Impacts of agricultural management on fluxes of nitrogen and greenhouse gases and on critical N load exceedances

Wim de Vries
Hans Kros, Gerard Velthof

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Need for integrated nitrogen research

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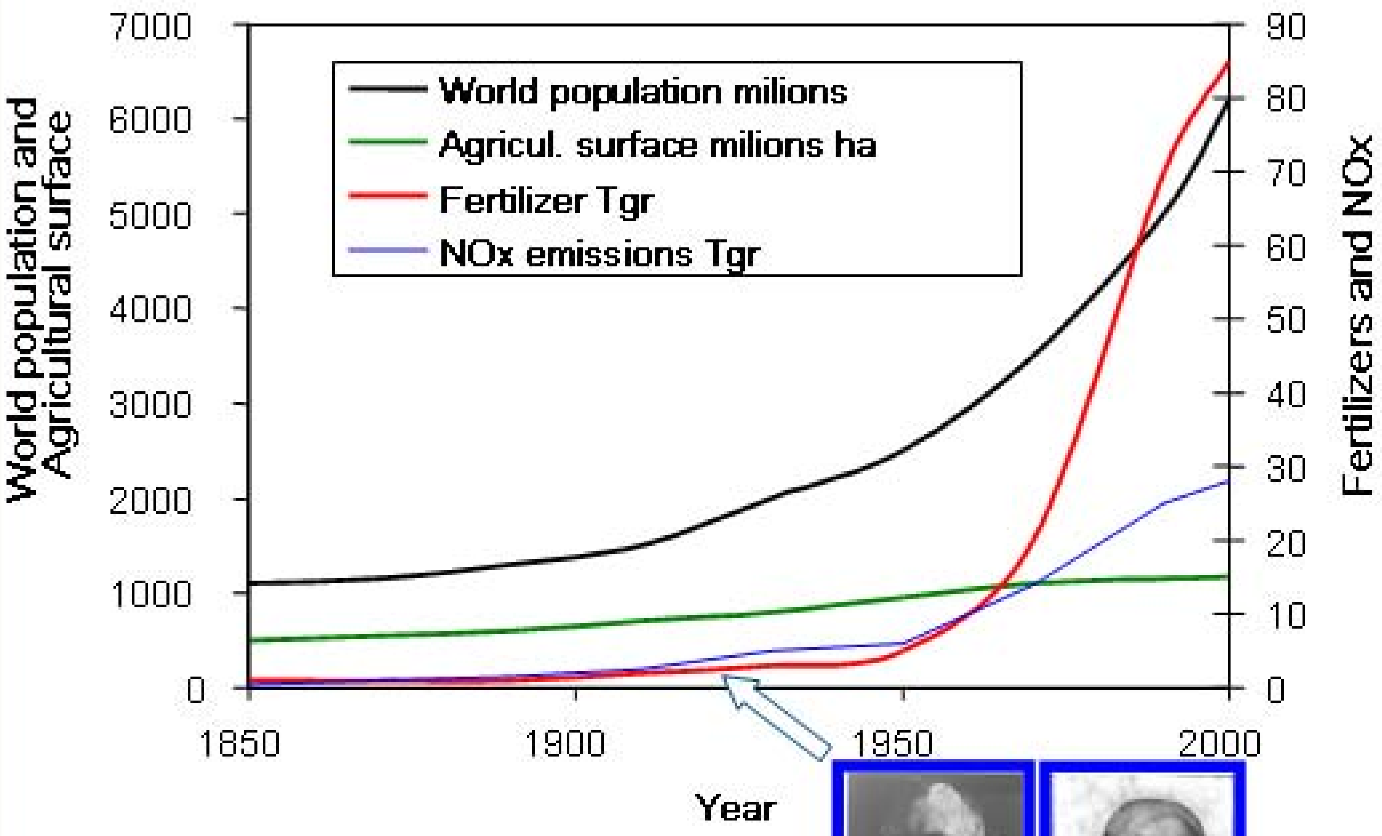
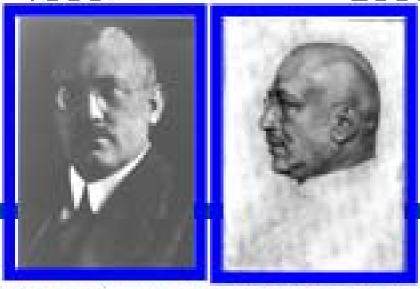
Accelerated global N cycle





Carl BoschFritz Haber

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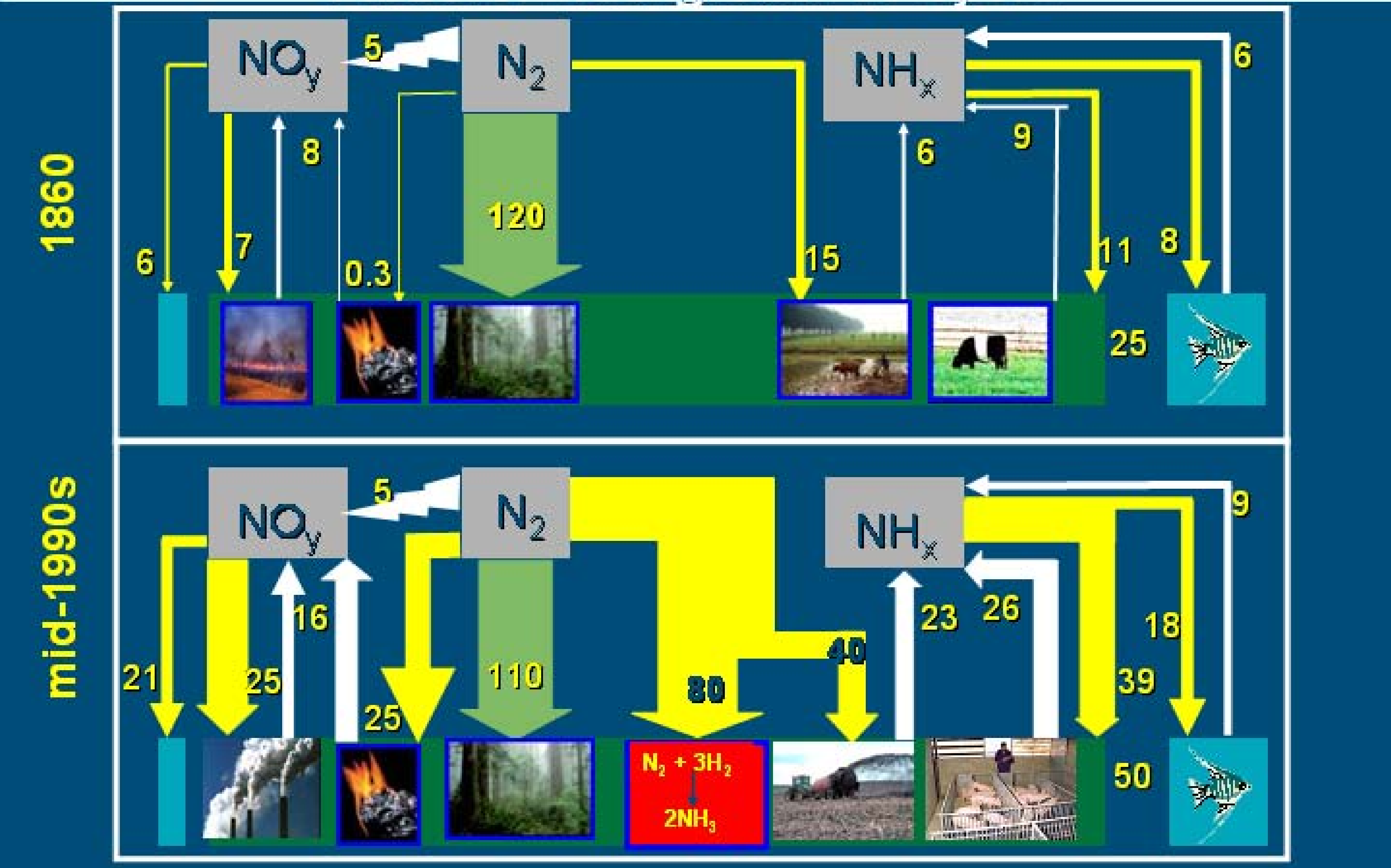
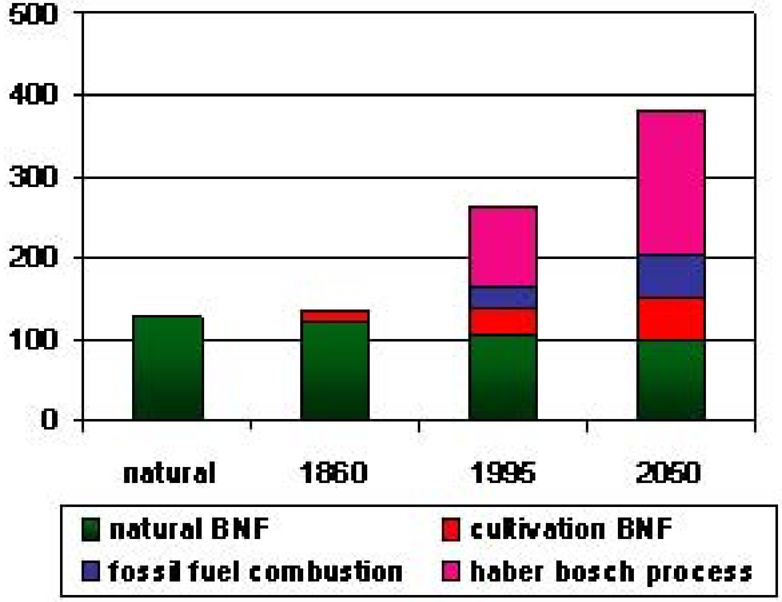
Accelerated global N cycle

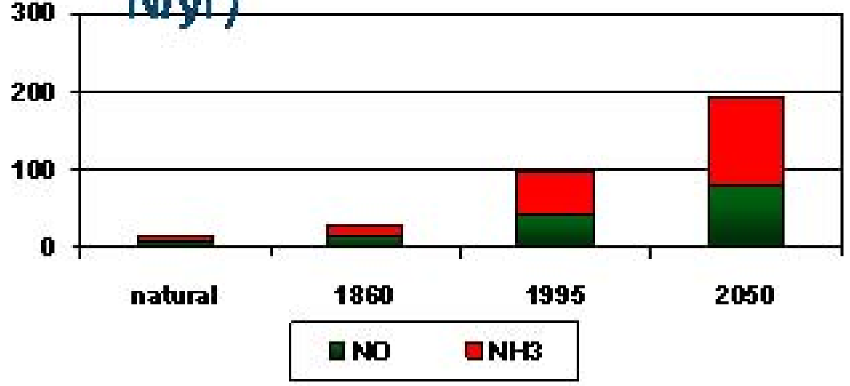


Nitrogen in the future

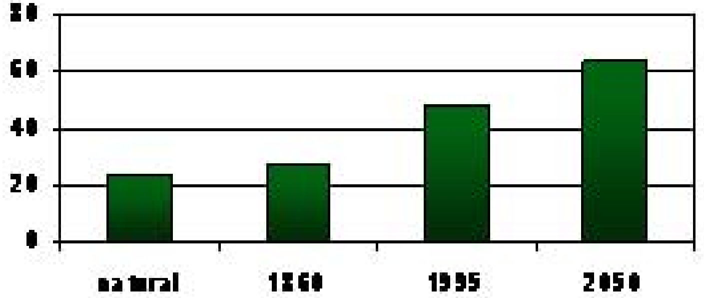
Natural and anthropogenic creation rates of reactive nitrogen (Tg N/yr)



