ECHANGES DE GAZ-TRACES ET DE PARTICULES ENTRE LA TROPOSPHÈRE ET LA BIOSPHÈRE

- **Contexte:**
  - **Pourquoi s'intéresser au échanges biosphère atmosphère?**
  - **Les grands cycles biogéochimiques**
- **Concepts importants**
  - **Dépôts secs et dépôts humides**
  - **Flux diffusifs et turbulents**
  - **La notion de résistance au transfert**
- **Les modèles de type résistifs**
  - **Introduction à la couche limite de surface**
  - **Les résistances aérodynamique et de couche limite**
  - **Les résistances de surface et la vitesse de dépôt**
  - **Modèles grandes feuilles et les modèles multicouches**
  - **Le cas des particules**

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Benjamin LOUBET Benjamin.Loubet@inrae.fr
www6.versailles-grignon.inrae.fr/ecosys

POURQUOI S'INTÉRESSER AU ÉCHANGES BIOSPHÈRE-ATMOSPHÈRE?

- Météorologie
  - Evapo-transpiration
  - Energie
- Fonctionnement des écosystèmes
  - Photosynthèse
  - Respiration
- Réchauffement global
  - Emissions de N_2O, CH_4
  - Emissions de NH_3
  - Dépôts de particules
- Pollution atmosphériques
  - Dépôts d'O_3
  - Dépôts de NO_x
  - Emissions de COVs
- Maladies / OGM
  - Particules biotiques
  - Pollens

LES GRANDS CYCLES BIOGÉOCHIMIQUES

- Le réchauffement global
- Le cycle des aérosols
- Les sources et puits de composés biogéniques
- Le cycle de l'azote
- Les impacts des polluants

OVERVIEW

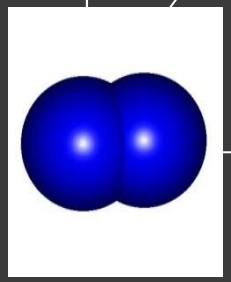
- Context
  - Global cycles (C, N, other)
  - A world under stress
  - A changing world (GHG, N-threats, agro-ecology transition)
- Upcoming challenges
  - Characterise and predict
  - Measurements and Modelling

