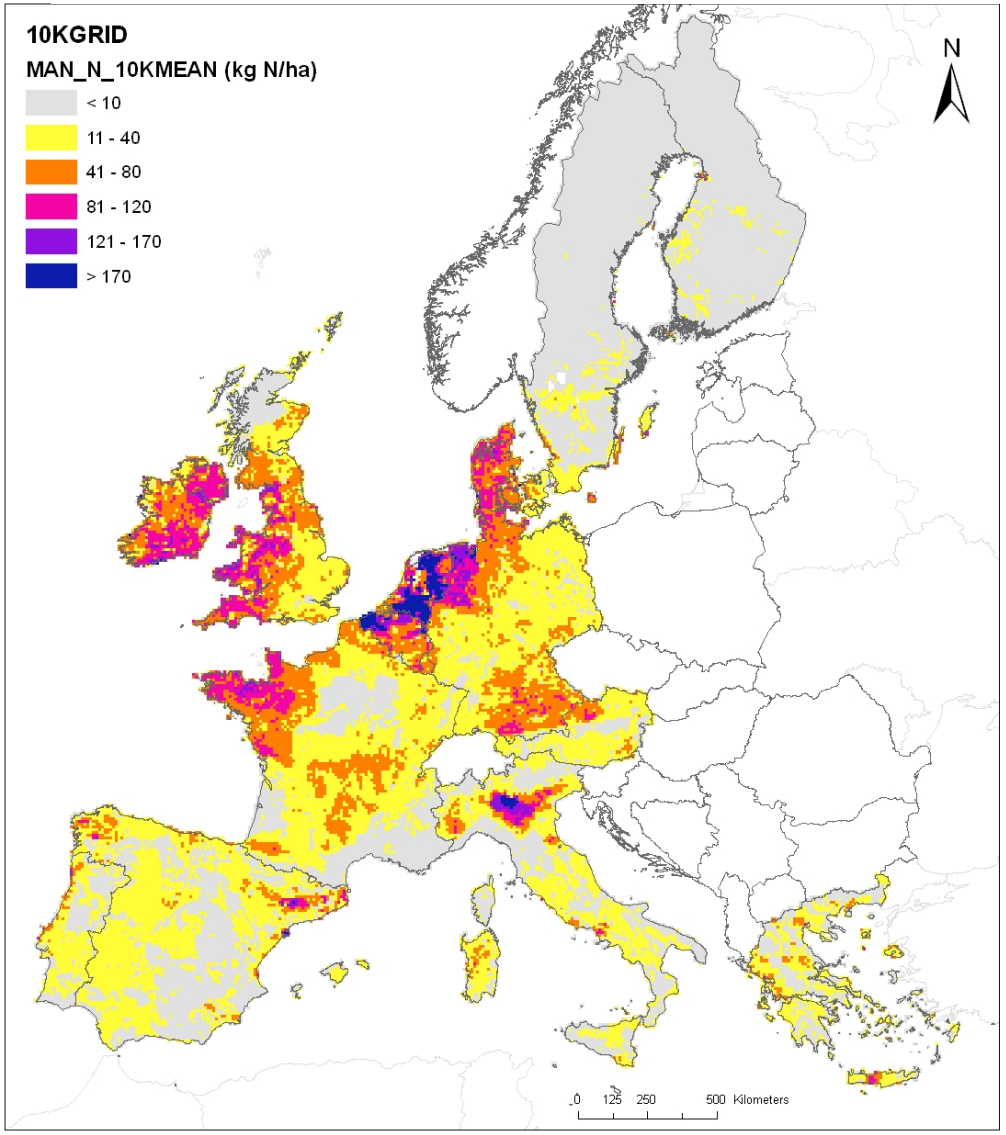
OECD (Organisation for Economic Co-operation and Development), 2007. (forthcoming). Environmental Indicators for Agriculture Volume 4, Paris, France, www.oecd.org/agr/env/indicators.htm