Atmospheric emission of reactive nitrogen (Tg N/yr)



Riverine transport of reactive nitrogen to coastal zone (Tg N/yr)



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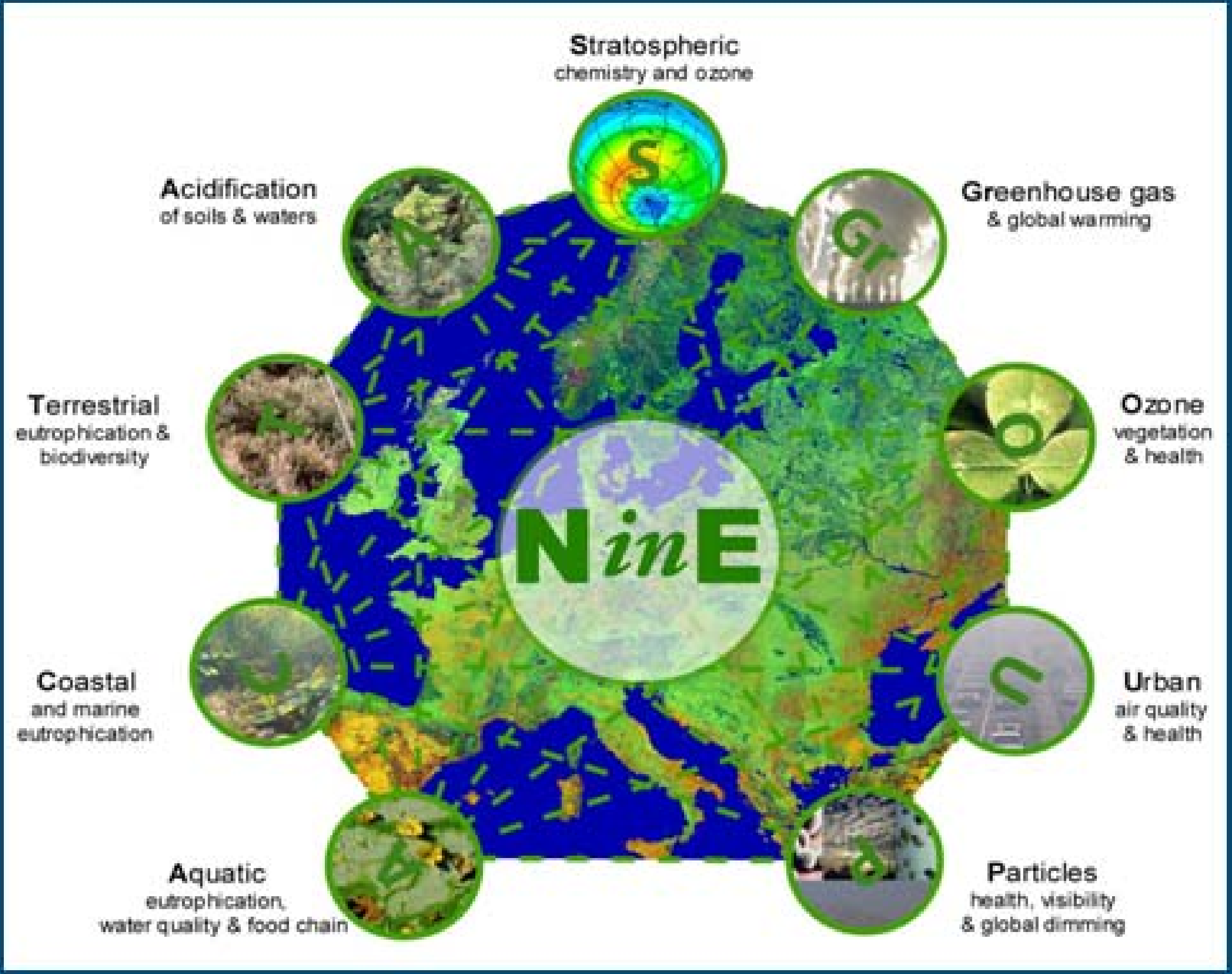
The N*in*E concept and logo



Why integrated nitrogen research?

- Emissions of ammonia and green house gases to **air** (health and climate impacts)
- Leaching and runoff of ammonium and nitrate to ground **water**s and surface waters (health and aquatic ecosystem impacts)
- Impact on terrestrial **ecosystems**/biodiversity
- Risk for the implementation of key European **policies** notably on air quality/ammonia emissions (NEC), climate change (Kyoto), water quality (WFD) and biodiversity (HD, CBD).

INITIATOR2: model predicting N and GHG fluxes at landscape/national scale

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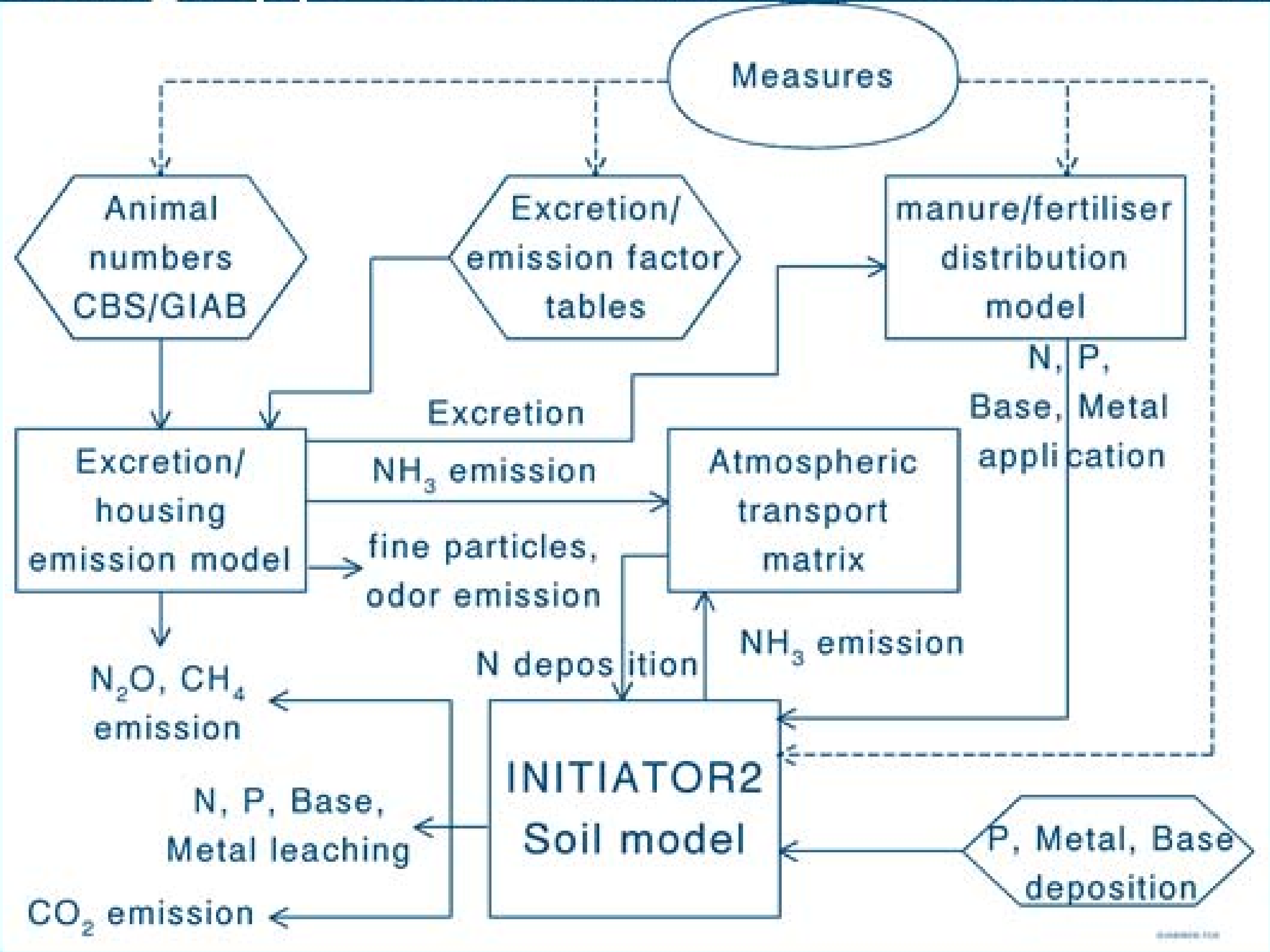
Modelling approach: aim of INITIATOR2

- INITIATOR2 aims to:
  - Quantify/optimize effectiveness of policies aimed at reduction of all relevant element fluxes (nutrient and contaminants)
  - to atmosphere, ground water and surface water.

- Relevant fluxes include:
  - Atmospheric emission of NH_3 and greenhouse gases (CO_2, CH_4, N_2O) from housing systems and terrestrial ecosystems.
  - Soil accumulation/release, leaching and runoff of C, N, P, base cations (Ca, Mg, K) and metals to ground water and surface water

Modelling approach: flowchart of INITIATOR2



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Application in Noordelijke Friese Wouden

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Noordelijke Friese Wouden (NFW)

- Area in the Northern part of the Netherlands.
- Farmers joined in an environmental cooperative.
- Agreement with government to achieve environmental targets at landscape level.
- Targets to be reached in 5 -10 years.
- Freedom regarding measures as long as the environmental targets are attained.