Global cycle - N – Nitrogen forms

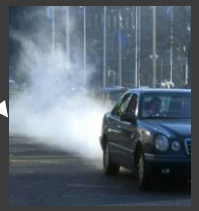
lightning

bacteria

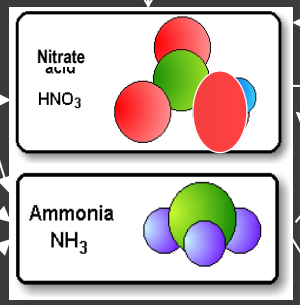
Manure

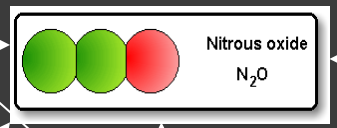


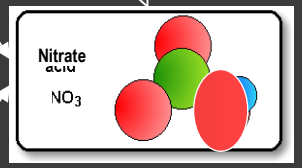
Fertilizer industry

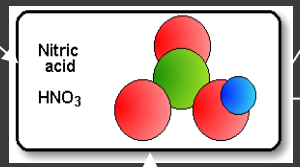


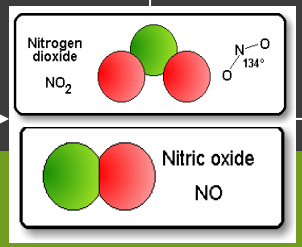
Combustion