Nitrogen Fertiliser maps

Nitrogen **mineral fertiliser** input per total surface, average on 10 km grid

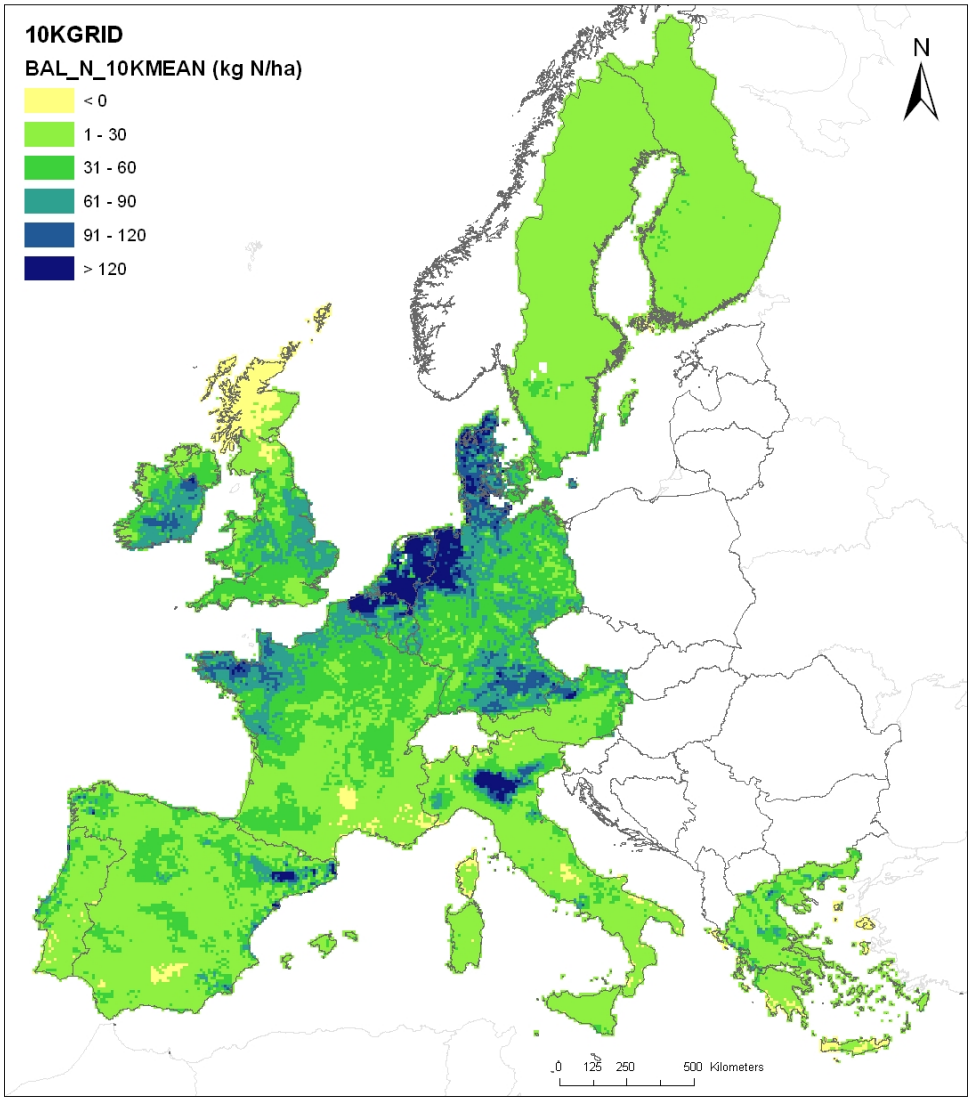


Nitrogen **manure** input per total surface, average on 10 km grid

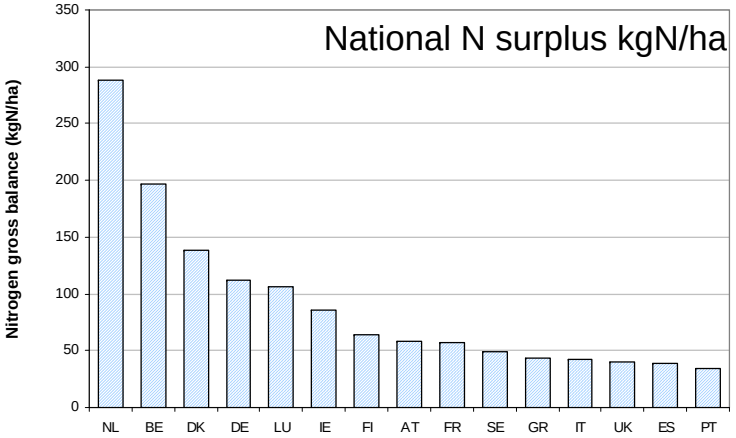


Spatialised Gross Nitrogen Balance

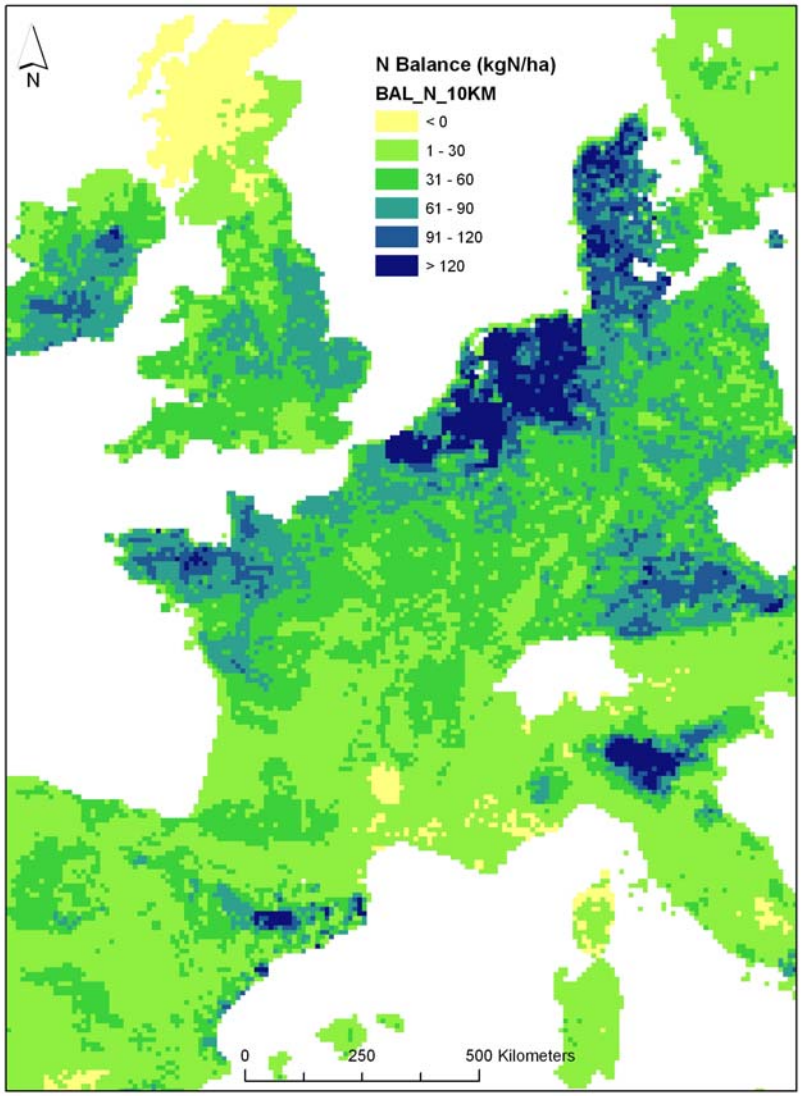
Gross nitrogen balance = (mineral fertilisers + livestock manure + biological fixation + atmospheric deposition) – crop uptake



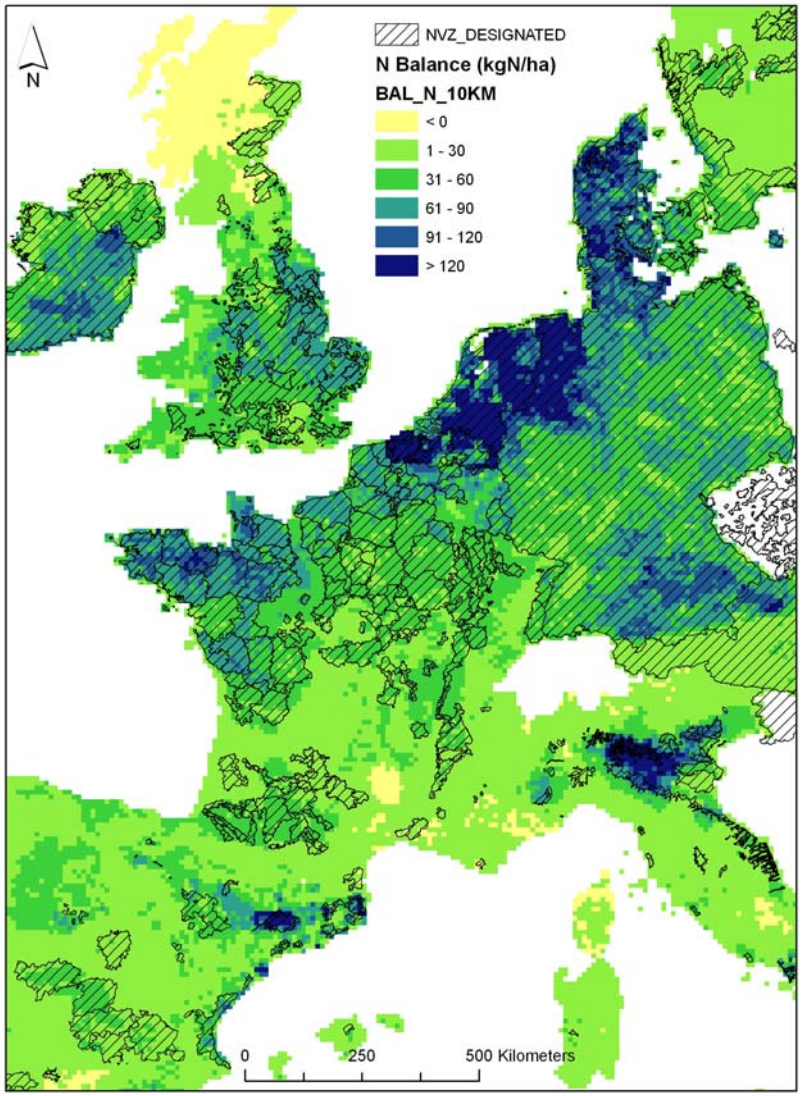
Spatialised **gross nitrogen balance** per total surface (average on 10 km grid)



N balance and N Vulnerable Zones



N balance and N Vulnerable Zones



Objective 2

2 Nitrogen pressures on surface water quality

Modelling pressures

modelling approach to evaluate the actual nutrient pressures on surface water quality at **medium and large basin scale (Europe)**, using **readily available data**

Main tasks:

1. Quantify the **diffuse emissions** of nitrogen to surface waters

2. Quantify the **contribution of different sources** (point and diffuse) to the total nitrogen export in river

Type of model

Which is a suitable model to fulfil the research objectives?