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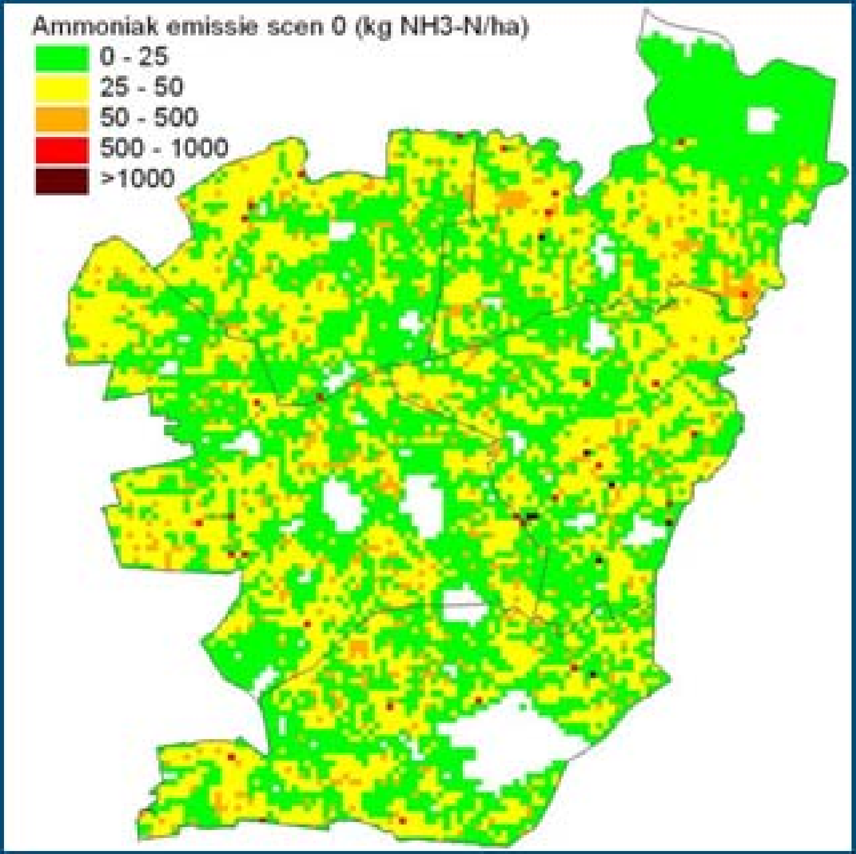
Environmental ambitions NFW

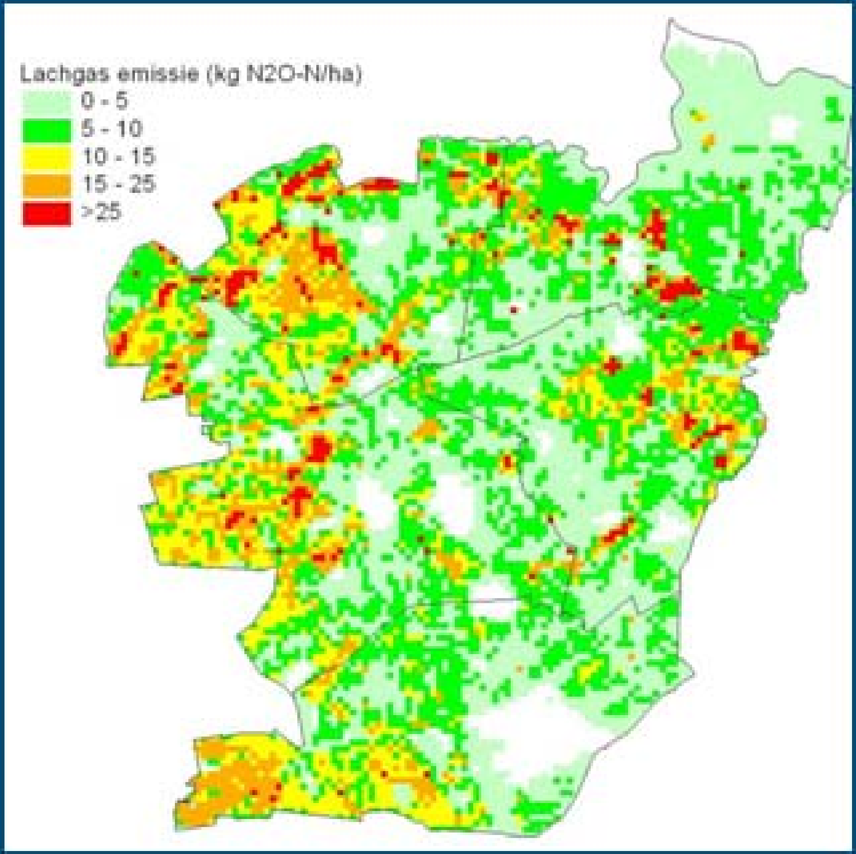
- Ground- and surface water:
  - NO_3 ground water < 50 mg l^{-1}
  - N in surface water < 2.2 mg l^{-1}
  - P in surface water < 0,15 mg l^{-1}

- Nature
  - Emission ceiling of 2 kton NH_3-N based on NEC of 93 kton NH_3 and the present ratio of NFW vs national emissions
  - Only 10% exceedance of critical N loads per nature target type; 90% protection of nature.

Emissions NH_3 and N_2O in NFW in 2004



NH_3 emission (kg NH_3-N ha^{-1})



N_2O emission (Kg N_2O-N ha^{-1})

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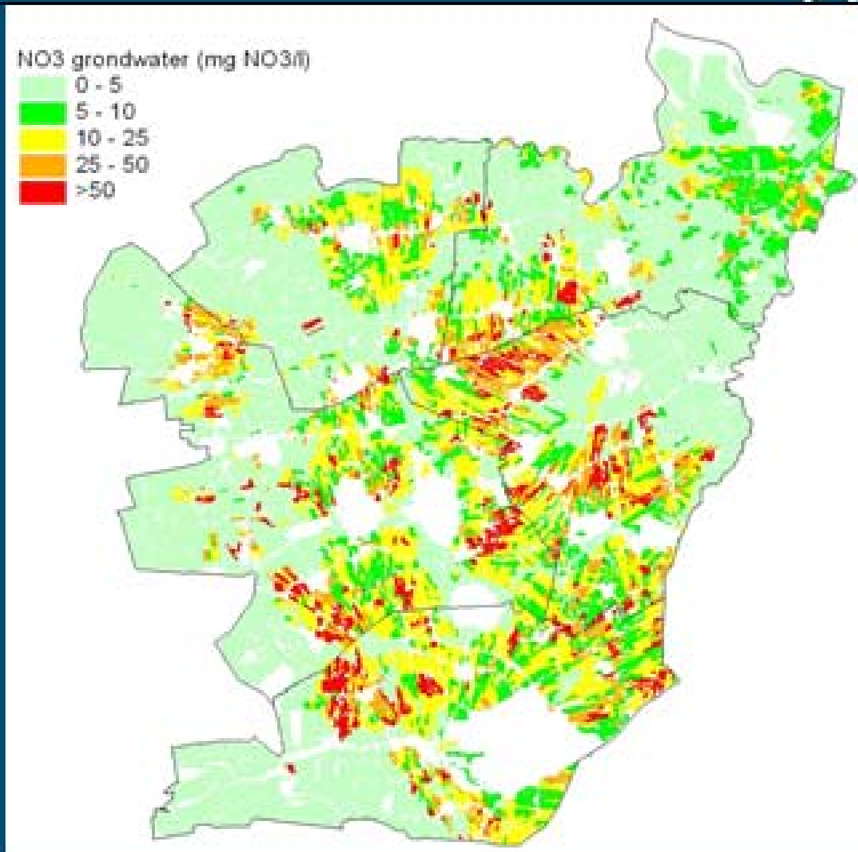
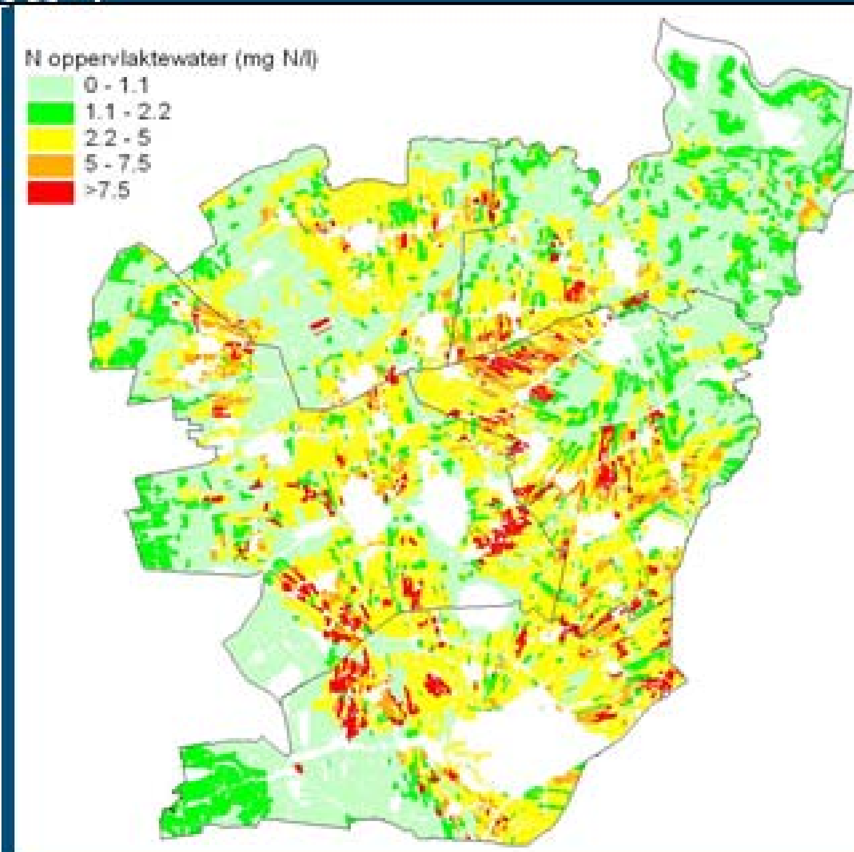
N conc. in ground and surface water in NFW in 2004