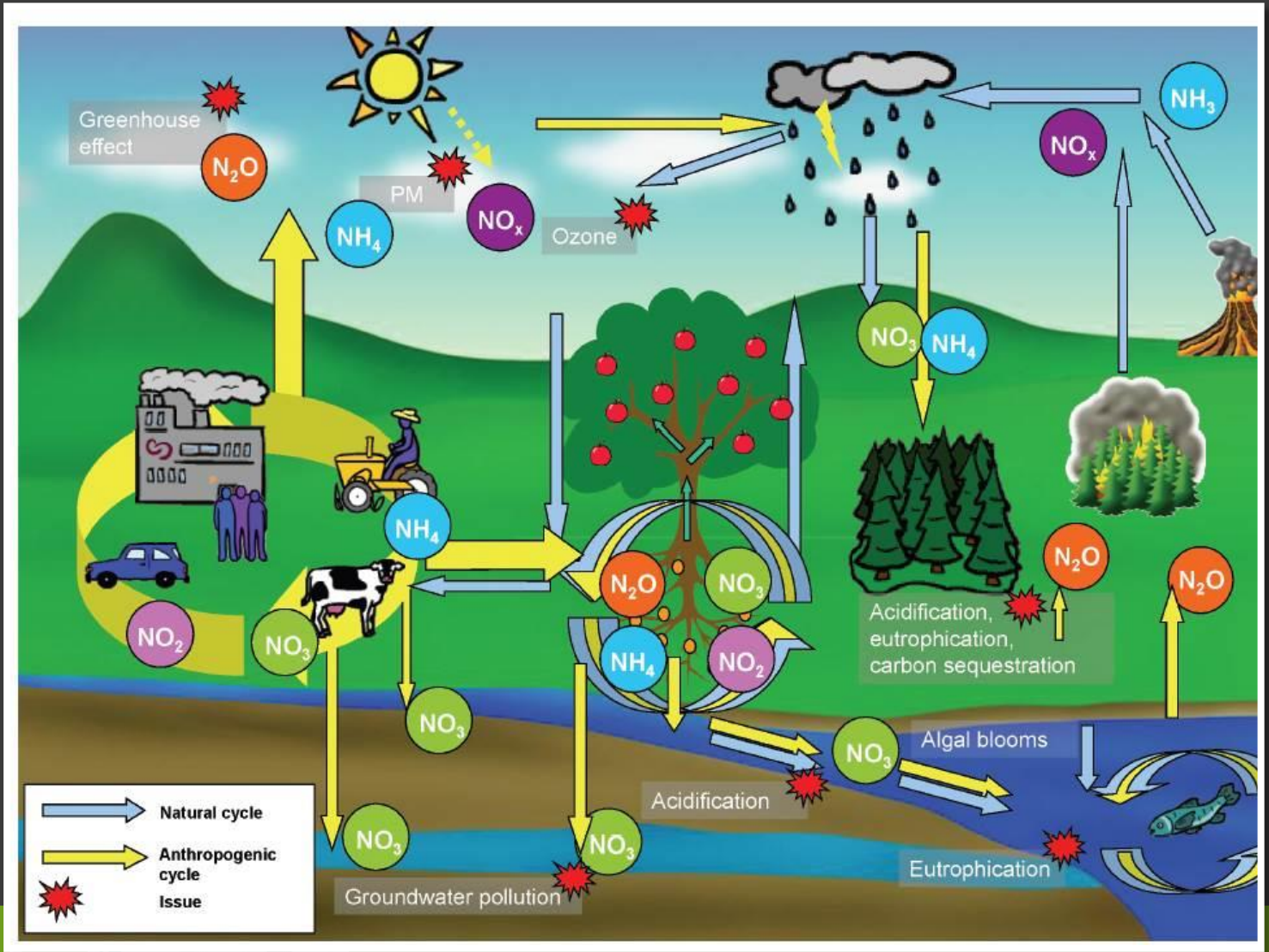




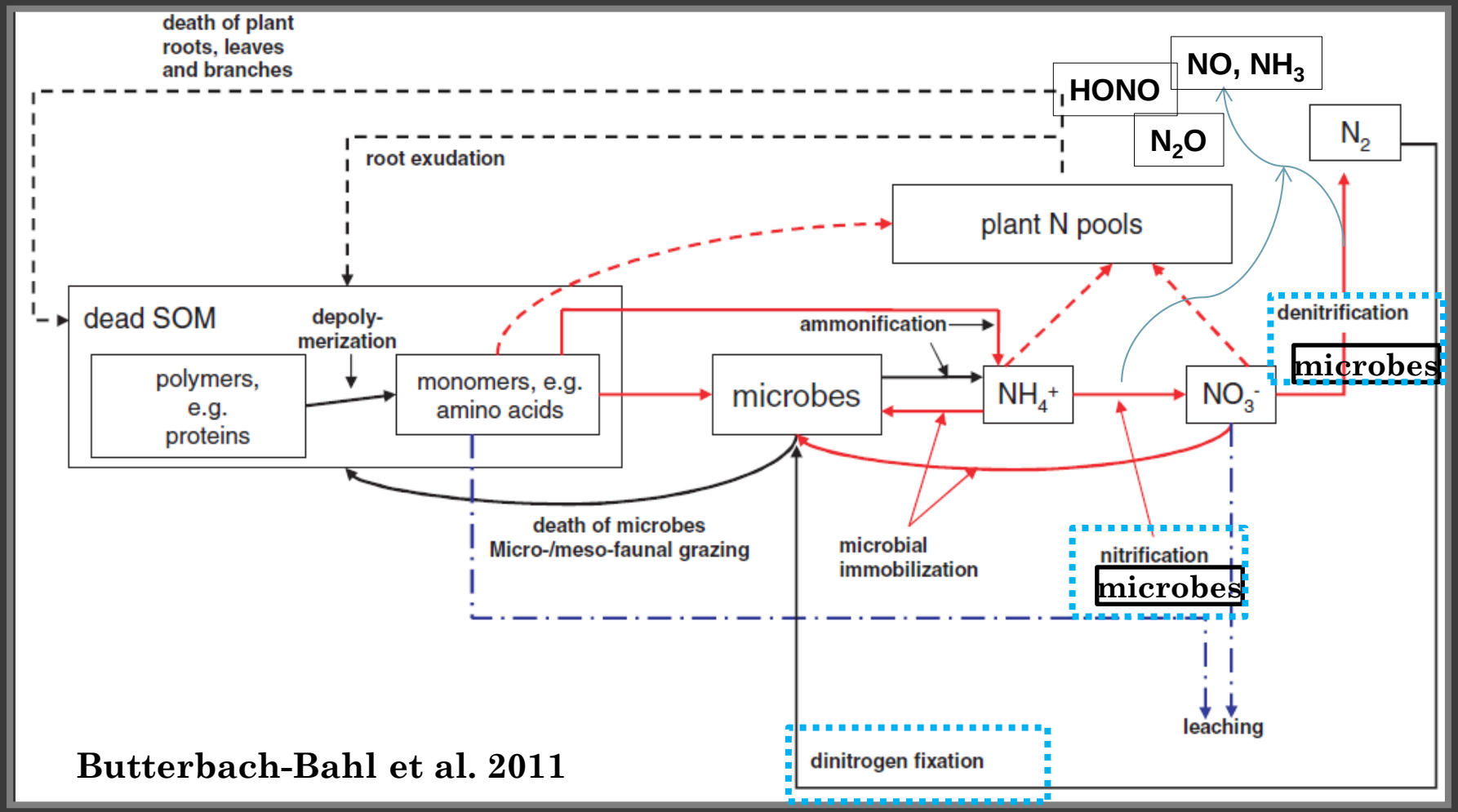




Global cycle - N

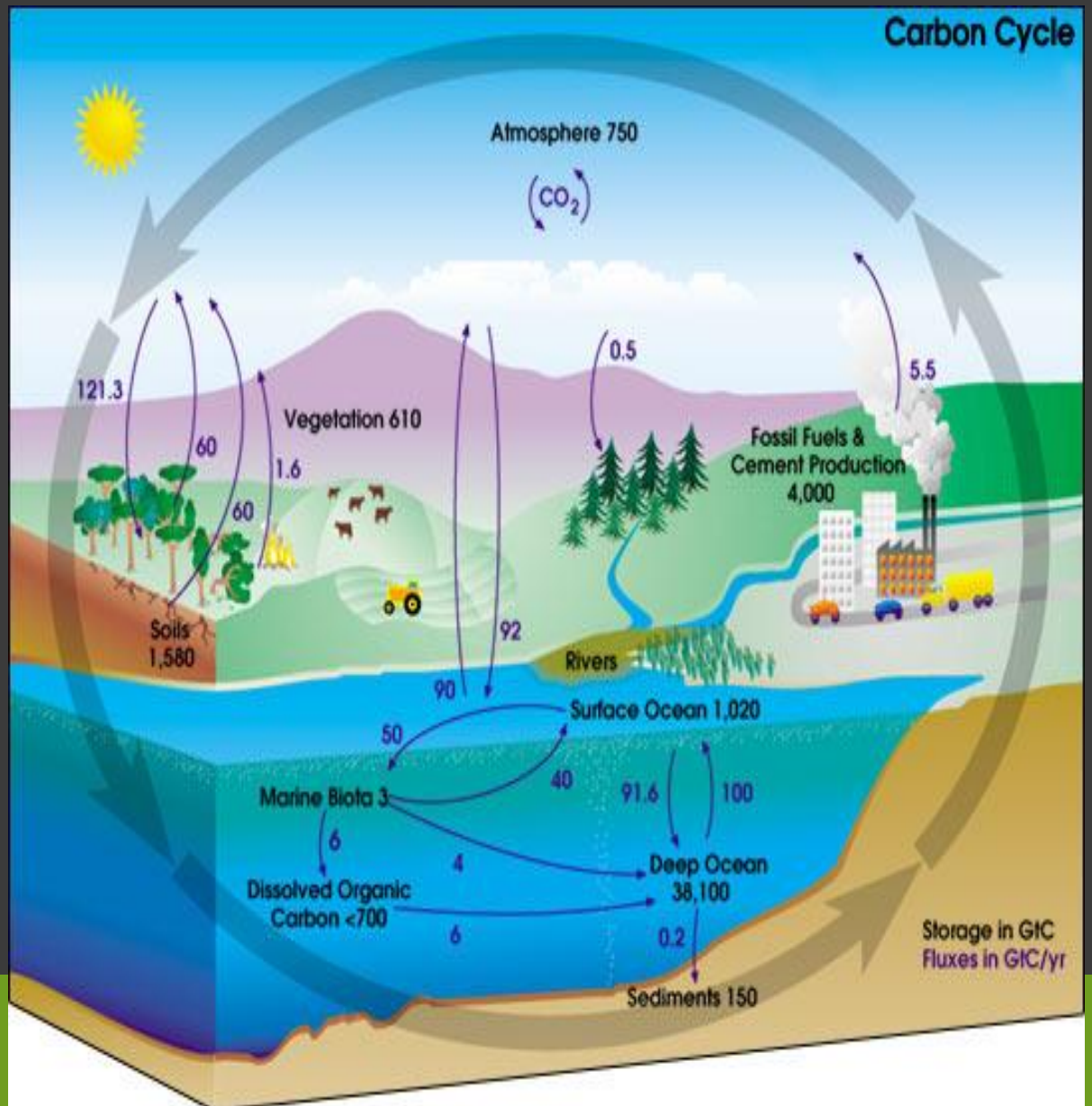


Global cycle - N – The role of microbes



Butterbach-Bahl et al. 2011

GLOBAL CYCLES - CARBON



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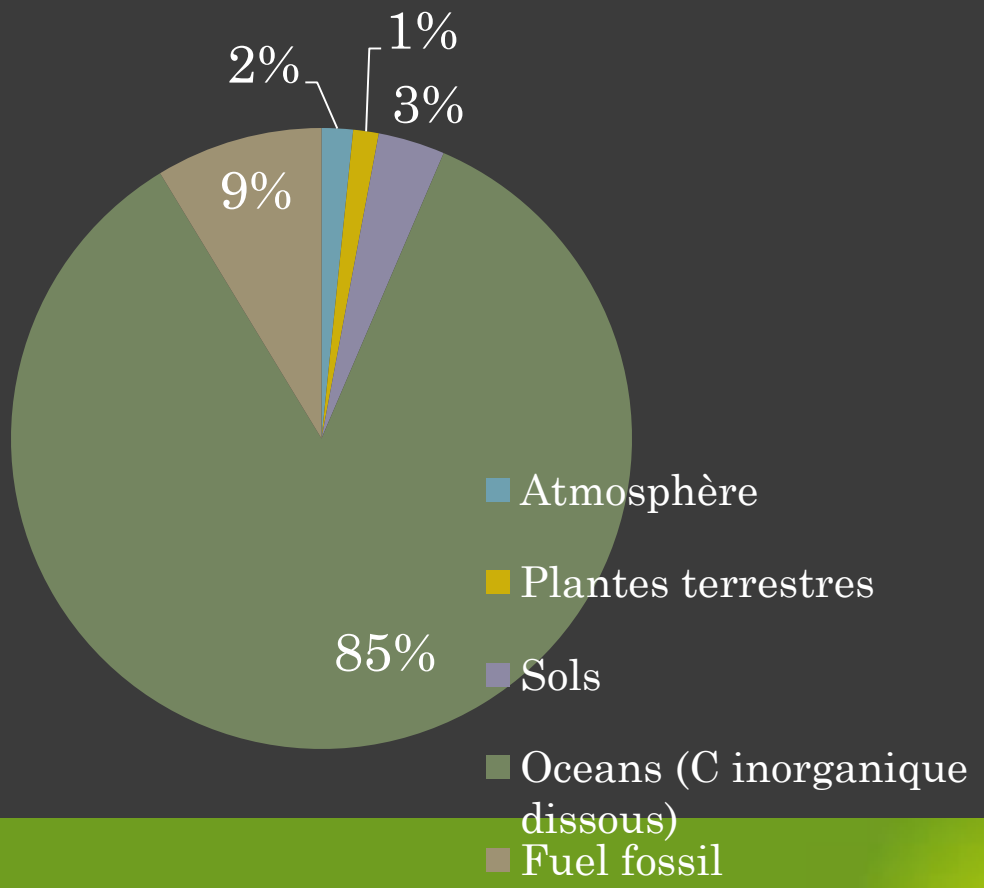
Global cycles - Carbon