↓

SPARROW model (Smith et al. 1997)

(spatial regression)

↓

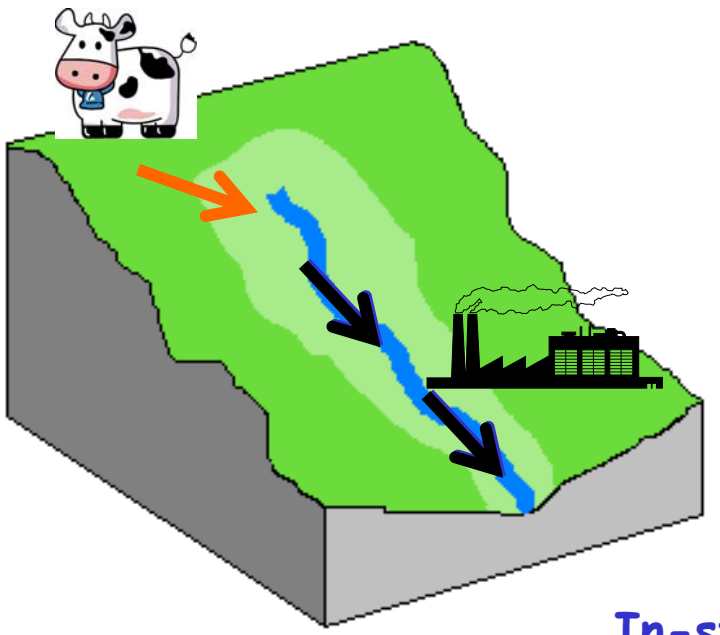
GREEN model (Geospatial Regression Equation for European Nutrient losses)

Model concept

DIFFUSE SOURCES

- Mineral fertilisers
- Manure
- Atmospheric deposition
- Scattered dwellings

Diffuse losses

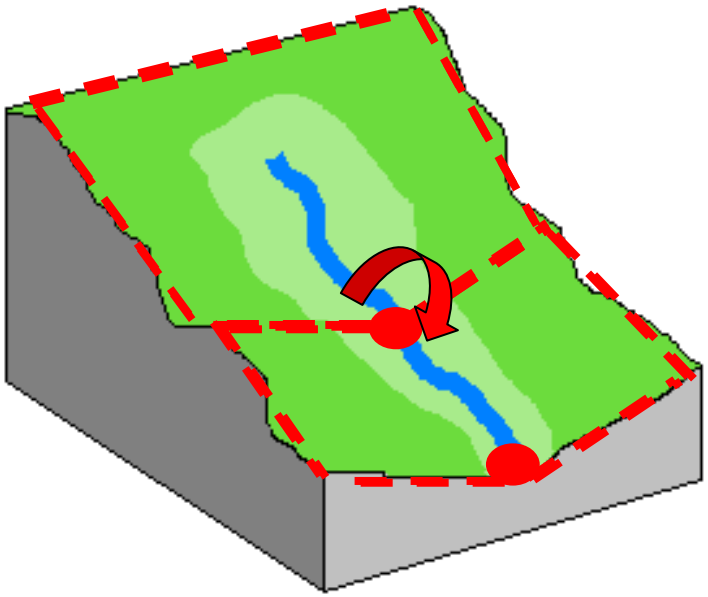


POINT SOURCES

- UWWTP
- Industries
- Paved areas

In-stream losses

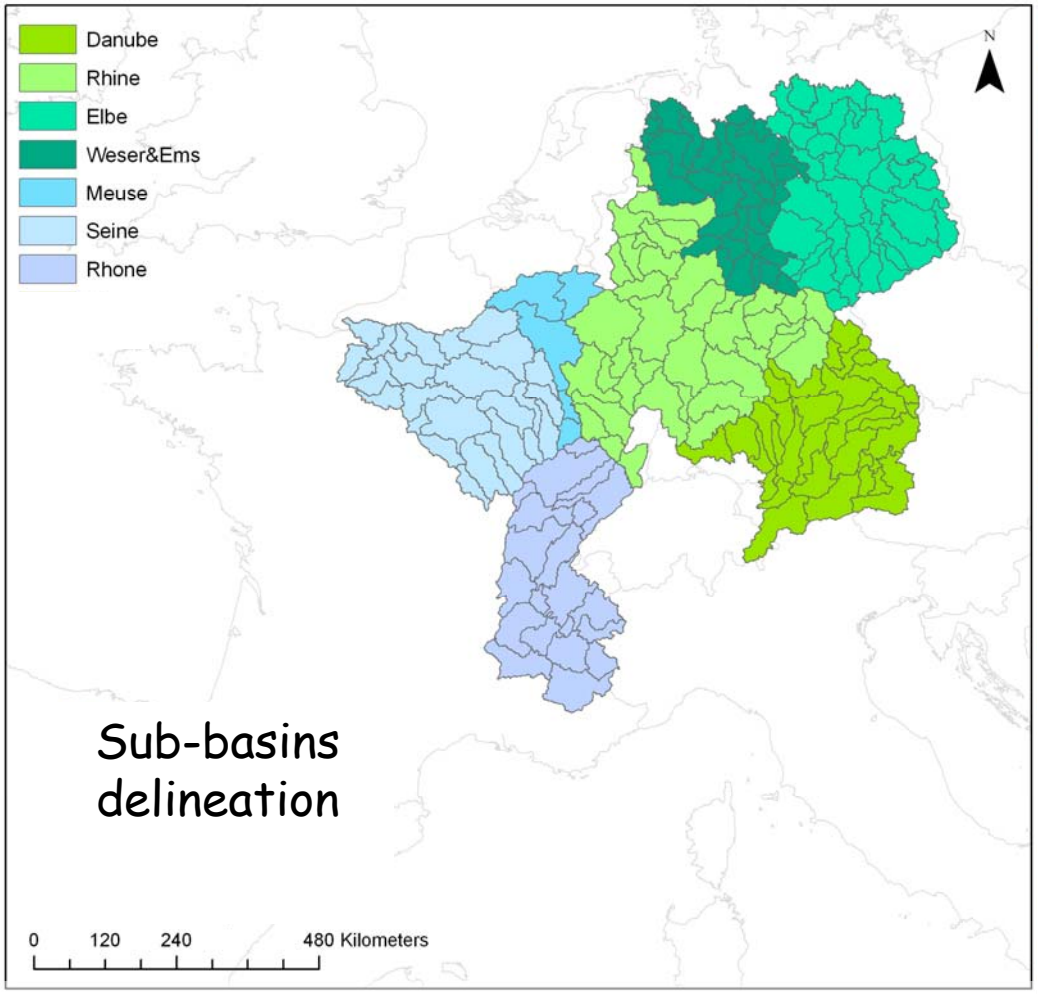
Routing structure



Measurements

Sub-basins

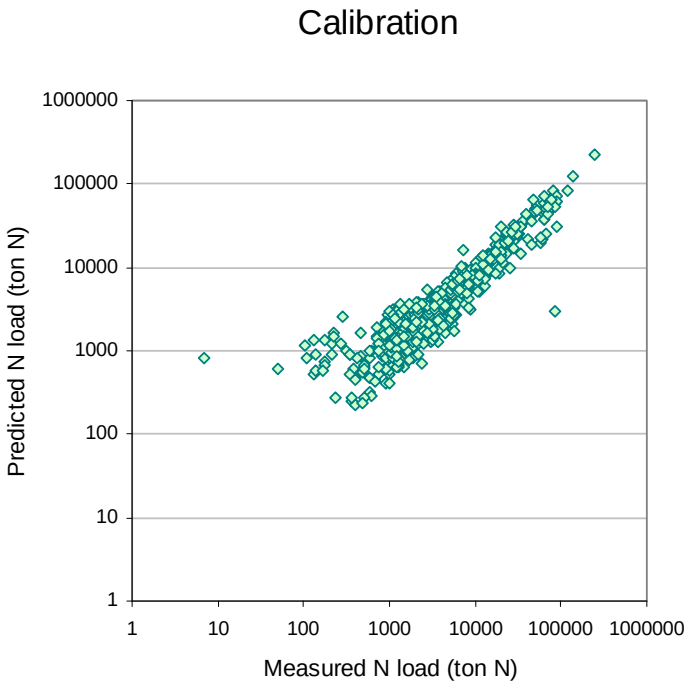
Calibration on 7 large river basins



Measured data for model calibration

Discretisation into sub-basins

(average sub-basin size 2500 km^2)



NS Efficiency 0.87

Basin	Area (km^2)	Rainfall (mm)	Flow (10^3 m^3/s)	Arable (%)	N fert (kg/ha)	P fert (kg/ha)	Populati (10^6 inh
Danube	77000	824	0.558	46	49	17	10.6
Rhine	120000	706	0.355	50	51	19	37.0
Elbe	84000	543	0.149	57	73	20	14.6
Weser/Ems	53000	678	0.246	62	93	28	10.3
Meuse	20400	898	0.519	49	44	18	3.0
Seine	75000	691	0.261	66	92	27	15.0
Rhône	69000	877	0.608	38	27	10	6.2