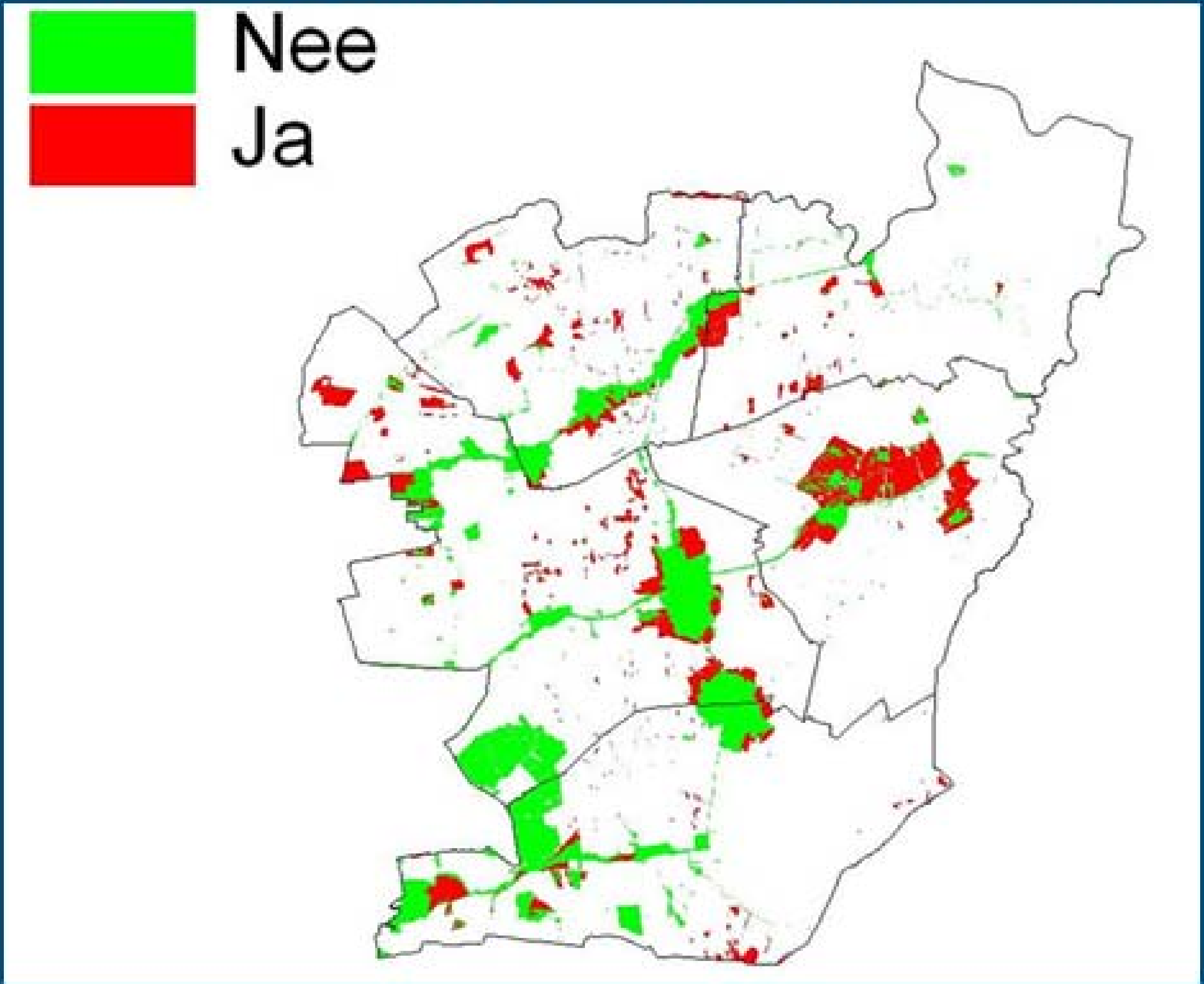


Nitrate in groundwater



Nitrogen in surface water

Exceedance critical N loads in NFW in 2004



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Effects on NH_3 and N_2O emissions and NO_3

Aspect	Present	Low protein feeding and manure spreading 35%
NH_3 emission (kton N)	2.2	2.0
N_2O emission (kton N)	0.46	0.35
Exceedance NO_3 limit (%)	5.7	2.7

Effects on the exceedance of criticalN N loads

	Deposition N Mol N /ha	Exceedance %
Present situation	1687	39.1
NH_3 emission NFW = 0	1040	6.1
Low protein feeding	1556	38.2
Low protein feeding+ injection 10-12%	1495	38.8

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INTEGRATOR/MITERRA Europe: model predicting N and GHG fluxes at European scale

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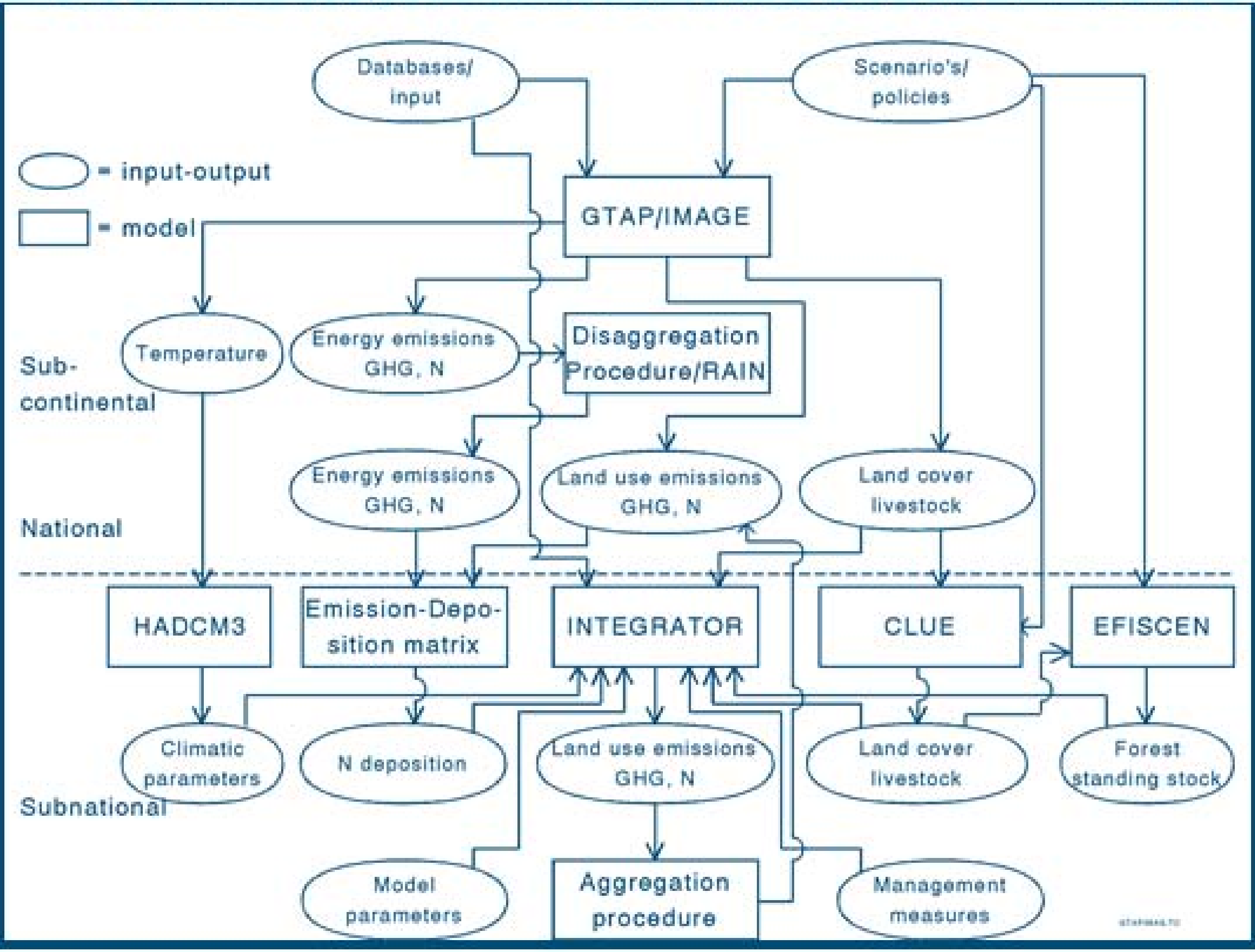
Objectives INTEGRATOR

- Develop and apply spatially explicit detailed ecosystem models and an integrated **tool** for the European scale to:
  - Assess **current** N (NH_3, NO_x) and GHG (CO_2, N_2O, CH_4) emissions from **terrestrial ecosystems** and **interactions** between N and C and between **agricultural and non-agricultural systems.**
  - Predict **past and future** N and GHG emissions/sinks in response to various scenarios on changes in: (i) land cover and land management and (ii) climate and N deposition

Approach to multi sector model INTEGRATOR



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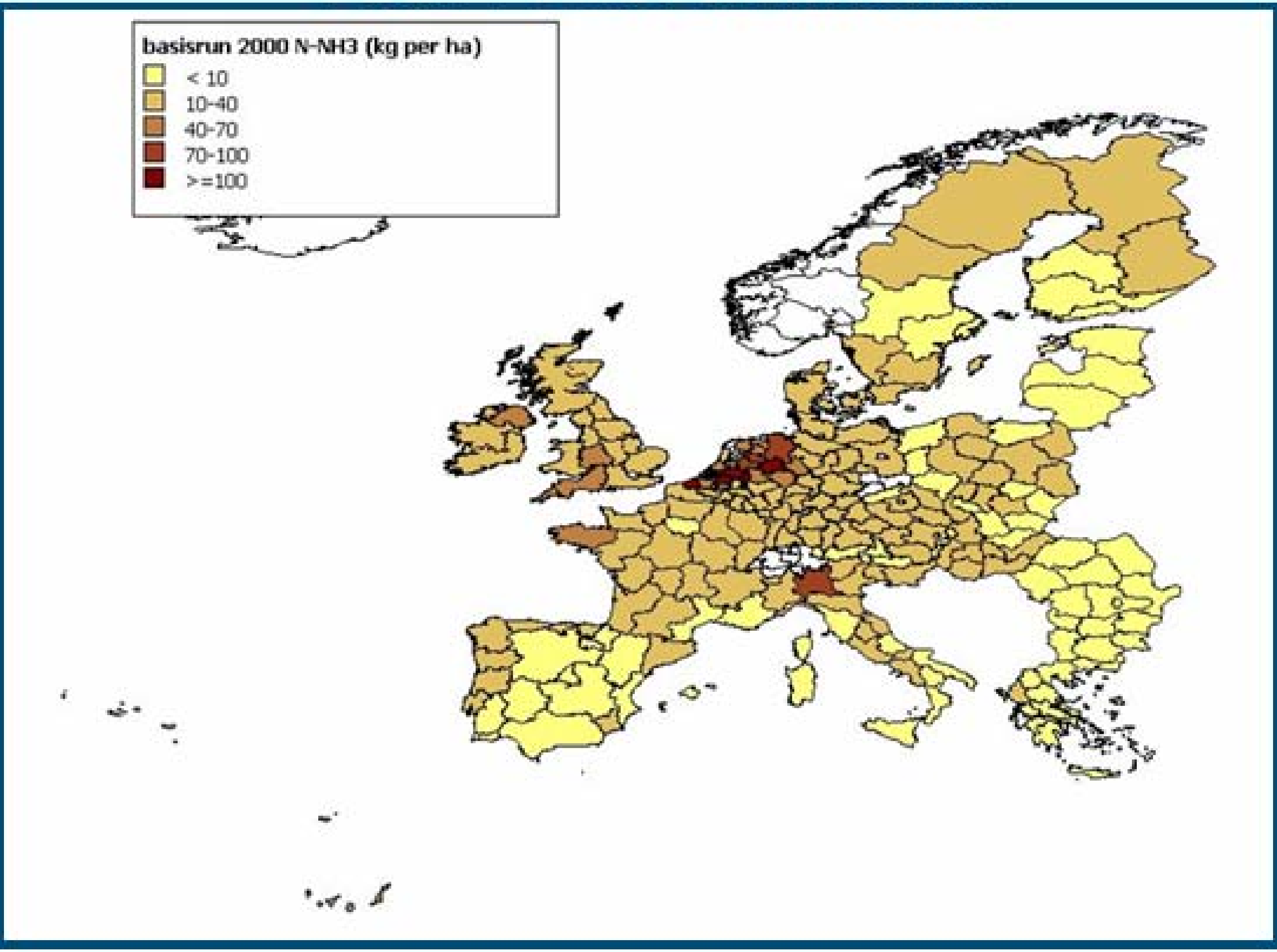
Agricultural module: MITERRA - EUROPE