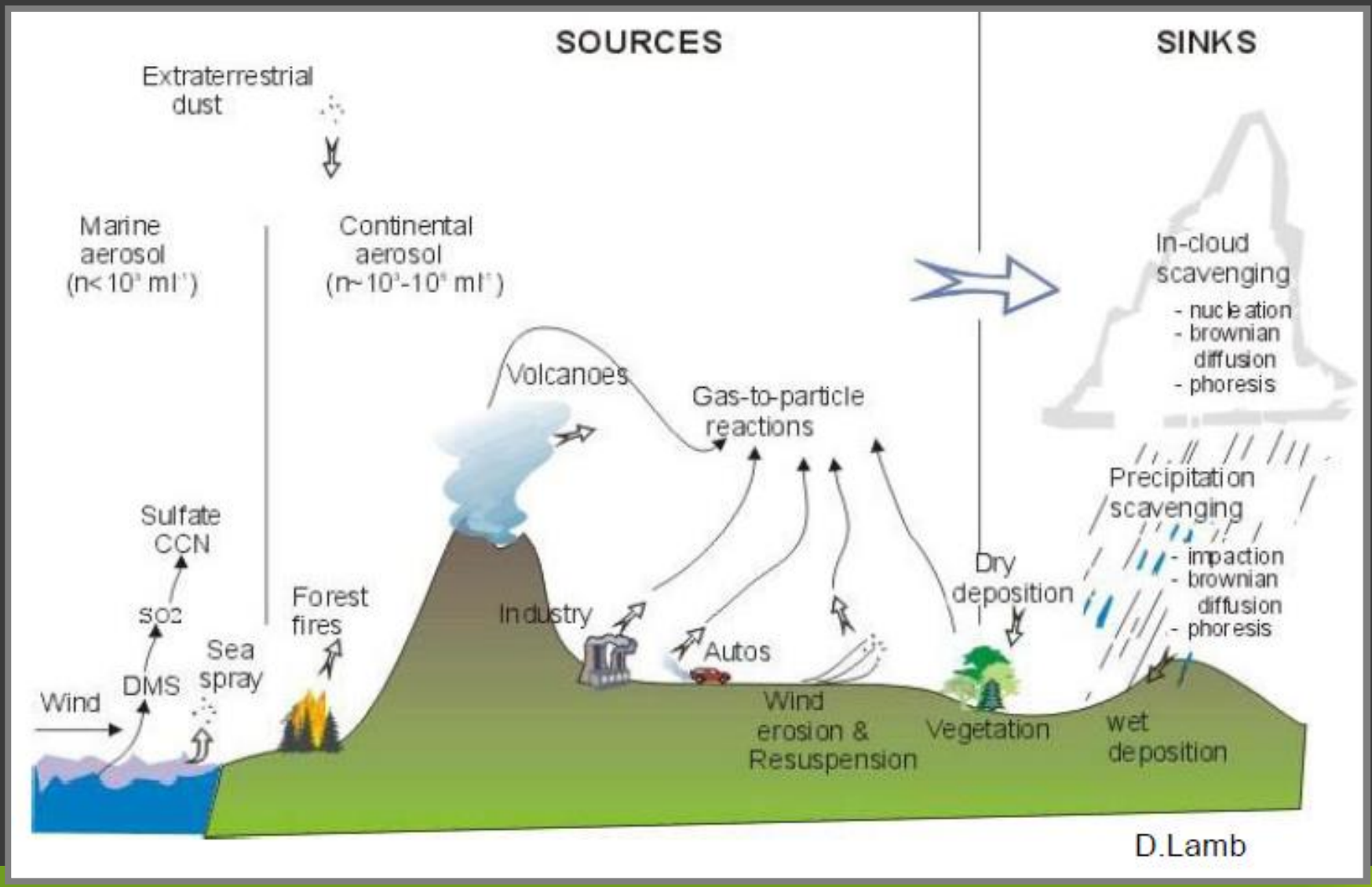
$\sim 10^{23}$ g C

Active vs sedimentary pools

Active Pools

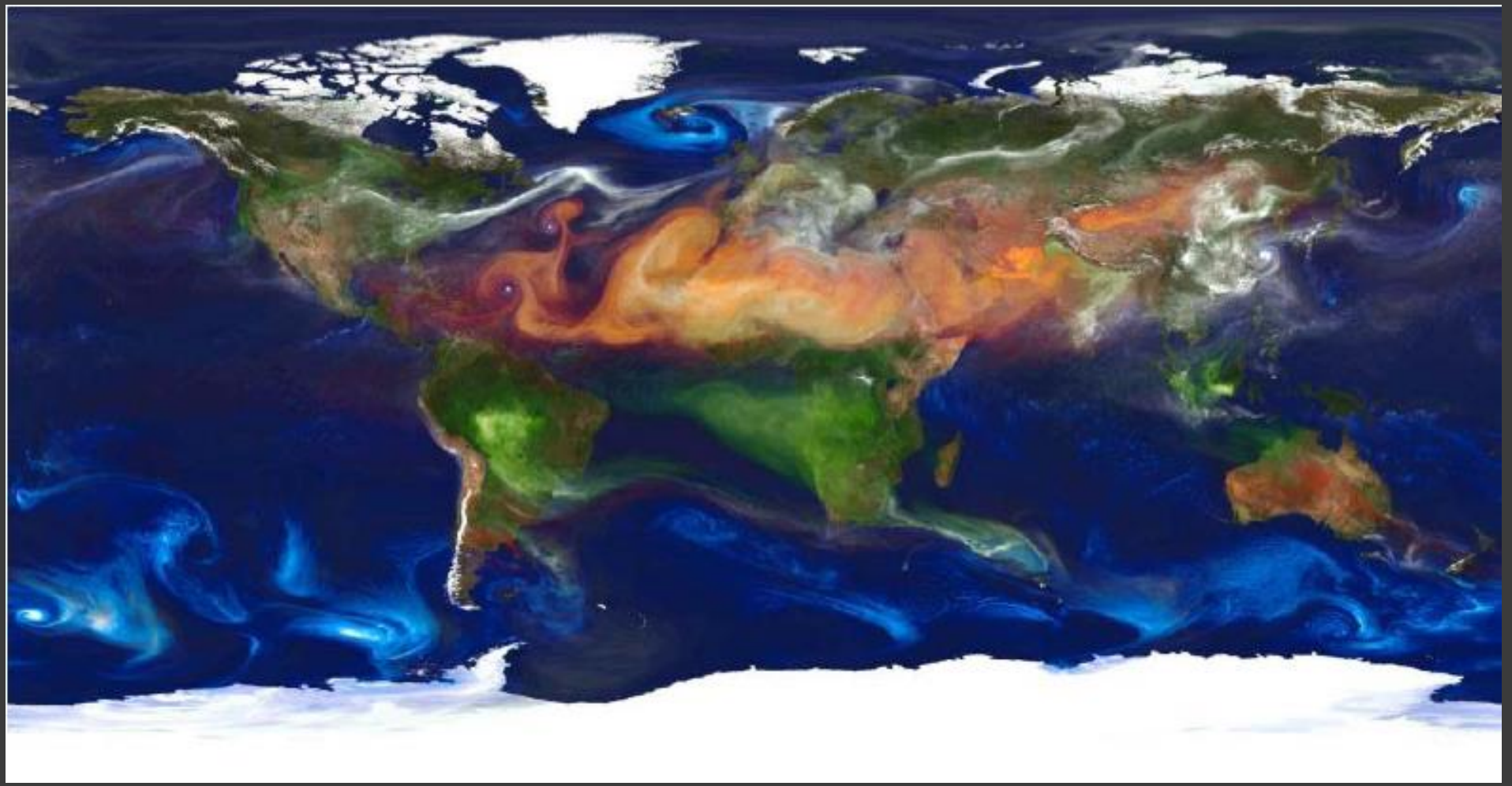


Global aerosol cycle

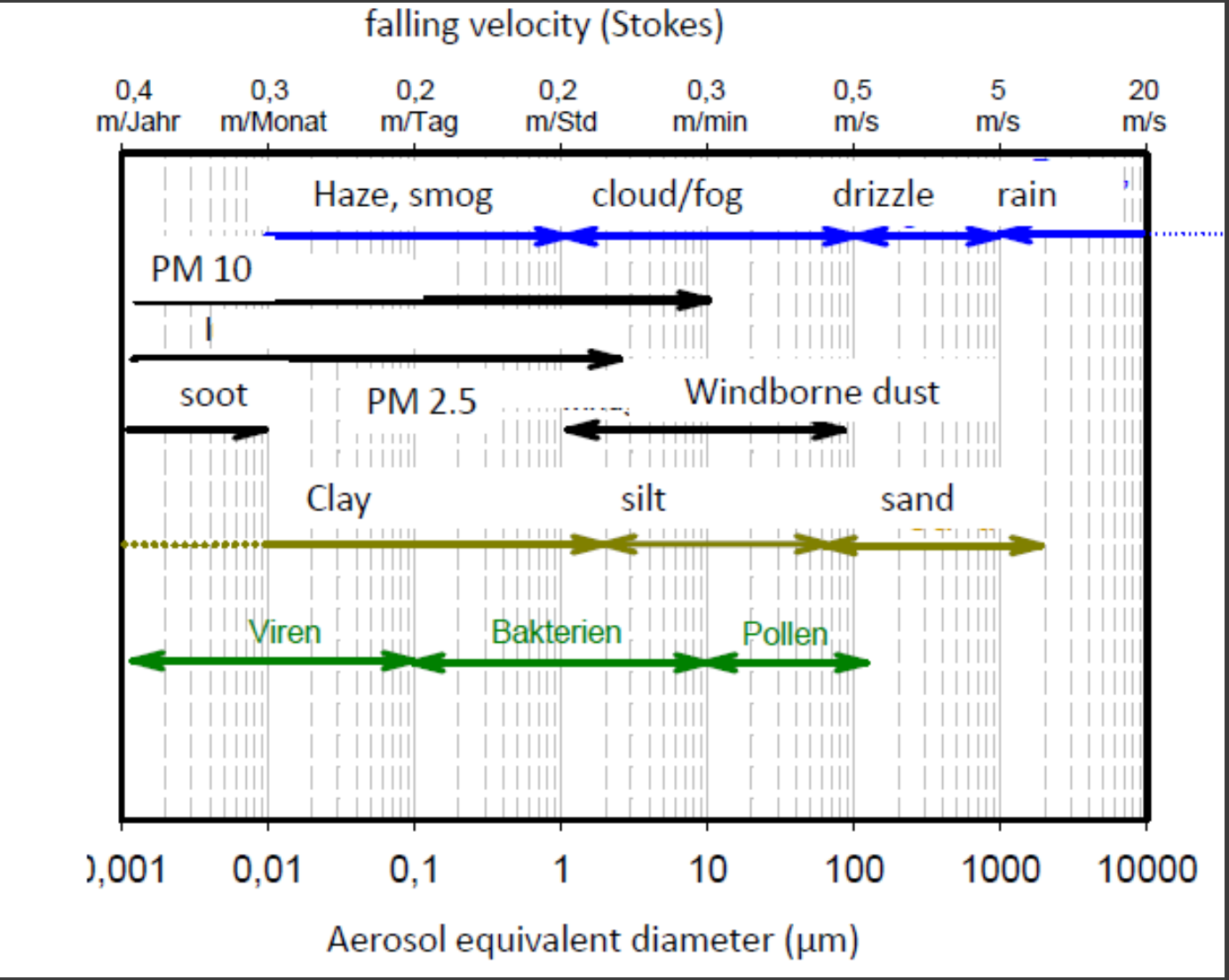


Burkhardt 2014

Aerosol cycles

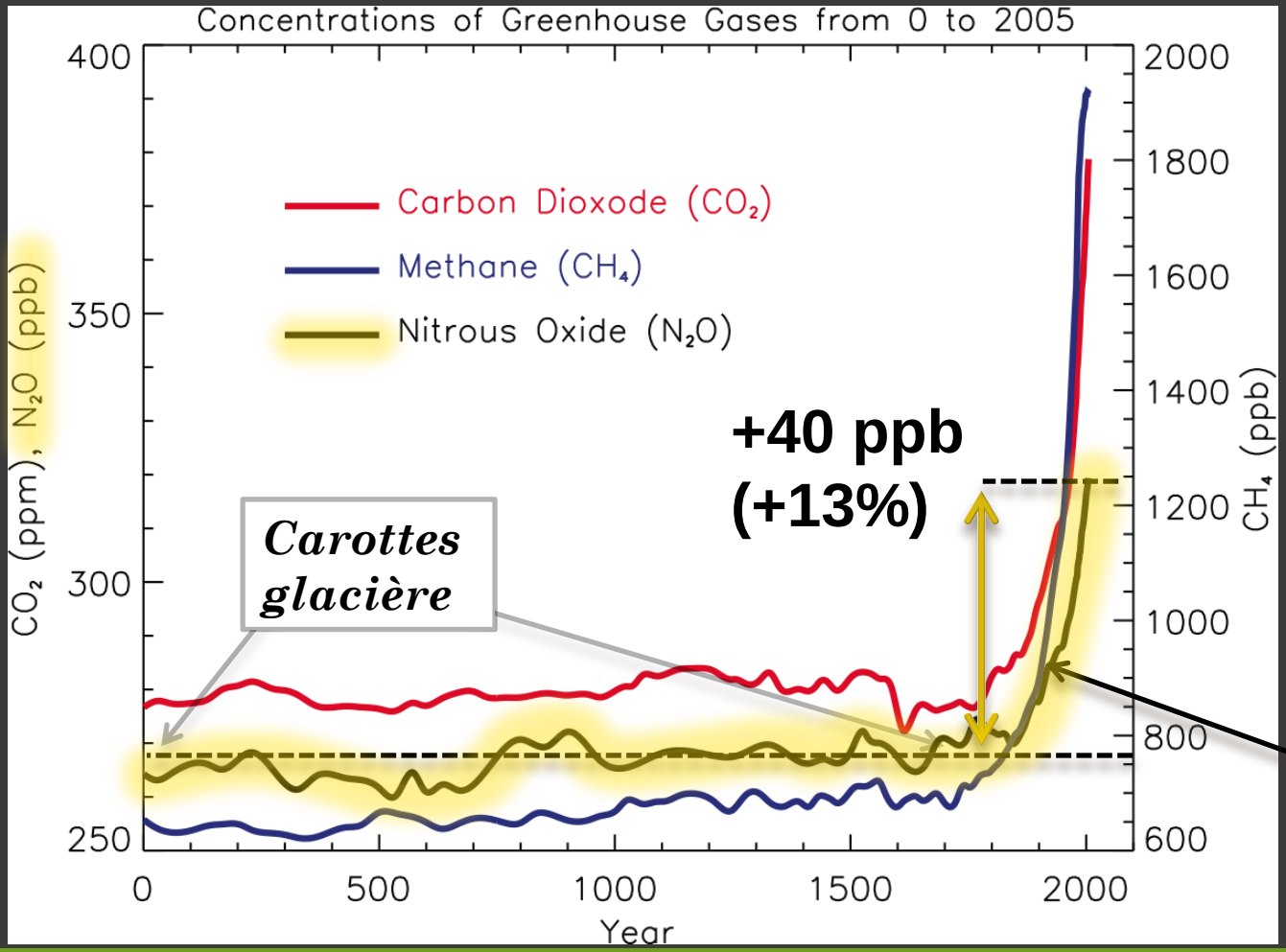


Burkhardt, 2014


falling velocity (Stokes)
0,4 m/Jahr
0,3 m/Monat
0,2 m/Tag
0,2 m/Std
0,3 m/min
0,5 m/s
5 m/s
20 m/s
Haze, smog
cloud/fog
drizzle
rain
PM 10
soot
PM 2.5
Windborne dust
Clay
silt
sand
Viren
Bakterien
Pollen
,001
0,01
0,1
1
10
100
1000
10000
Aerosol equivalent diameter (µm)

A WORLD UNDER PRESSURE

LA CONCENTRATION DES GES AUGMENTE



James Lovelock (1958)