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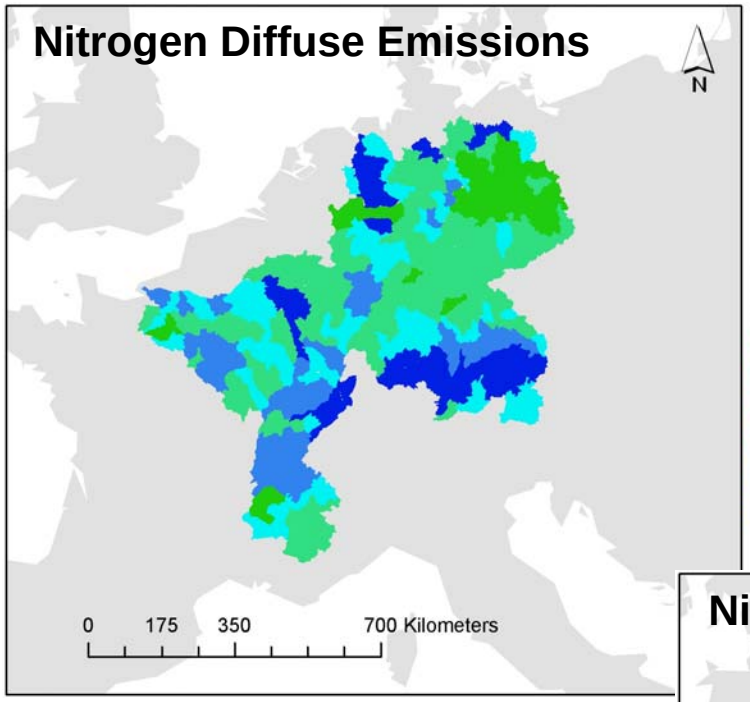
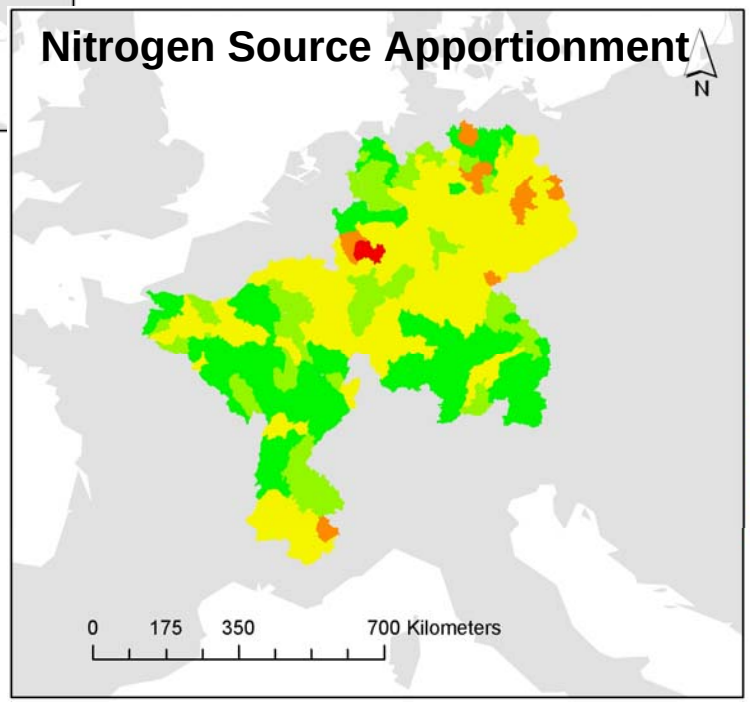
Estimation of nutrient pressures

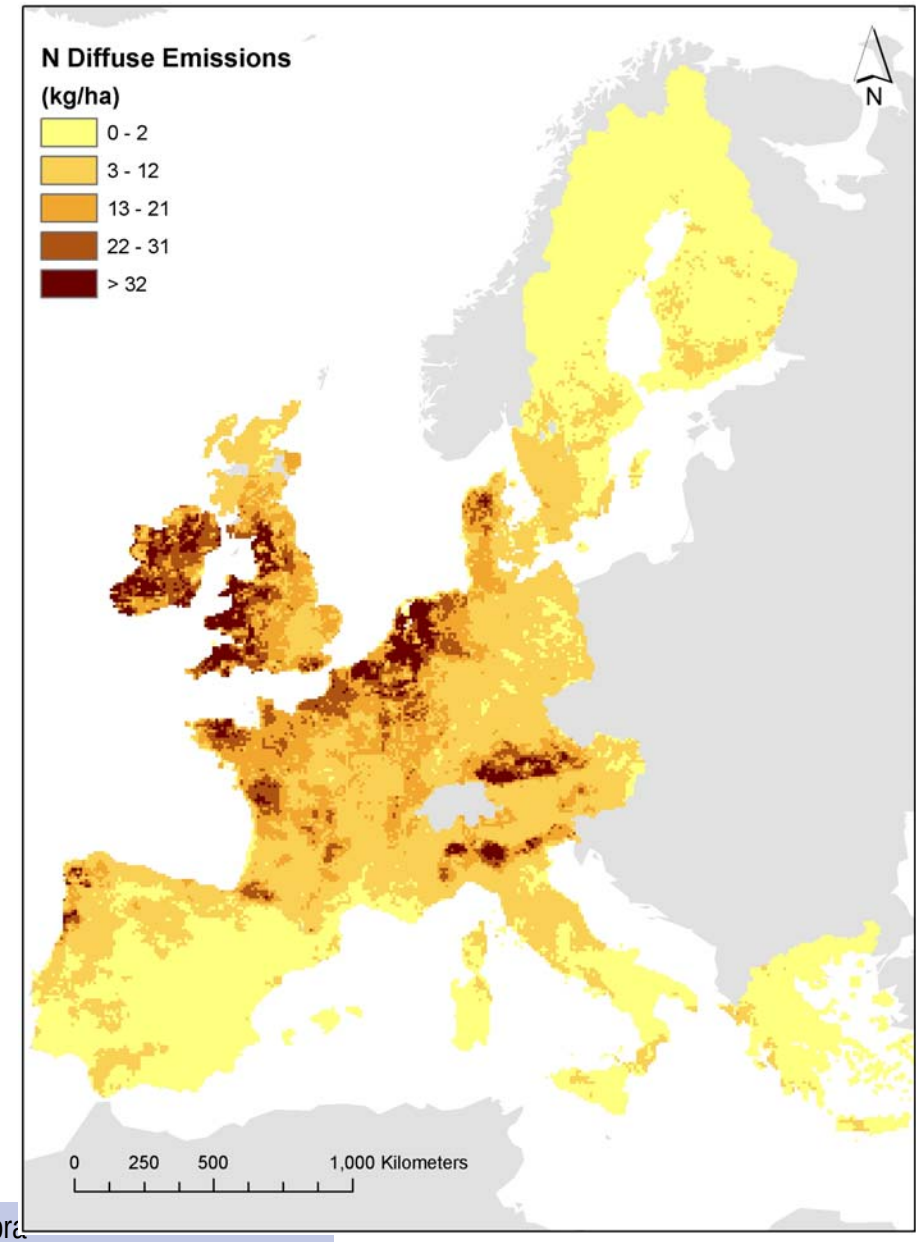


N Diffuse emissions
(kg/ha)
- 0 - 4
- 4 - 8
- 8 - 12
- 12 - 16
- 16 - 33



N Source Apportionment
(% N Diffuse sources)
- 26
- 27 - 50
- 51 - 75
- 76 - 85
- 86 - 100