- Includes ammonia, nitrous oxide and methane emissions and nitrate leaching from housing and manure storage systems and from agricultural soils
- Steady state model: no dynamics included
- Focused on evaluation of measures to mitigate ammonia and nitrate emissions

Year 2000: ammonia



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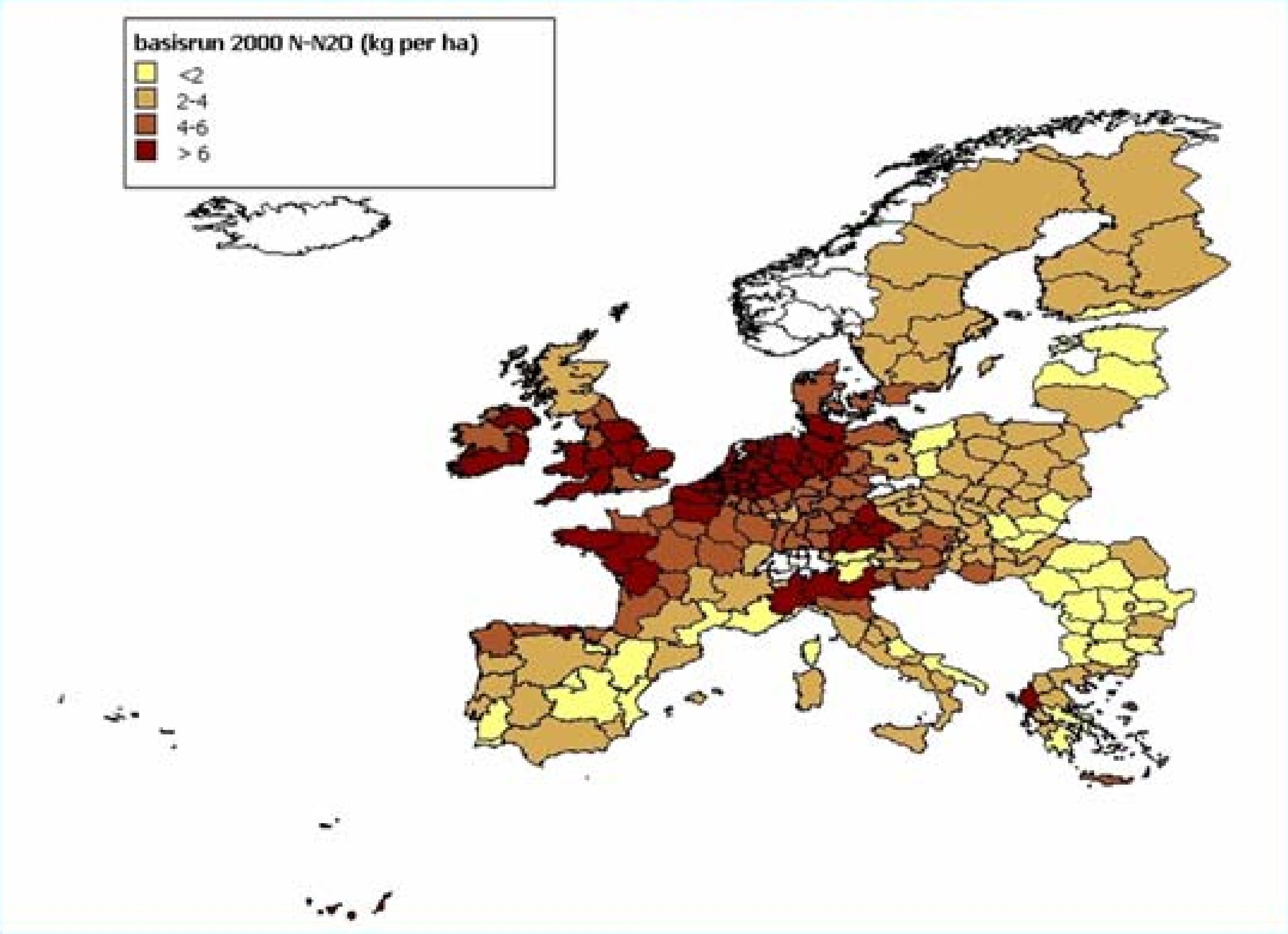
Year 2000: nitrous oxide



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Ammonia measures (from RAINS)

- Low Nitrogen Fodder (dietary changes)
- Stable Adaptation by improved design and floor construction
- Covered Manure Storage
- Biofiltration (air purification)
- Low Ammonia Application of Manure
- Substitution of urea with ammonium nitrate
- Incineration of poultry manure

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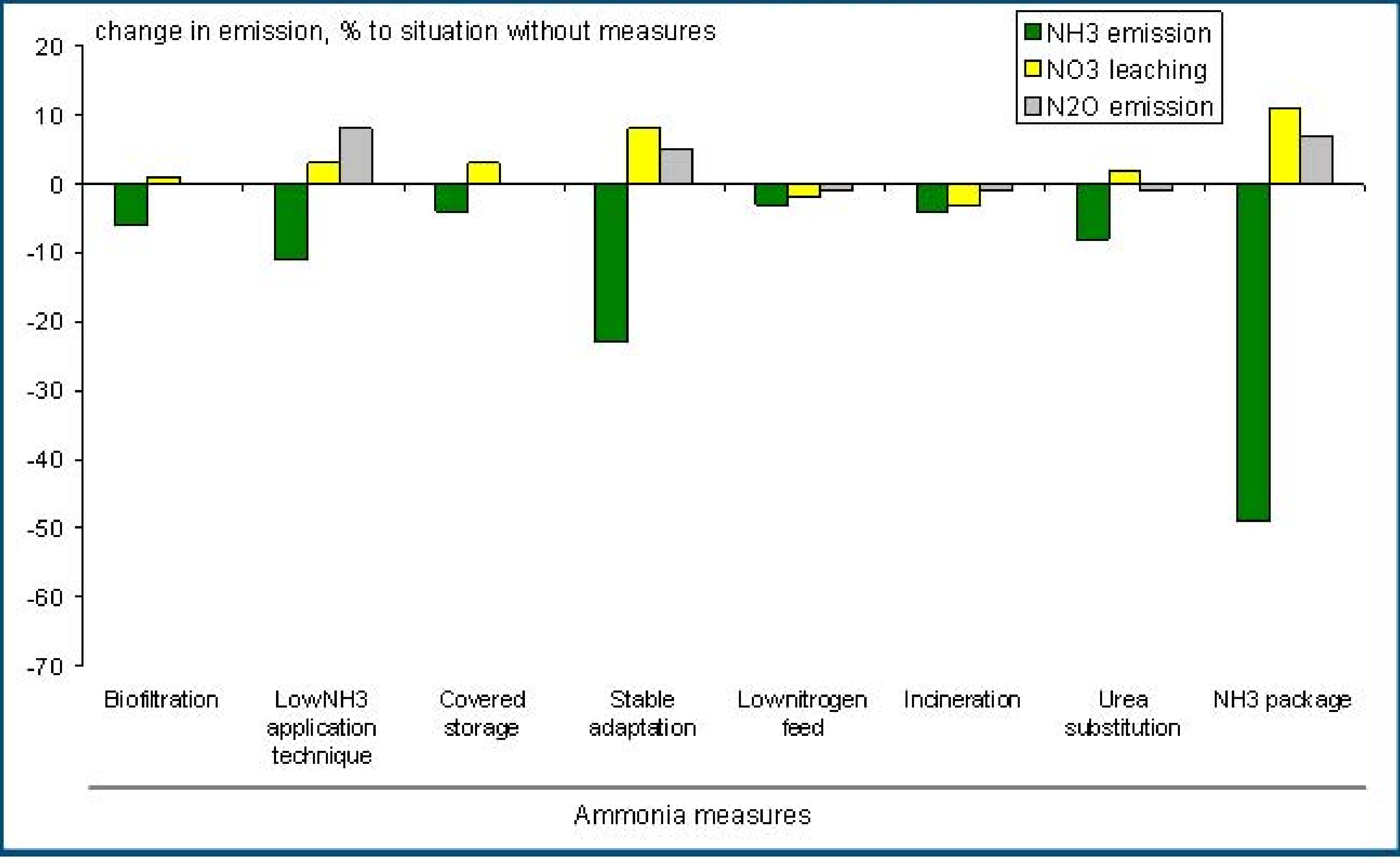
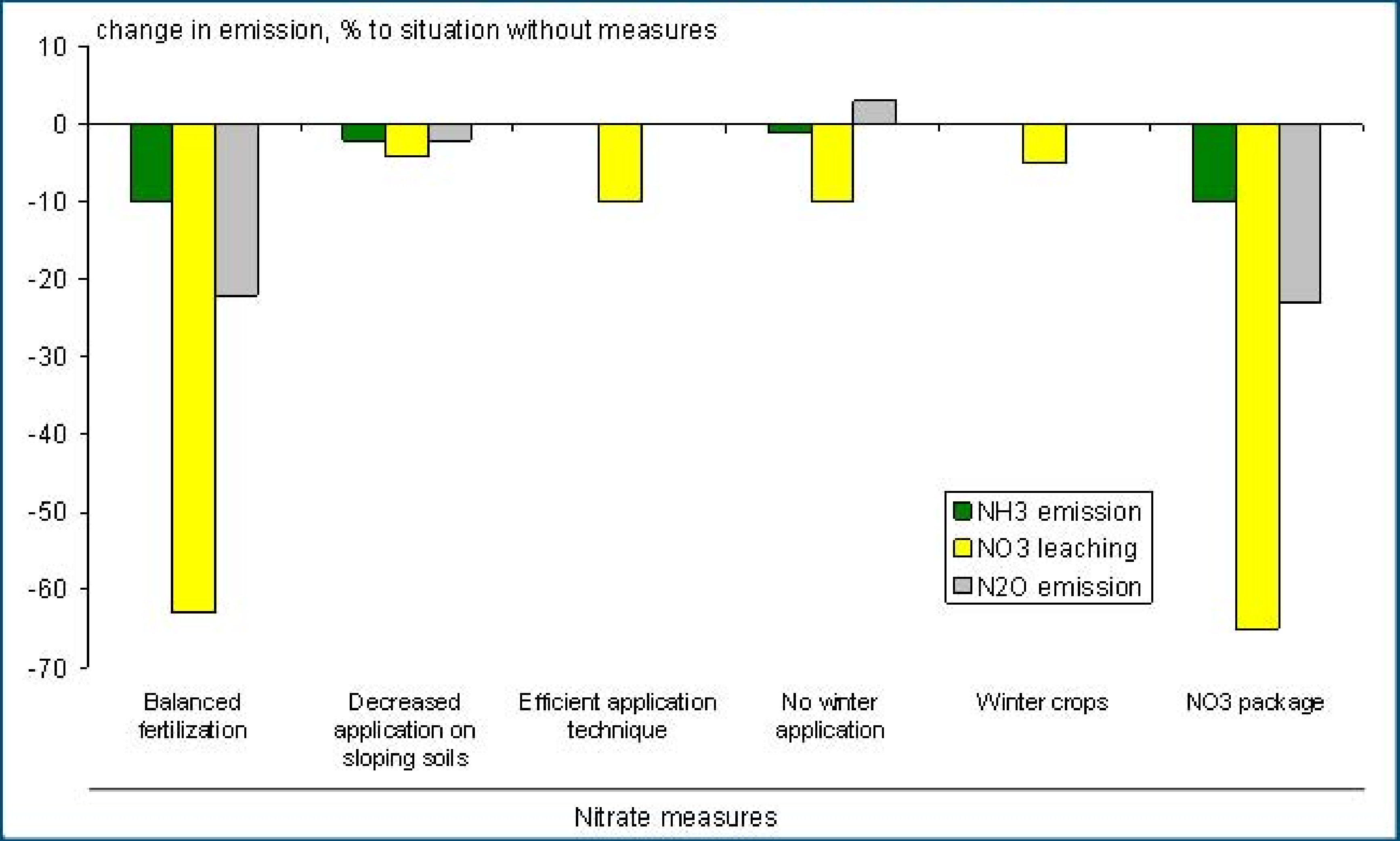
Selected nitrate measures from Nitrate Directive