Chromatographie gazeuse & détecteu à capture d'électron

IPCC, 2007

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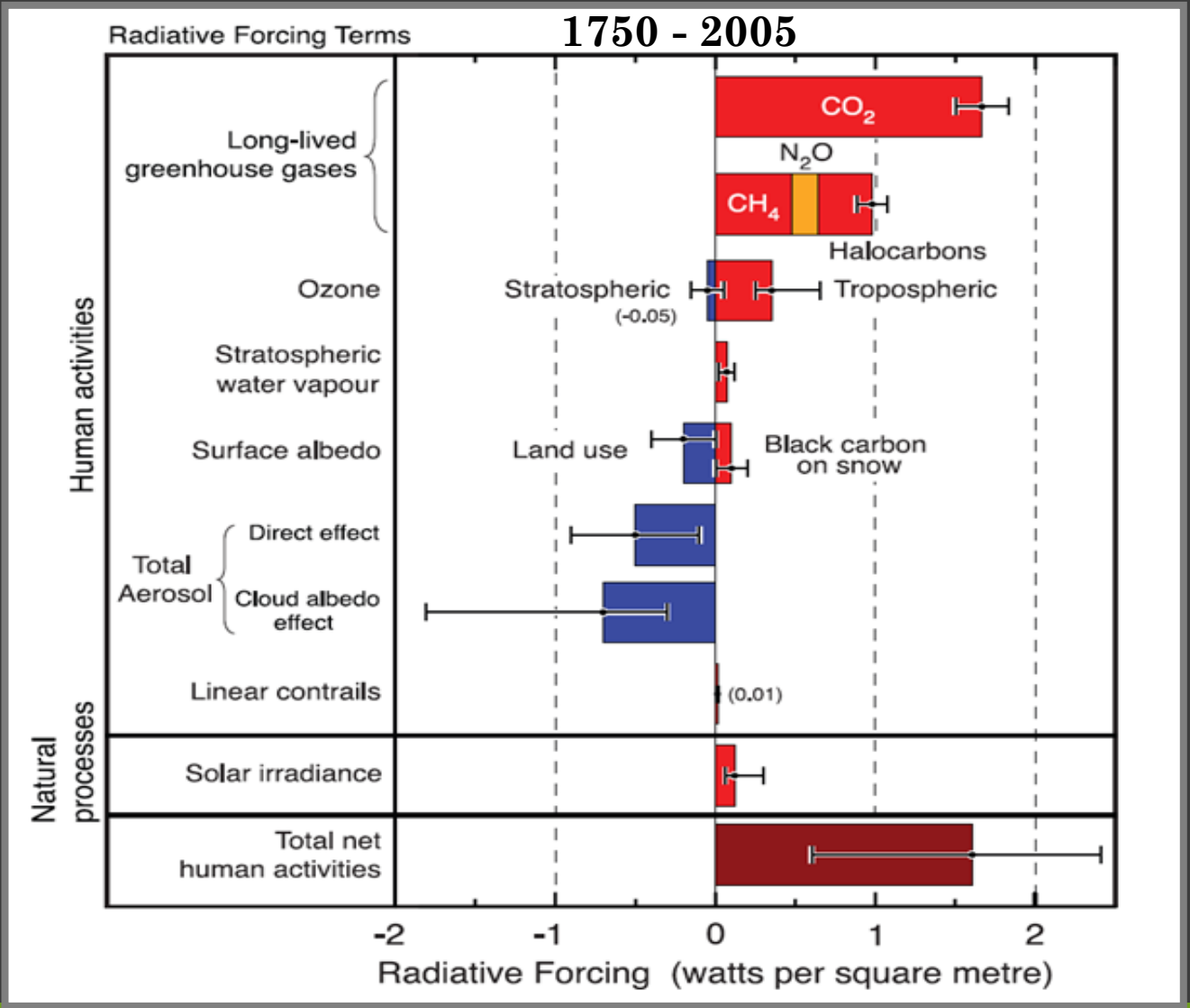
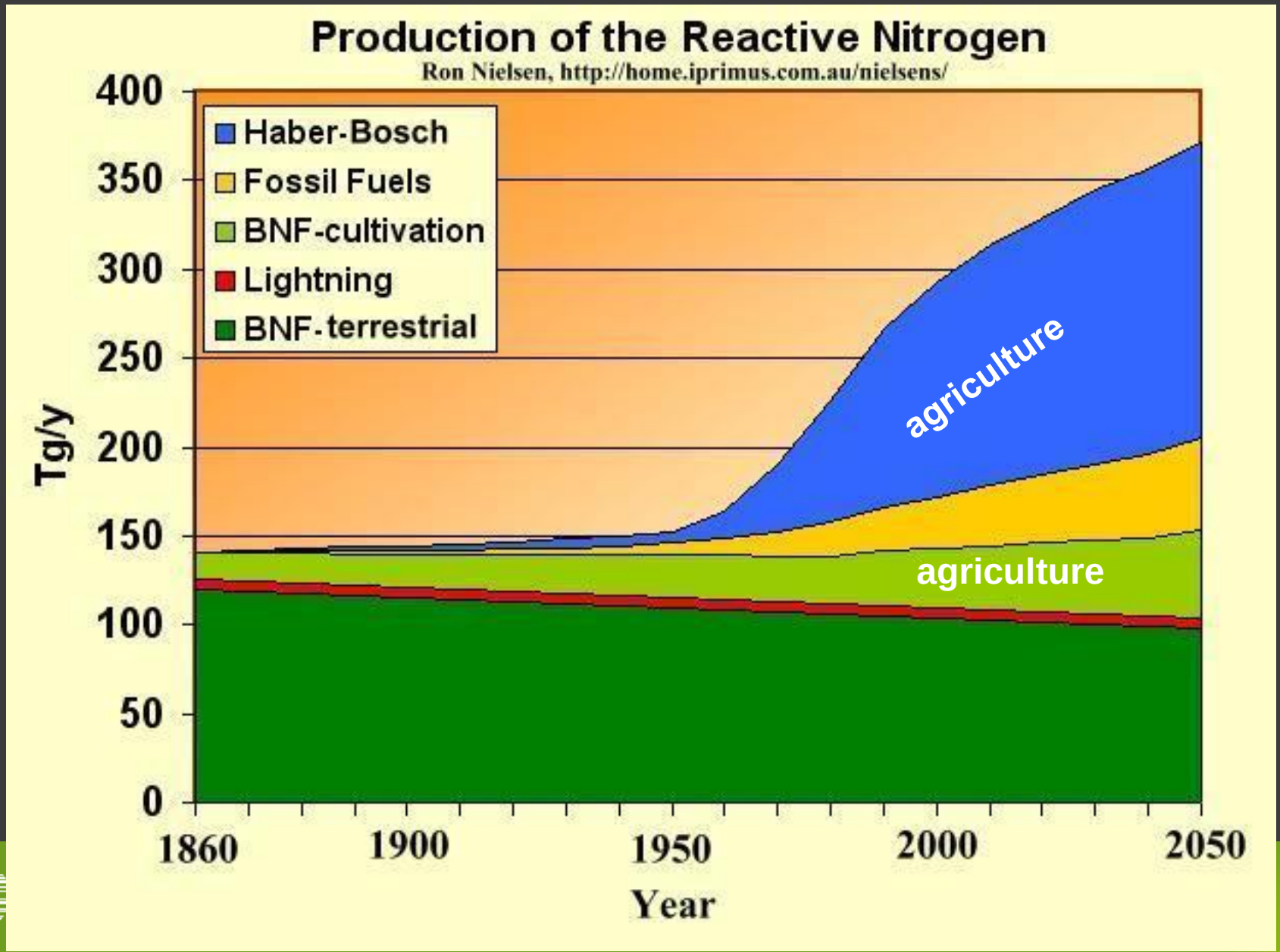
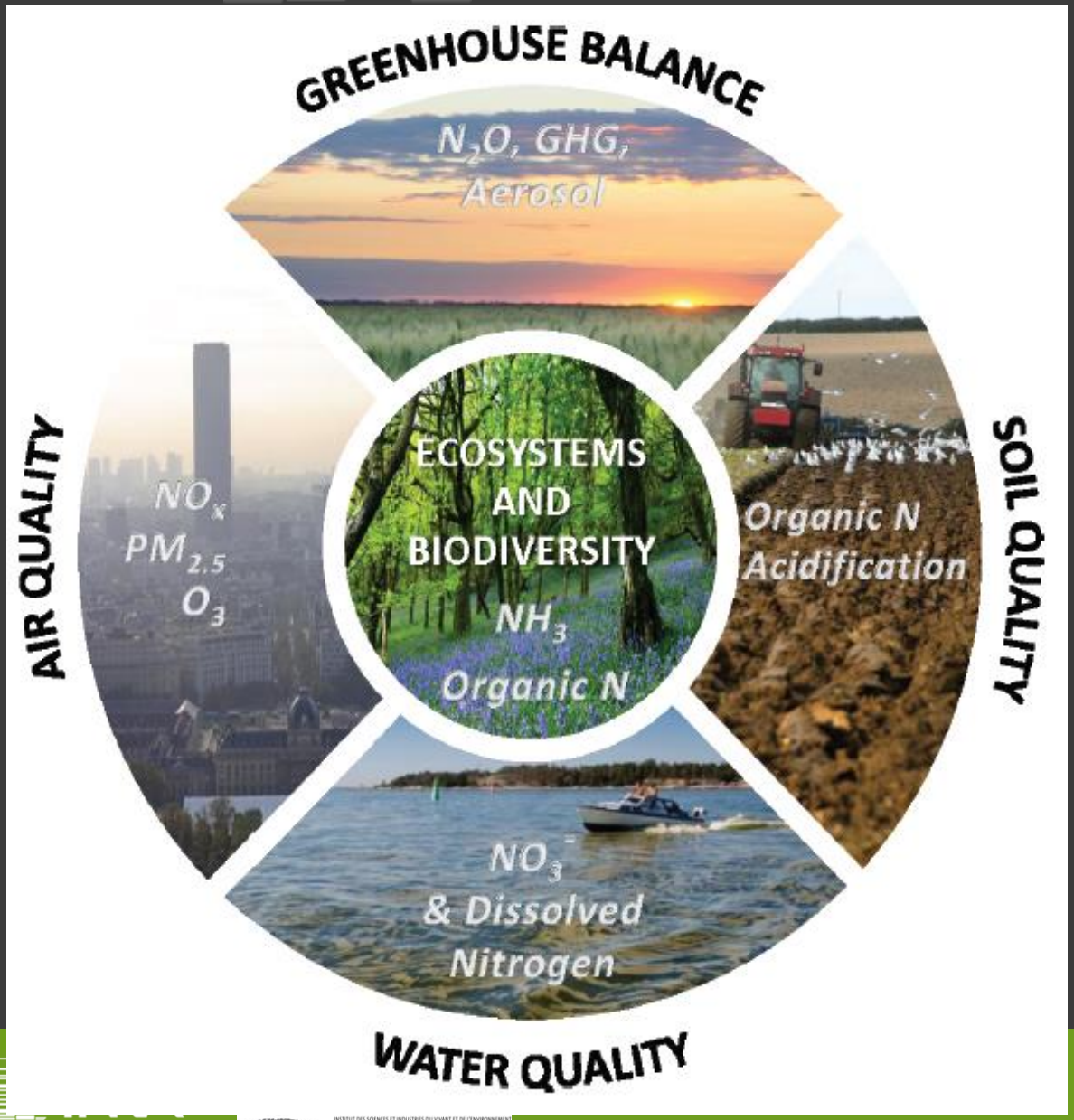
LE FORCAGE RADIATIF ET LE RÉCHAUFFEMENT GLOBAL