Estimation of nutrient pressures in EU Diffuse Emissions



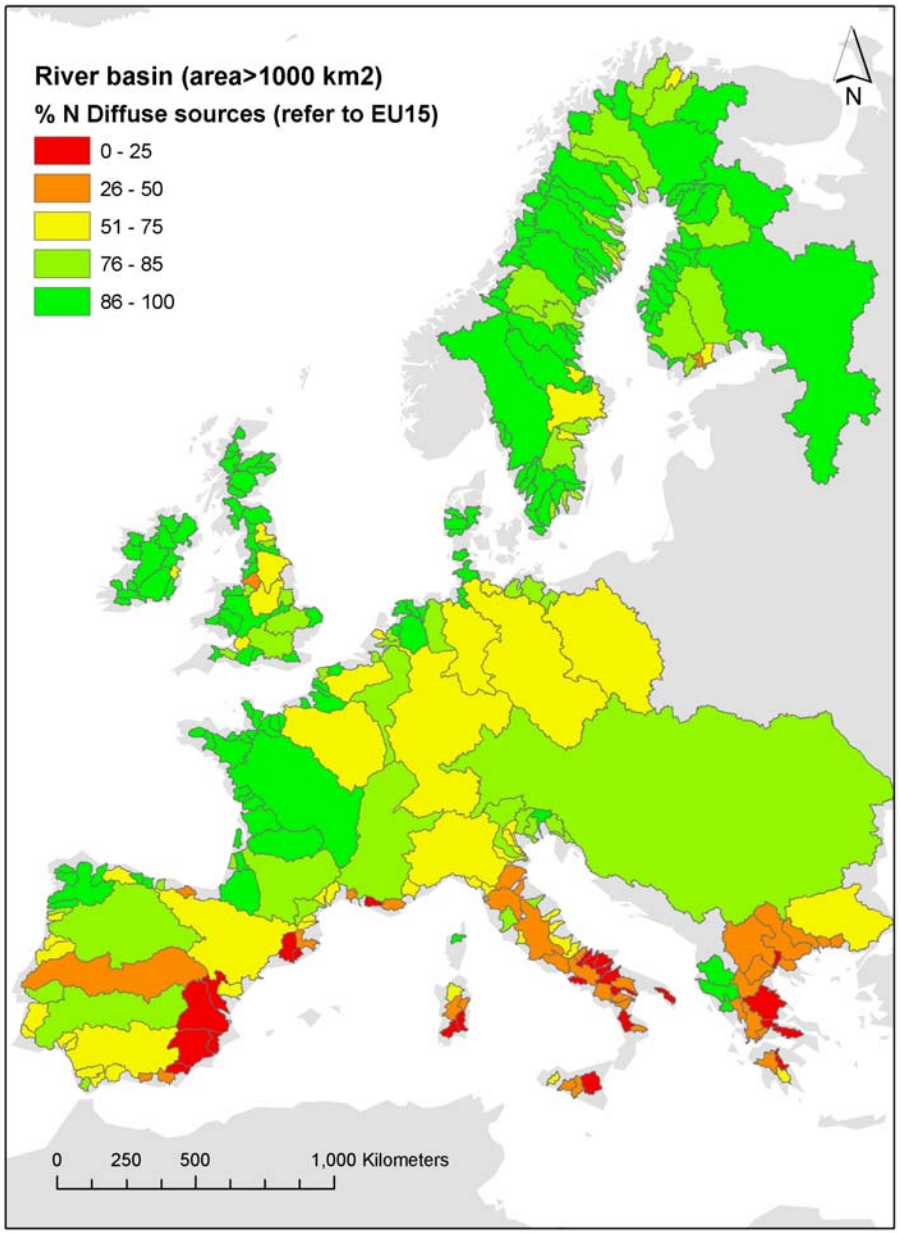
Spatial **Nitrogen Diffuse Emissions** (average on 10 km grid)

Estimated by the GREEN model

The parameter value obtained in the calibration was used to extrapolate model estimations to the EU

Nitrogen Diffuse Emissions: input of nitrogen into surface waters originated from diffuse sources

Estimation of nutrient pressures in EU Source Apportionment



Nitrogen Source Apportionment
in major EU15 river basins

Estimated by the GREEN model

Nitrogen Source Apportionment: contribution of each source (point and diffuse) to the river nitrogen load

Objective 3

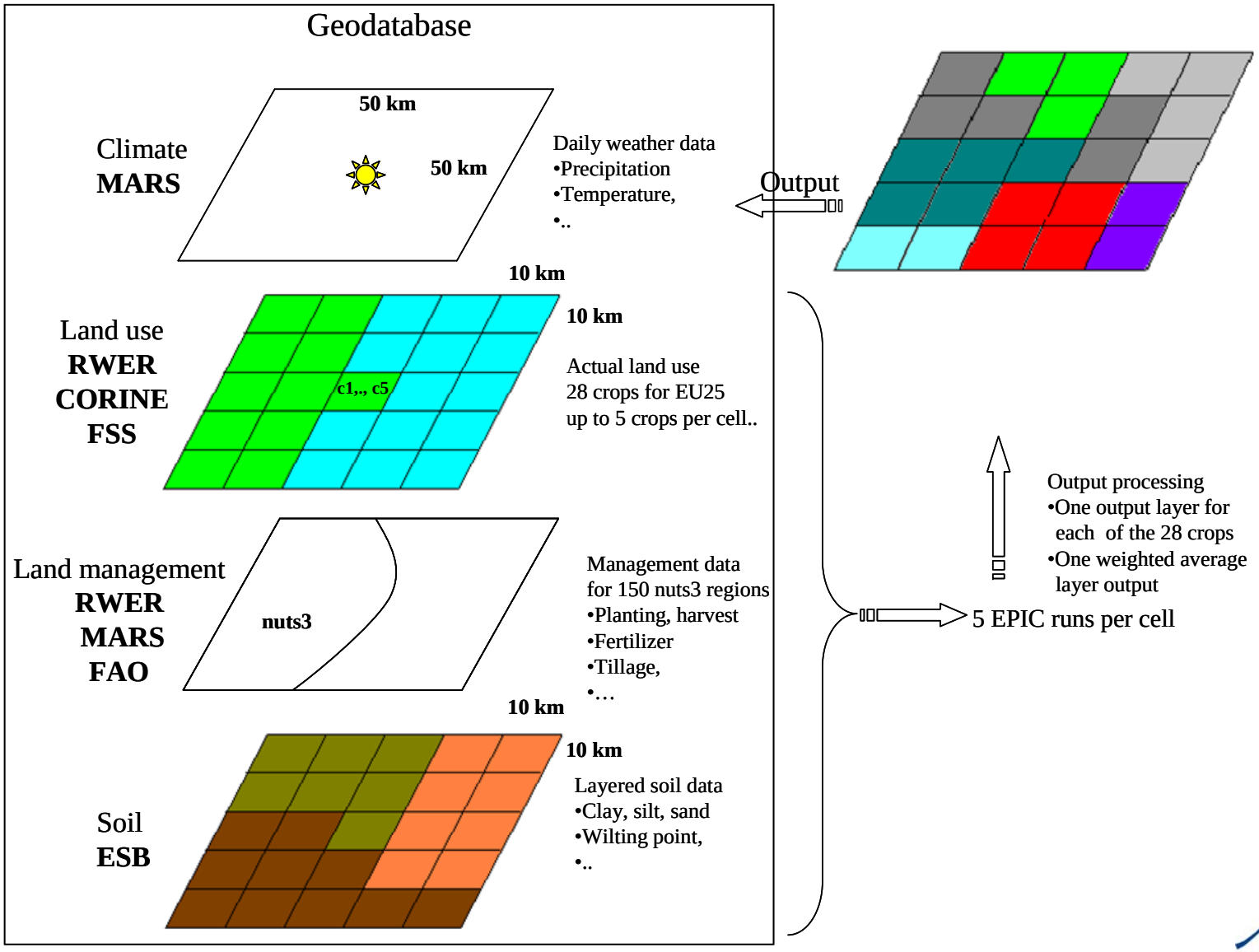
3 Effects of climate change

European Agrochemicals Geospatial Loss Estimator: EAGLE

EAGLE is composed of three components:

1. **EPIC model** (Williams, 1995) EPIC is a continuous simulation model that can be used to determine the effect of management strategies on agricultural production and soil and water resources
2. **Database**. The EAGLE European geodatabase holds all the necessary data (soil, meteorological, crop management, etc.) to perform EPIC simulations to formulate and evaluate various management scenarios
3. **GIS Interface**. This is an ESRI ArcMap customization that allows the use of EPIC using data stored in the previously described geodatabase through an intuitive GIS interface.