- balanced N fertilizer application
- maximum manure N application rate
- no fertilizer and manure application in winter and wet periods
- limitation to fertilizer application on sloping grounds
- manure storage with minimum risk on runoff/seepage
- appropriate fertilizer and manure application techniques
- growing winter crops
- Buffer strips near water courses

Effect of single measures



Effect of single measures

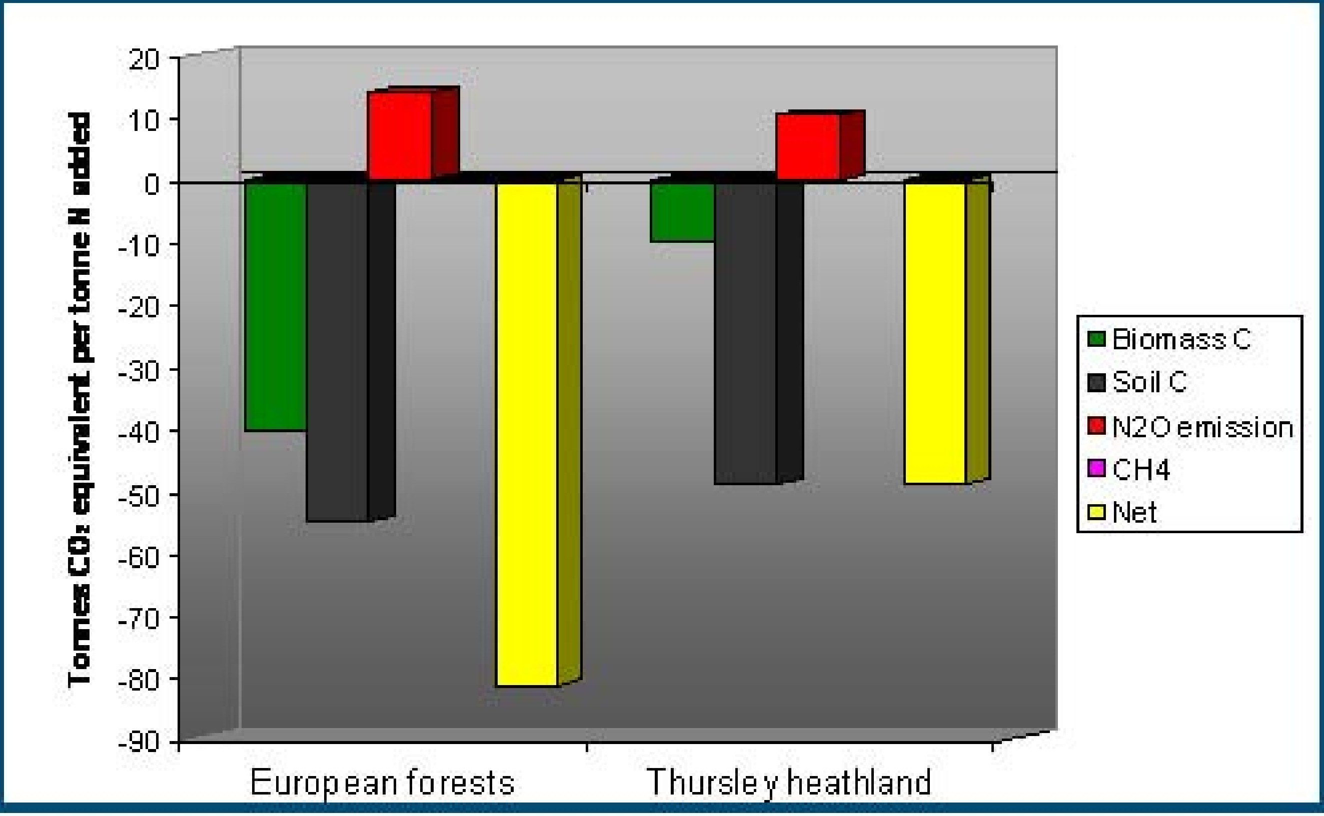


Non agricultural model for impacts of N deposition on GHG exchange

- An increase in nitrogen deposition leads to an enhanced :
  - Growth and thus an increased CO_2 sequestration in trees
  - Carbon input by litterfall and often a retarded decomposition and thus an increased CO_2 sequestration in soil
  - Nitrogen cycle and thereby an increased nitrification and denitrification and thus an increased N_2O emission
  - CH_4 sink by oxidation in a strongly nitrogen limited ecosystem and a reduced CH_4 sink in all other ecosystems

Nitrogen deposition and CO_2 sequestration

Comparison of net greenhouse gas budget (in CO_2 equivalents) per unit N added, European forests and Thursley Common



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Way forward in UNECE context

Way forward

- Include relationships in soil (acidification) models between: (i) N deposition and C/N dynamics, (ii) C/N dynamics and N availability and biodiversity.
- Include relationships between C/N dynamics and N_2O emissions (good empirical relationships): relation N deposition and GHG exchange >> climate change .
- Include impacts of temperature on biogeochemical processes to evaluate impacts of climate change.

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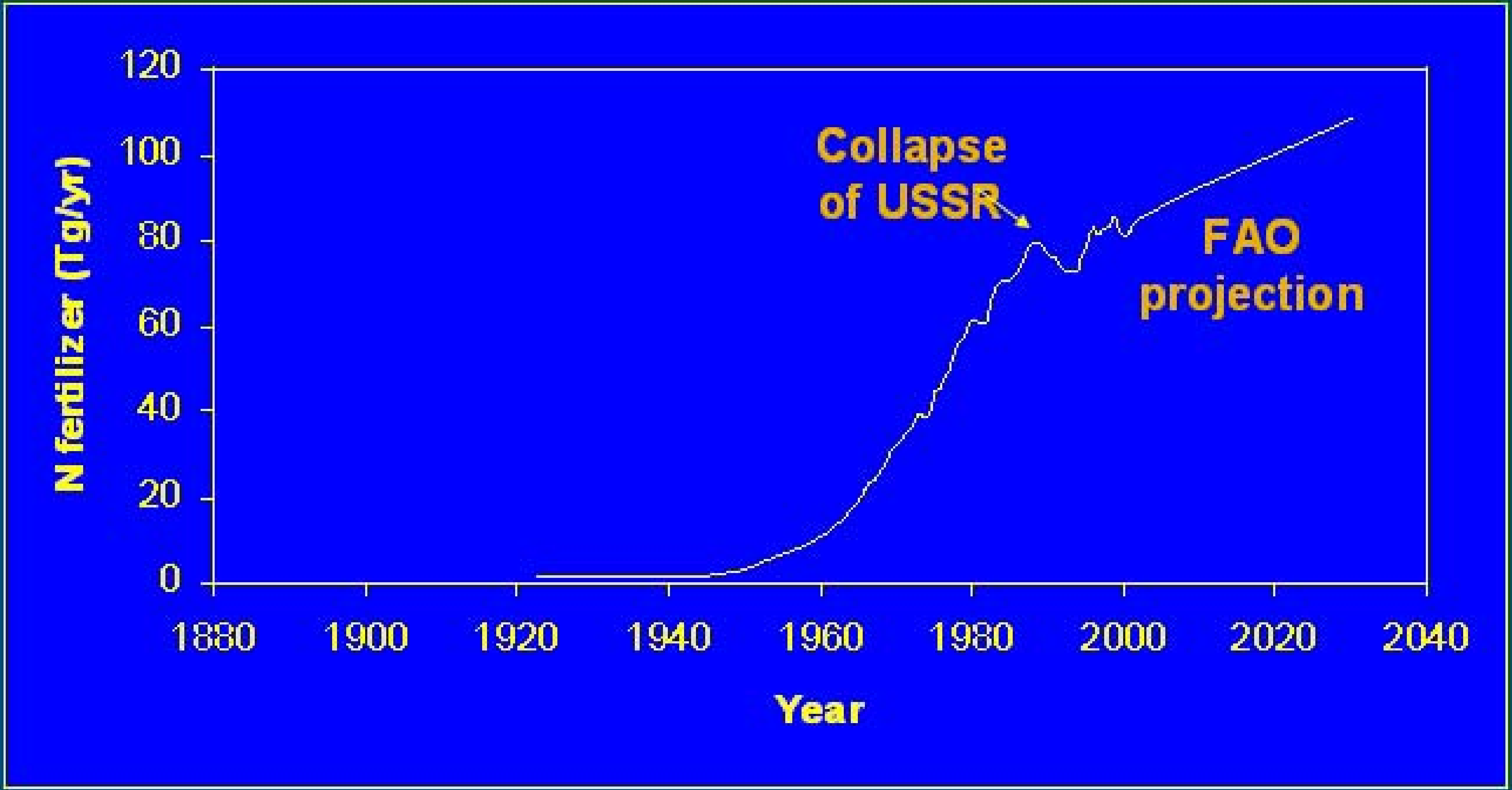
Accelerated global N cycle