Trends in Reactive nitrogen

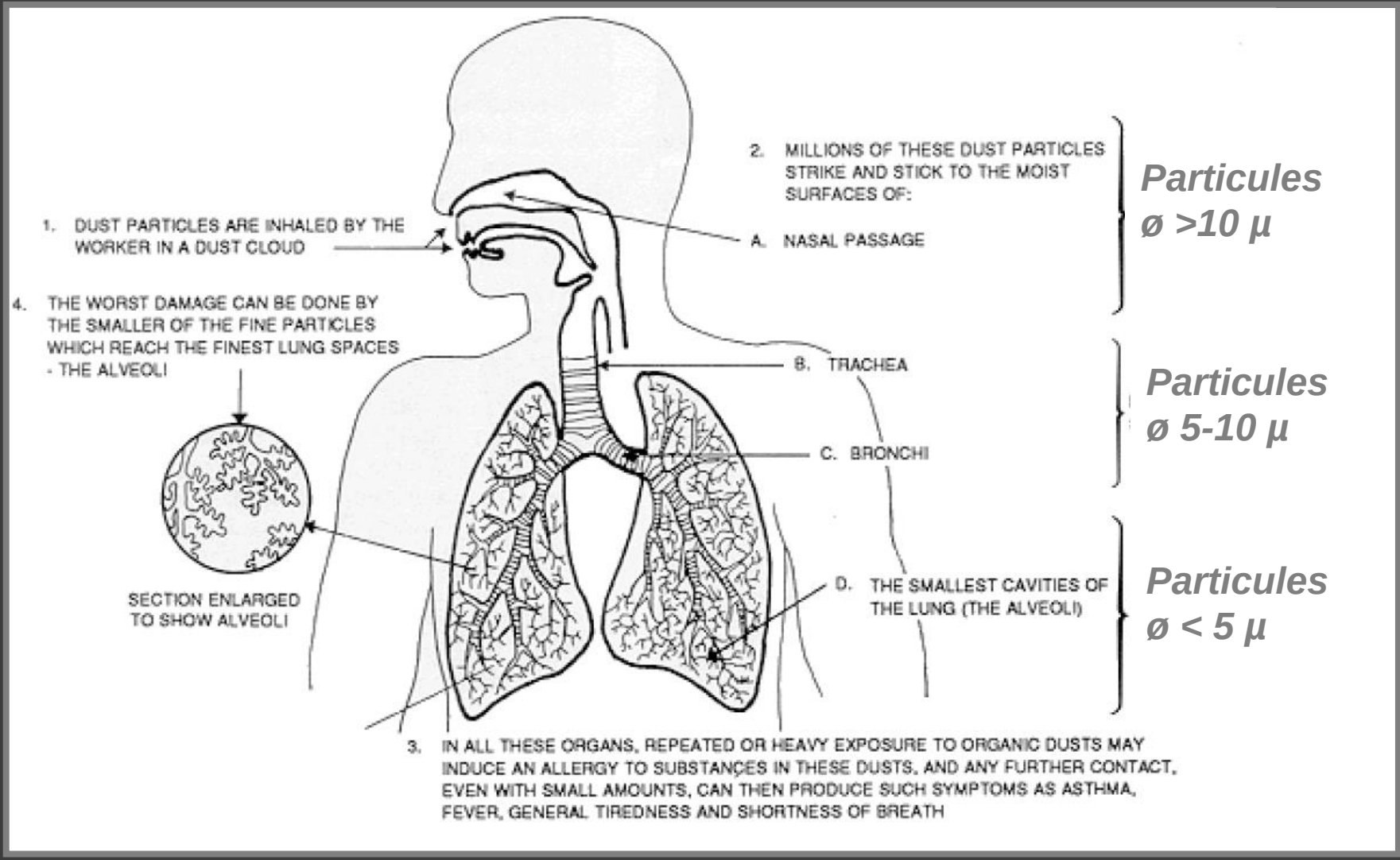


THREATS : NITROGEN



Sutton et al. 2011

IMPACTS SUR LA SANTÉ DES AÉROSOLS



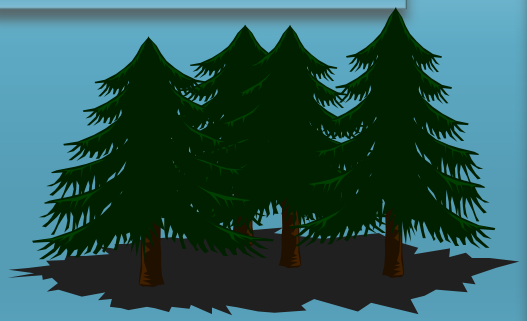
DES EFFETS COMPLEXES SUR L'ENVIRONNEMENT
EXEMPLE DE L'AMMONIAC

NH_3
NH_4^+

Formation d'aérosols

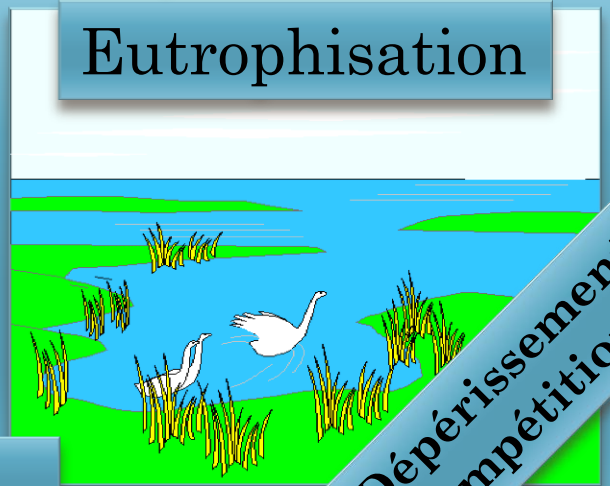
NH_4^+ NO_3^- SO_4^{--} Cl^-

Acidification



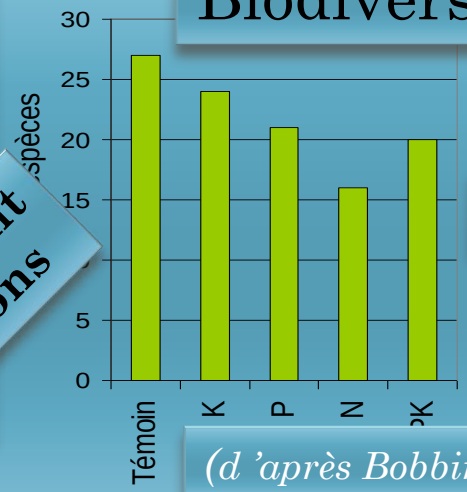
$NH_4^+ \rightarrow NO_3^- + 2H^+ + \ldots$

Eutrophisation



Dépérissement
compétitions

Biodiversité



Prairie

(d 'après Bobbink, 1991)

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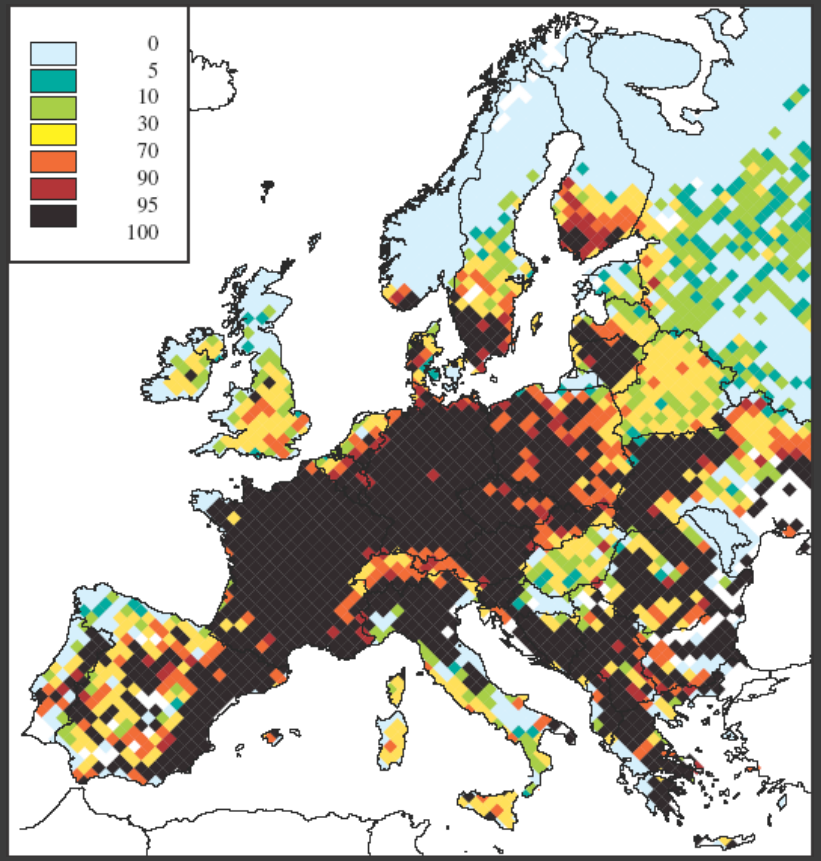
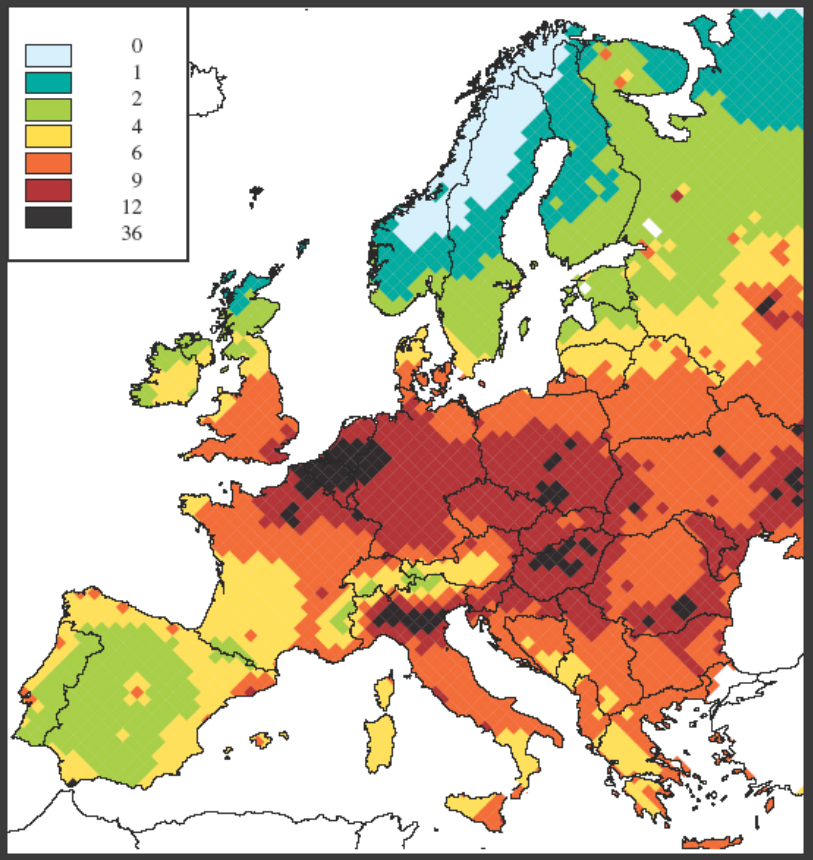
THREATS : NITROGEN