EPIC –GIS link

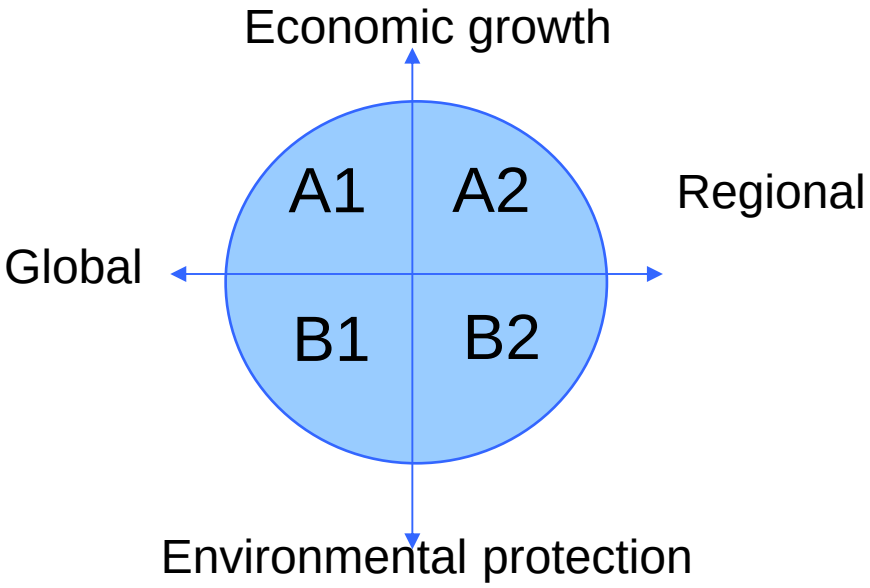


Climate change scenarios

5 Global Climate Models:

- CGCM2 (Flato and Boer, 2001)
- CSIRO2 (Gordon and O'Farrell, 1997)
- ECHAM4 (Roeckner et al., 1996)
- HadCM3 (Mitchell et al., 1998)
- PCM (Washington et al., 2000)

4 Emission Scenarios:



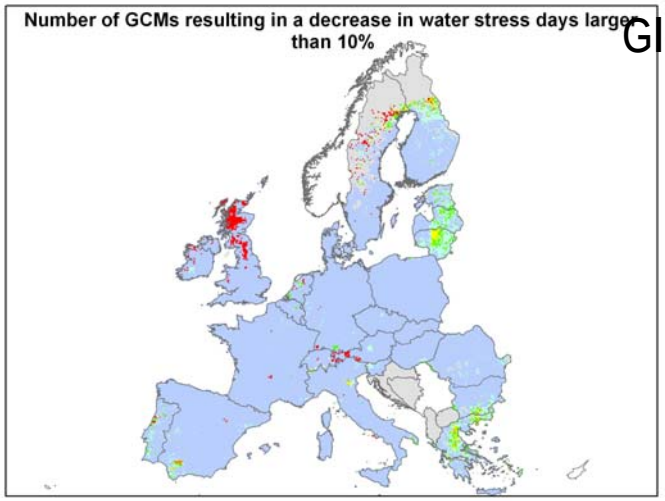
Climate Change Scenario inputs were provided by the Tyndall Centre for Climatologic Research (University of East Anglia, Norwich UK)

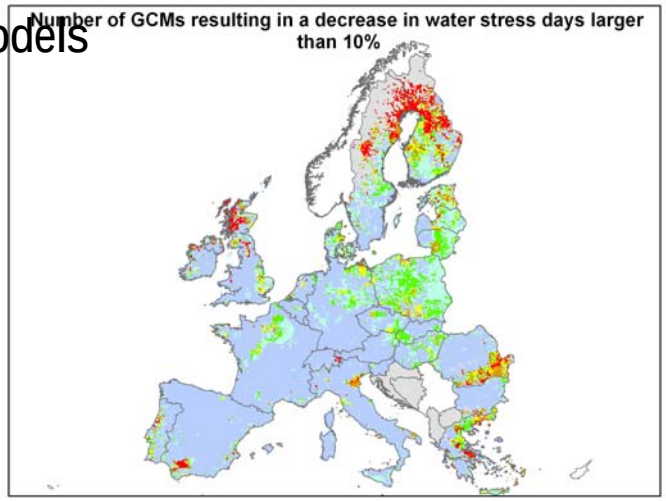
1. Absolute changes
2. Relative changes
3. Models agreement