Fertilizer production



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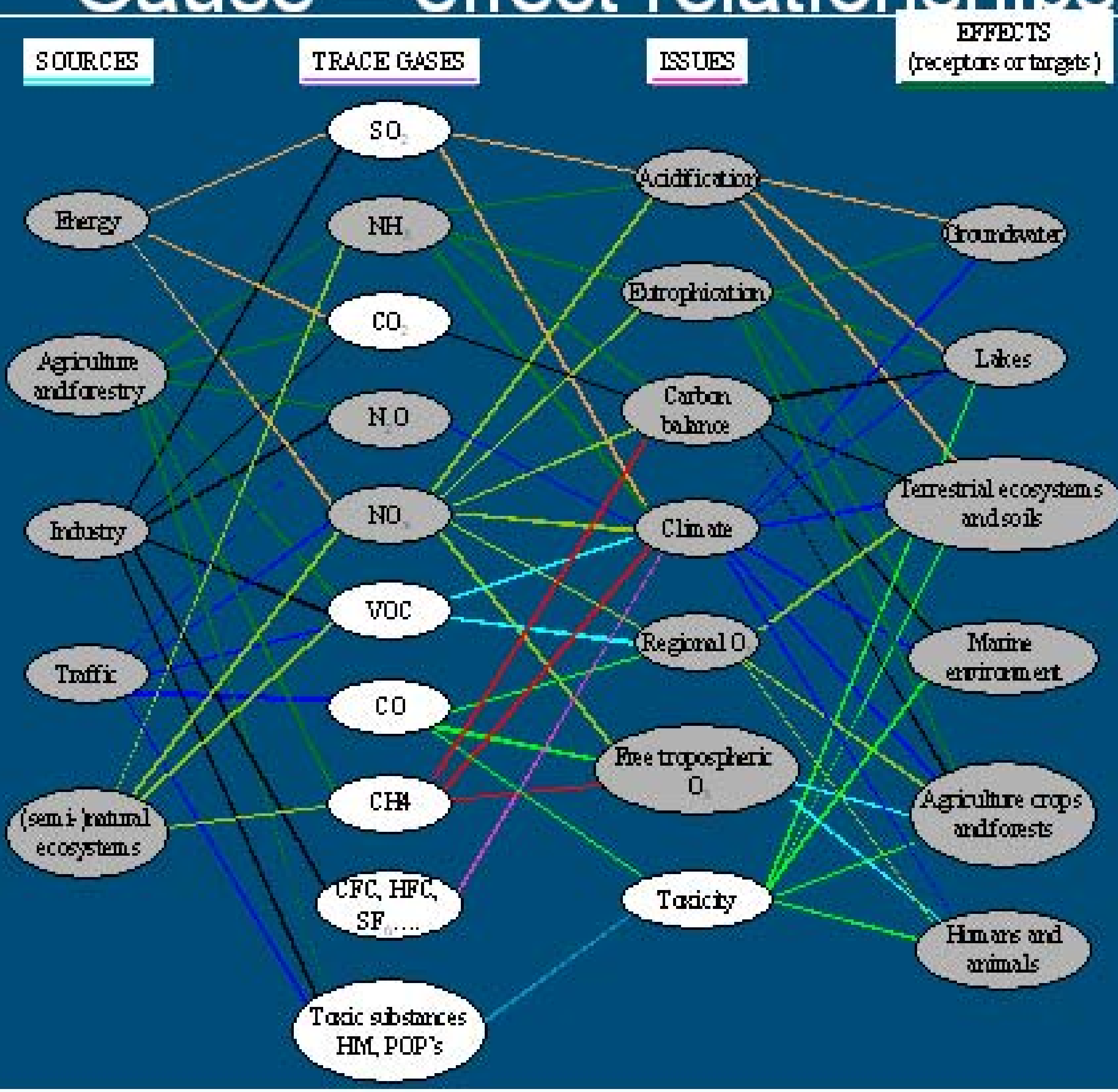
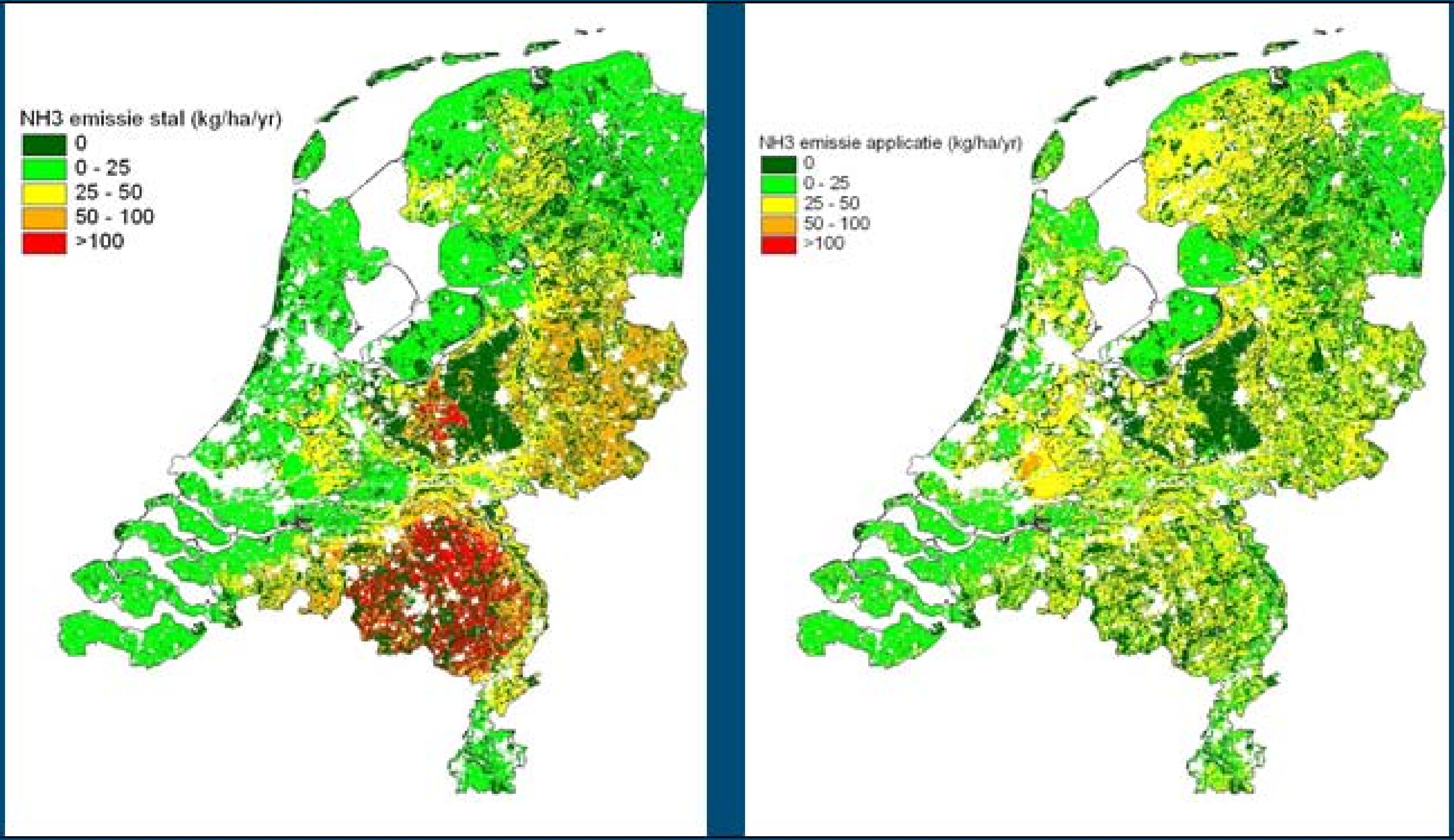
Cause – effect relationships



ESF – Research Network Programme: Nitrogen in Europe: Problems and Solut[ions]

- Running for 5 years, started March 2006
- Aims to integrate European research and researchers
- Delivering an assessment report of the state of European nitrogen, sources, transformations and impacts, as well as establishing a basis to recommend future solutions

Housing and soil emissions ammonia in 2000



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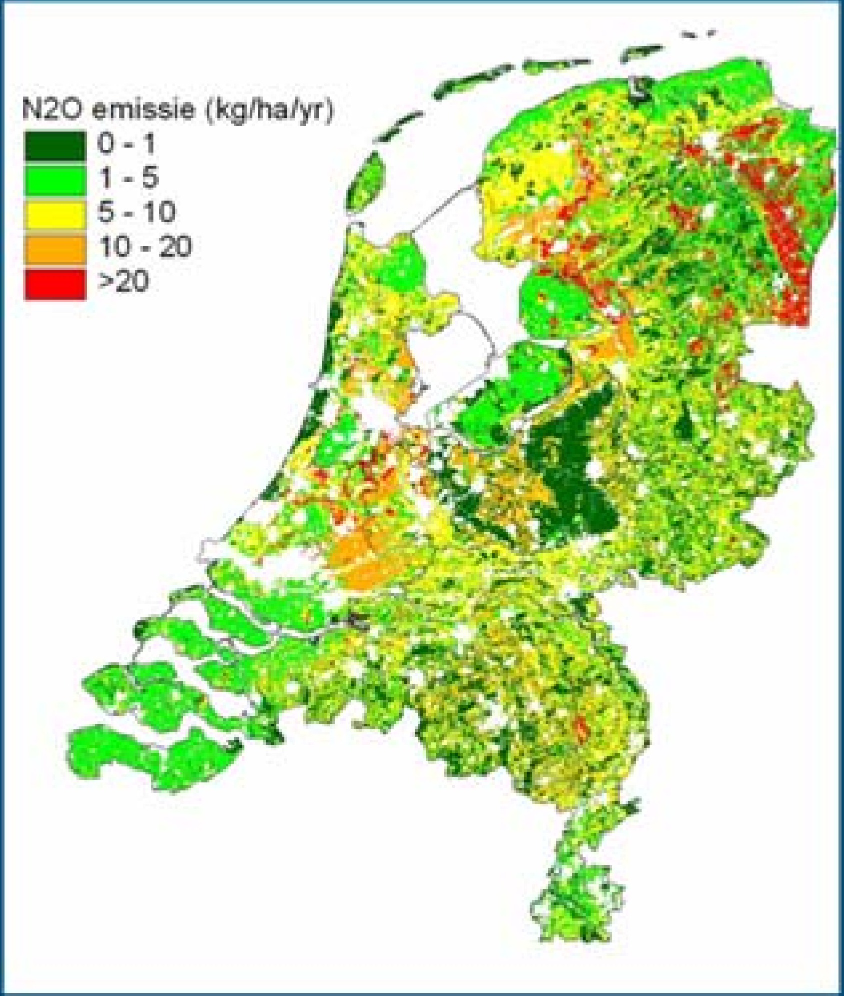
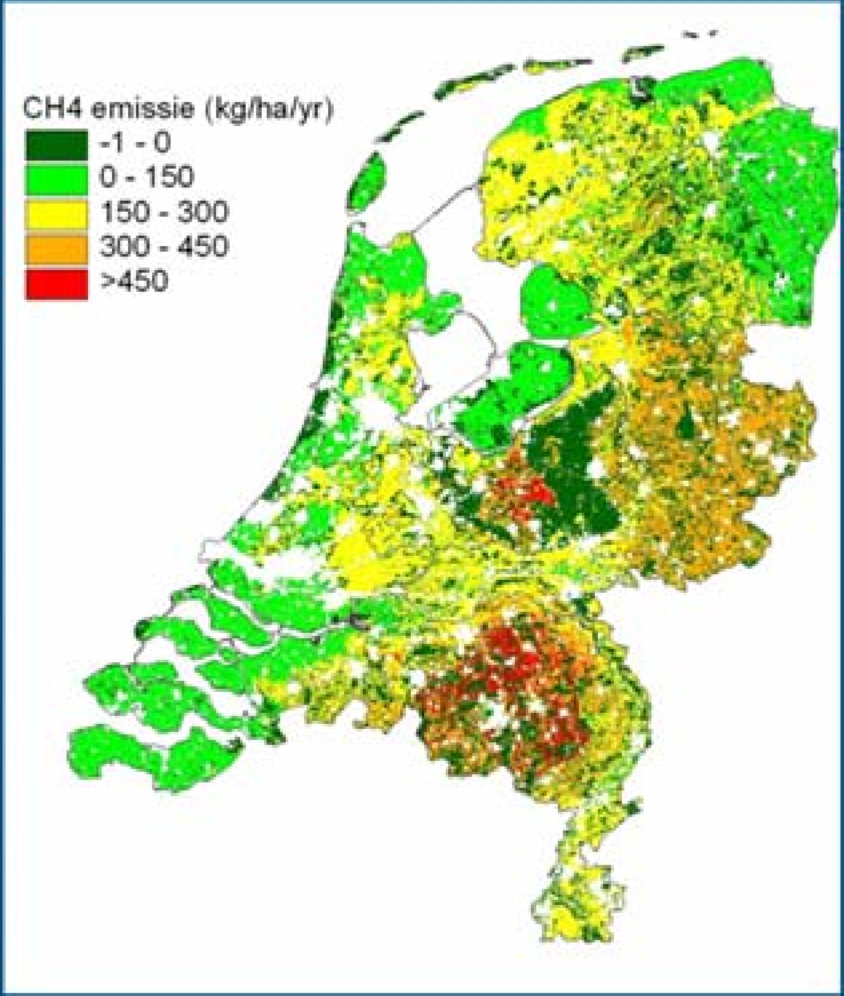
Emission of nitrous oxide and methane in 2000





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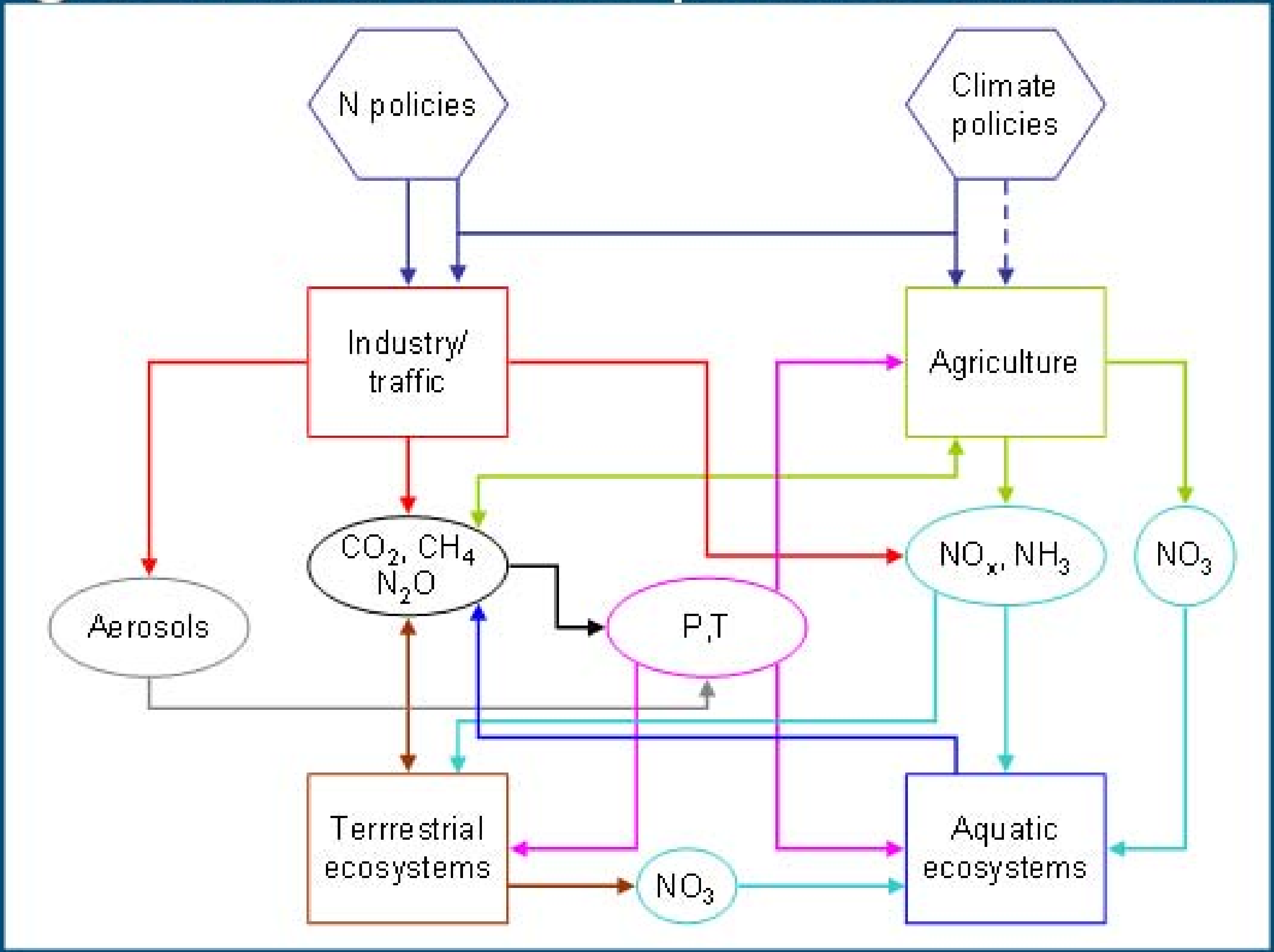
Scales

- Spatial:
  - 27 member countries
    - Country level
    - Nuts 2 level
    - Nitrate Vulnerable Zones
- Temporal: yearly

Input data

FAO	Fertilizer (national), yields
CAPRI	Area of crops
	distribution of animals over NUTS II
RAINS	Animal numbers and excretion factors
	Manure management systems
JRC/CAPRI	Soil and meteorological data
Alterra/EU	NVZ maps
Service contract	N contents and crop residues
	Grassland area and yields

Linkages N and climate policies and GHG



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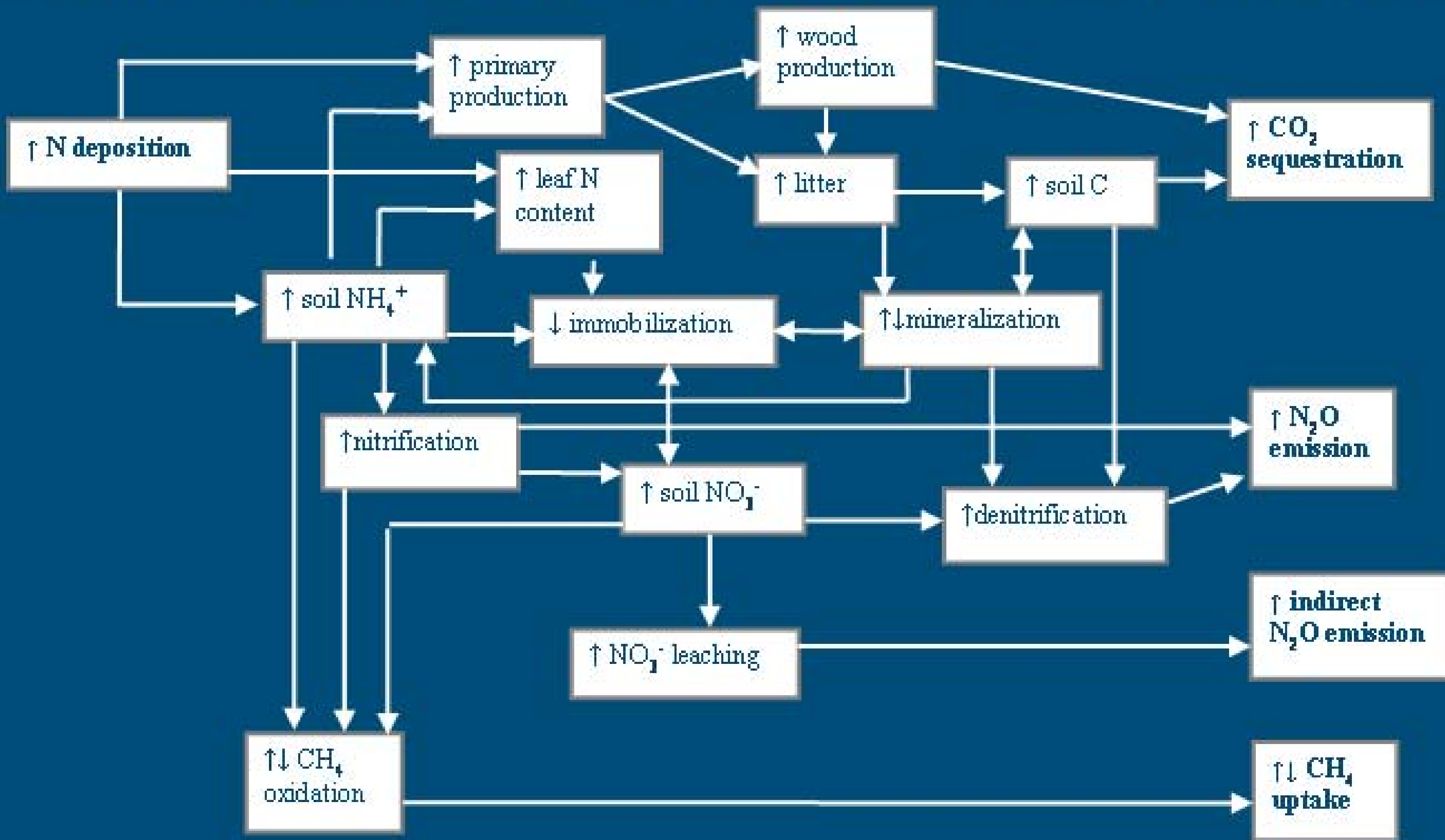
Impacts of N deposition on GHG exchange



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Impacts of N deposition on GHG exchange

ΔC sequestration = **Δ N deposition** x (frN_{uptake} x $C/N_{stemwood}$ + $frN_{immobilisation}$ x C/Nsoil)

- with frN_{uptake} = f (N deposition)
- $frN_{immobilisation}$= f (C/N soil ratio, NH_4/NO_3 deposition ratio)

Δ N2O-N emission = A + 0.018 **Δ N deposition**

- with A = f (temperature, precipitation, tree species, texture, organic matter content, pH)

Δ CH_4 uptake = -0.0058 x CH_4 uptake $_{(Ndep=0)}$ x **Δ N deposition**

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Impacts of N deposition on GHG exchange

Green house gas	GWP (kg CO2 equivalents/ ha/ yr)[1]	
	Total estimates	N deposition impacts[1]
CO_2-C	- 2200-3300 (-2750)	-220-330 (-275)
N_2O-N	+ 140 -325 (230)	+ 20 -50 (35)
CH_4	- 5-70 (-40)	+ 0.1- 1.1 (0.6)

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