Climate Change results: water stress

Scenario A1

Scenario B2



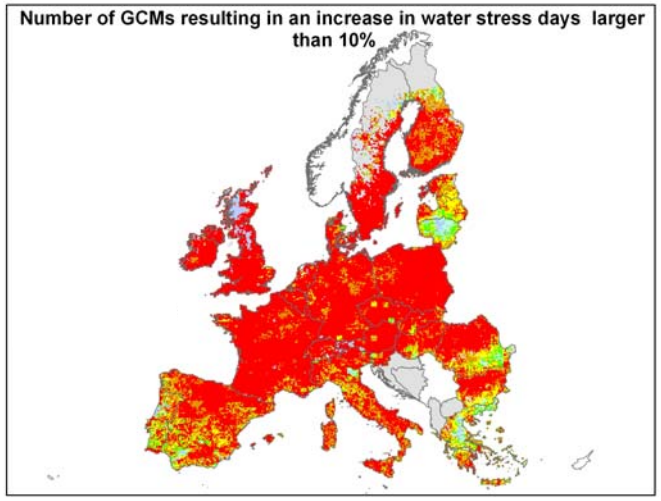


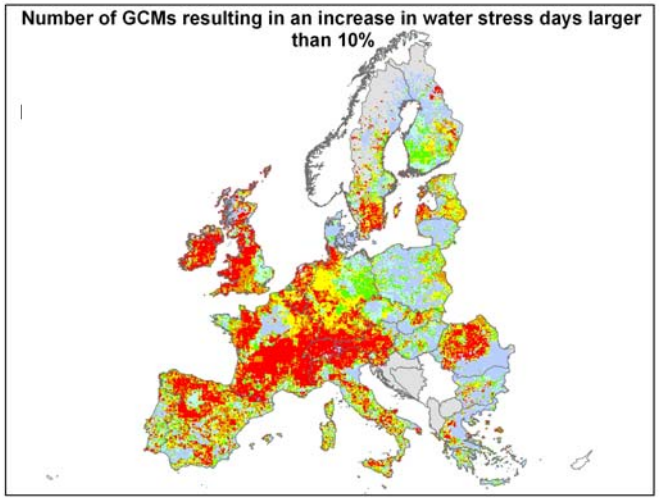
Global Climate Models

Agreement on decrease

Number of models

5
4
3
2
1
0
non agri





Agreement on increase

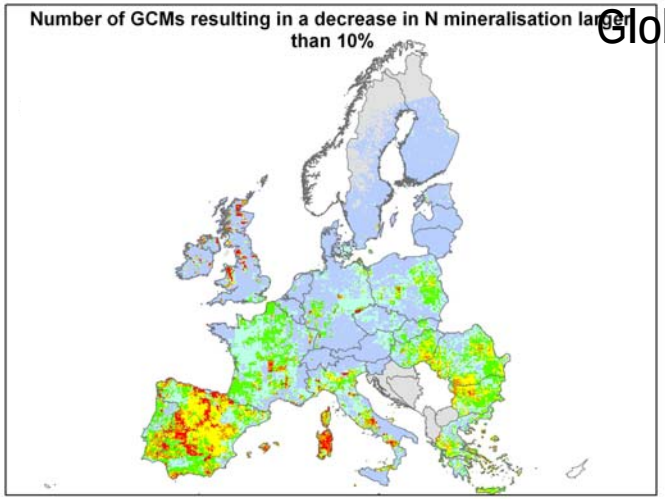
Climate Change results: mineralisation

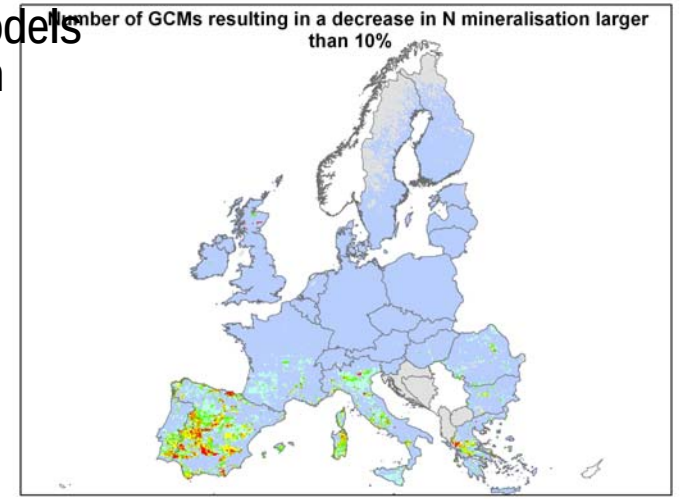
Scenario A1

Scenario B2

Global Climate Models

Agreement on decrease





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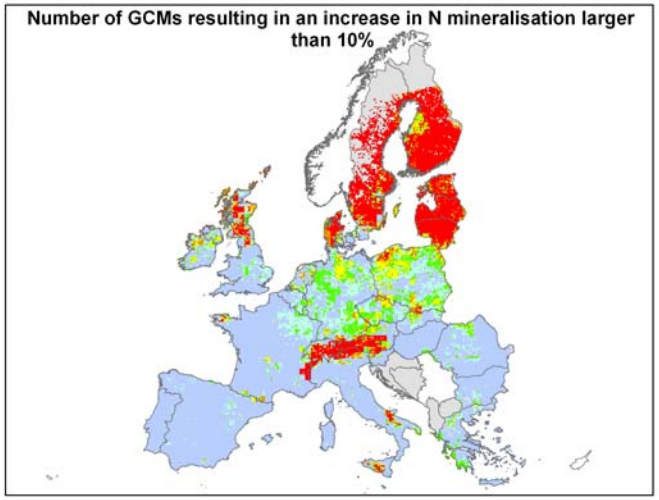
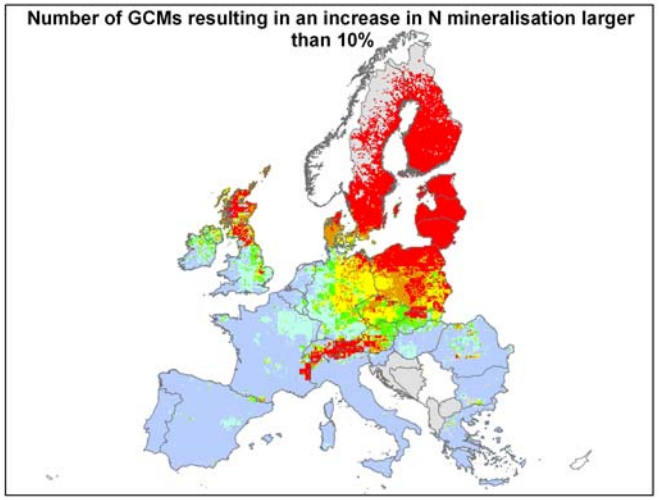


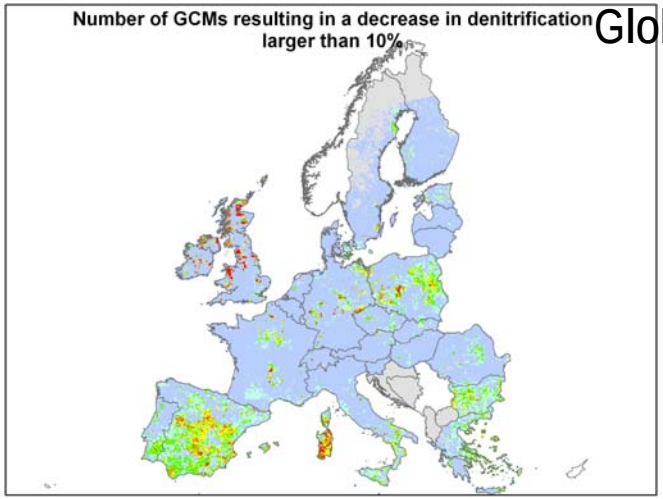


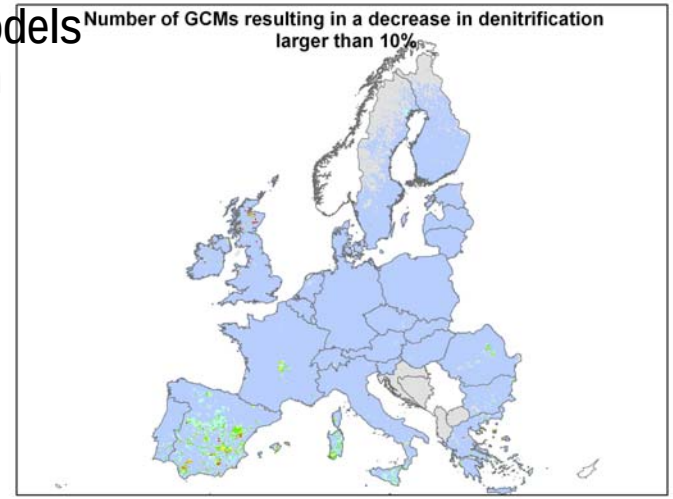
Agreement on increase

Climate Change results: denitrification

Scenario A1

Scenario B2





Global Climate Models

Agreement on decrease

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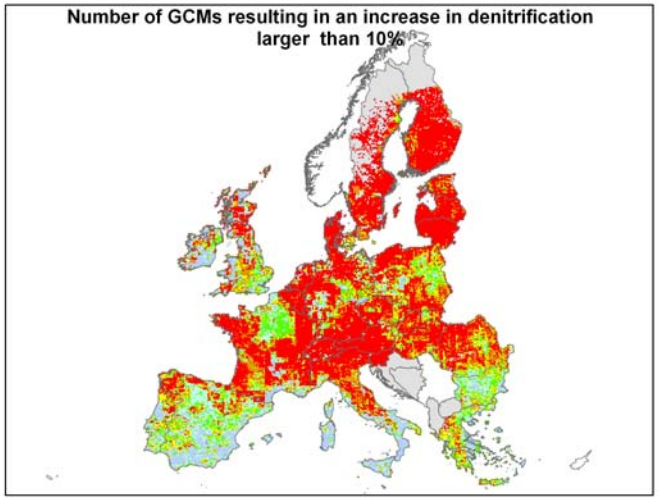
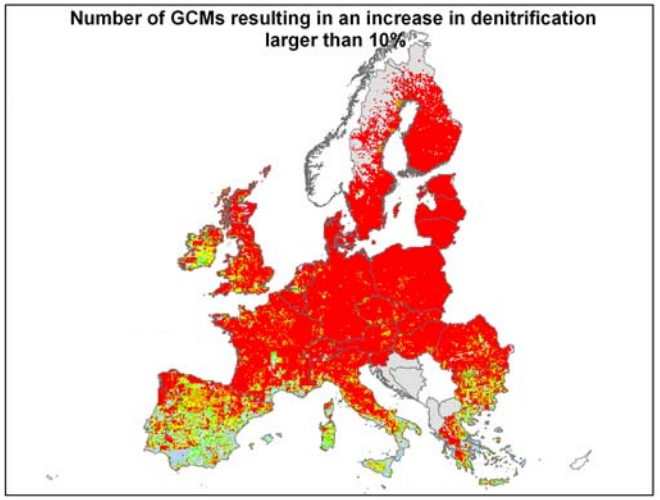


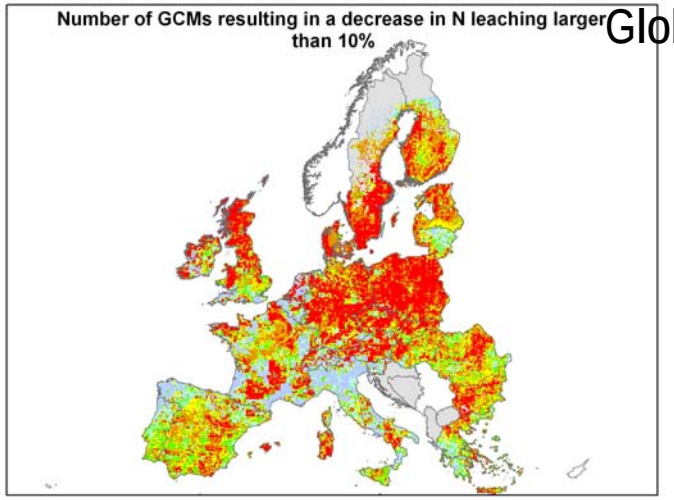


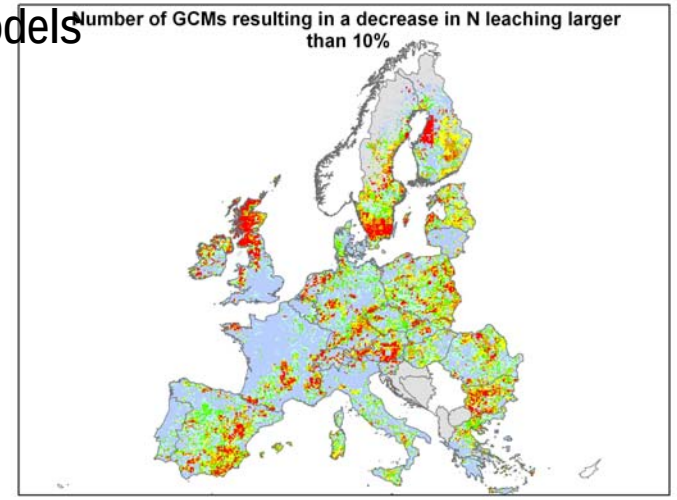
Agreement on increase

Climate Change results: N leaching

Scenario A1

Scenario B2





Global Climate Models Agreement on decrease

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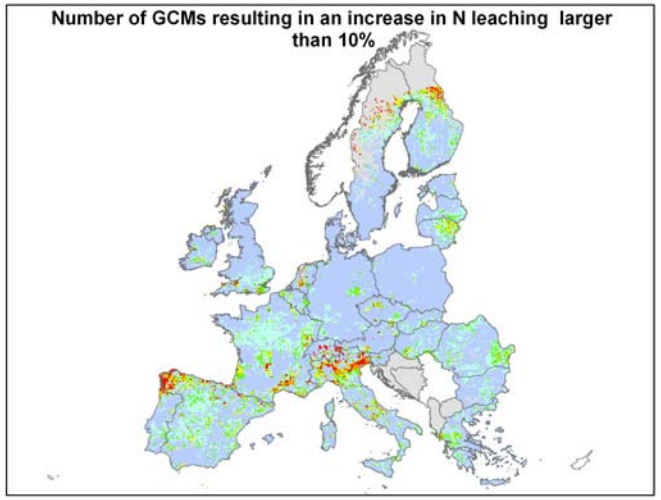
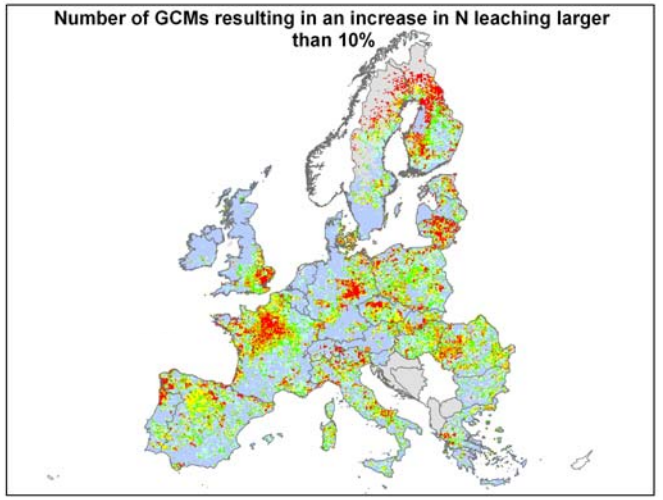


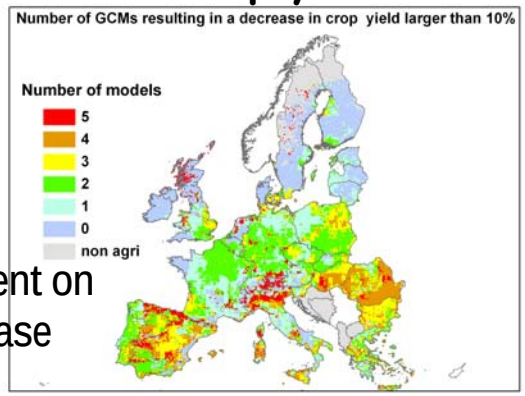


Agreement on increase

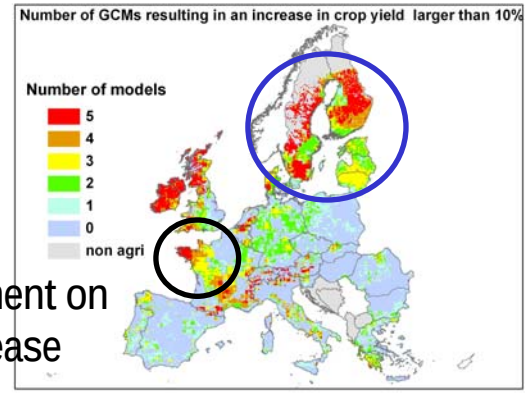
Climate Change results: N use efficiency

Scenario A1

Crop yield

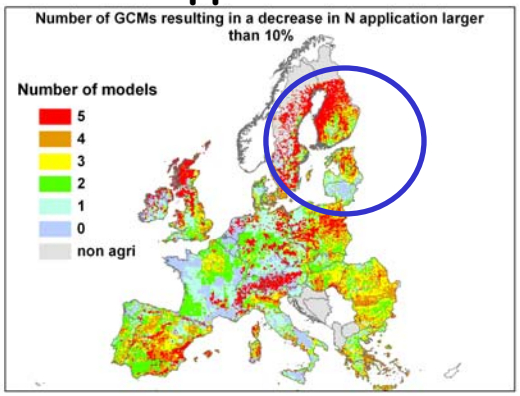


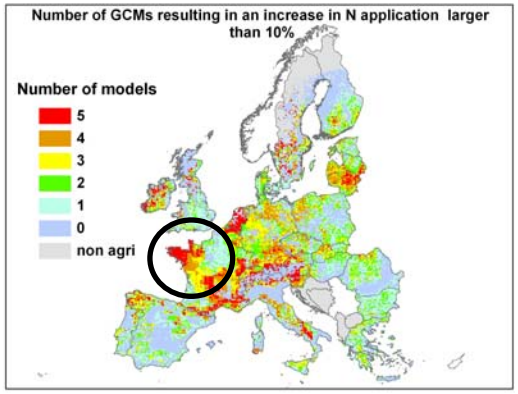
Agreement on decrease



Agreement on increase

N application





1. There is a large variability about the model prediction according to the climate scenario used
2. Some trends can identified

- General increase of water stress throughout Europe
- Crop yield will tend to decrease in the south and increase in the north
- Nitrogen application will decrease in the north, the crop requirements coming from other sources

Conclusions


Thank you…
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Picture from Mulligan 2007