Critical load exceedance for N effects on ecosystems



% of ecosystems area with grid average N deposition > eutrophication (for 2000)

Loss in life expectancy attributable to $PM_{2.5}$



Loss in average life expectancy in months due to identified anthropogenic $PM_{2.5}$ (for 2000)

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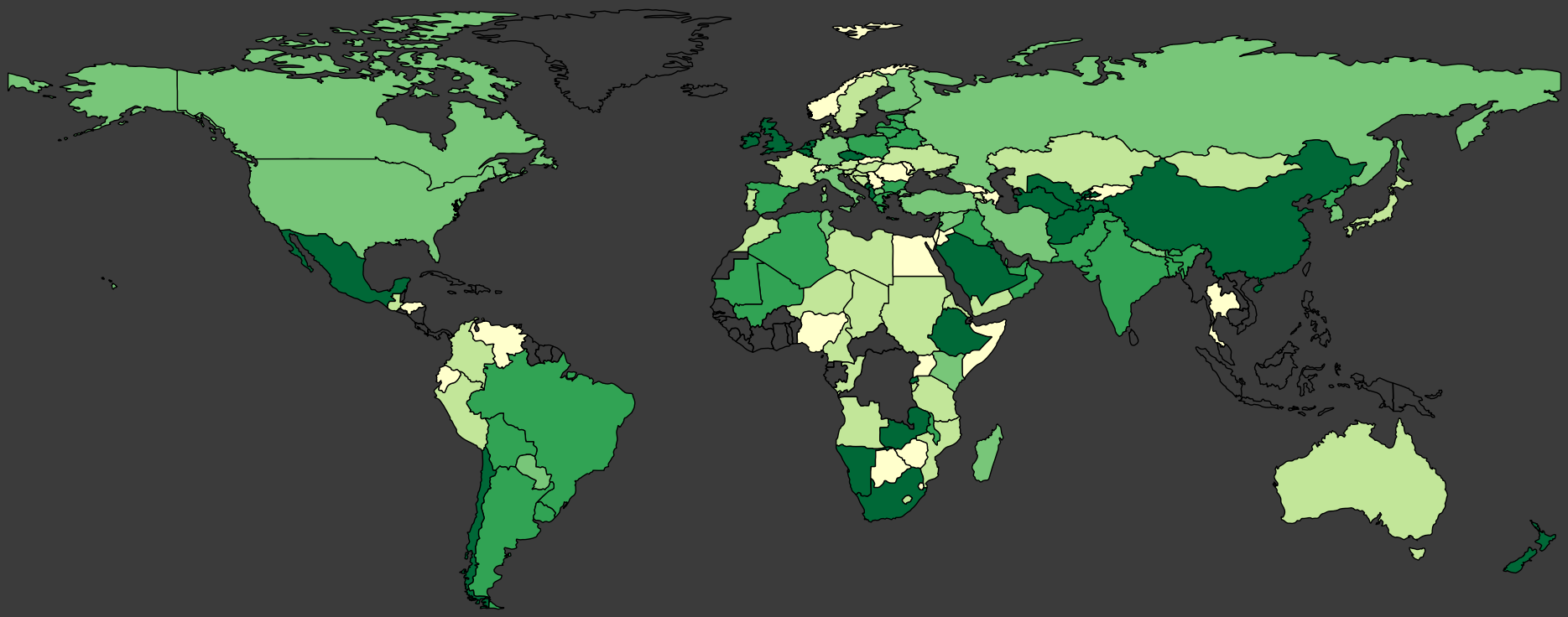
EXAMPLE BIODIVERSITY LOSSES : EFFECT OF N

Understorey in Sweden before and after 10 years N supply

THREAT : FOOD SECURITY

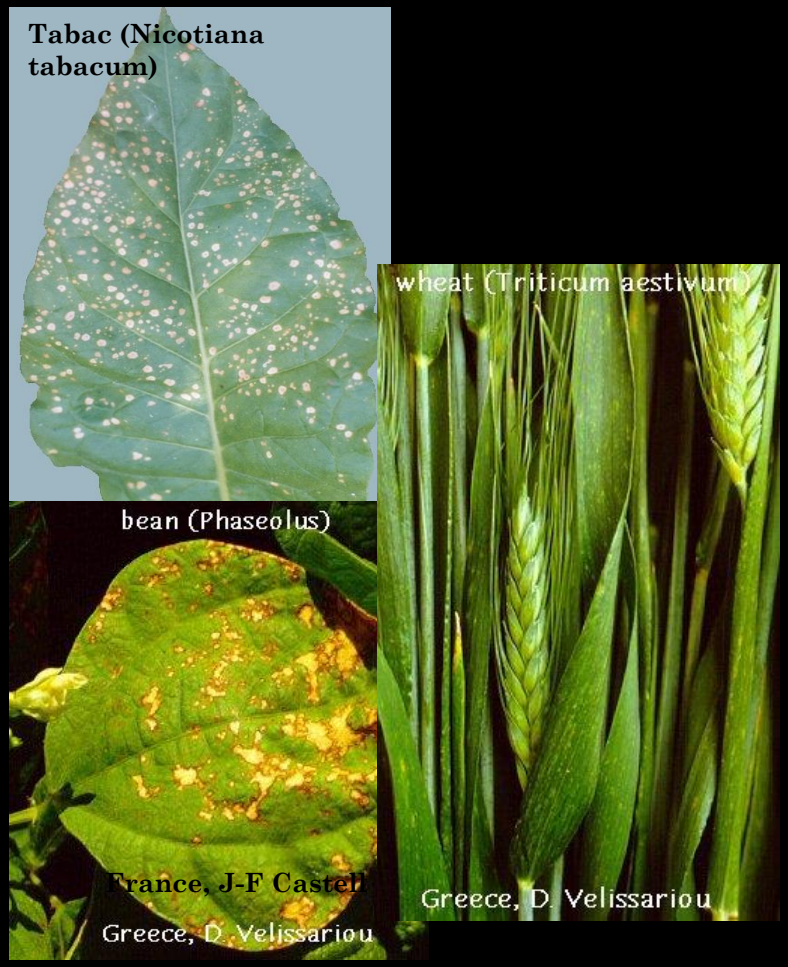
Wheat yield increase in 2010



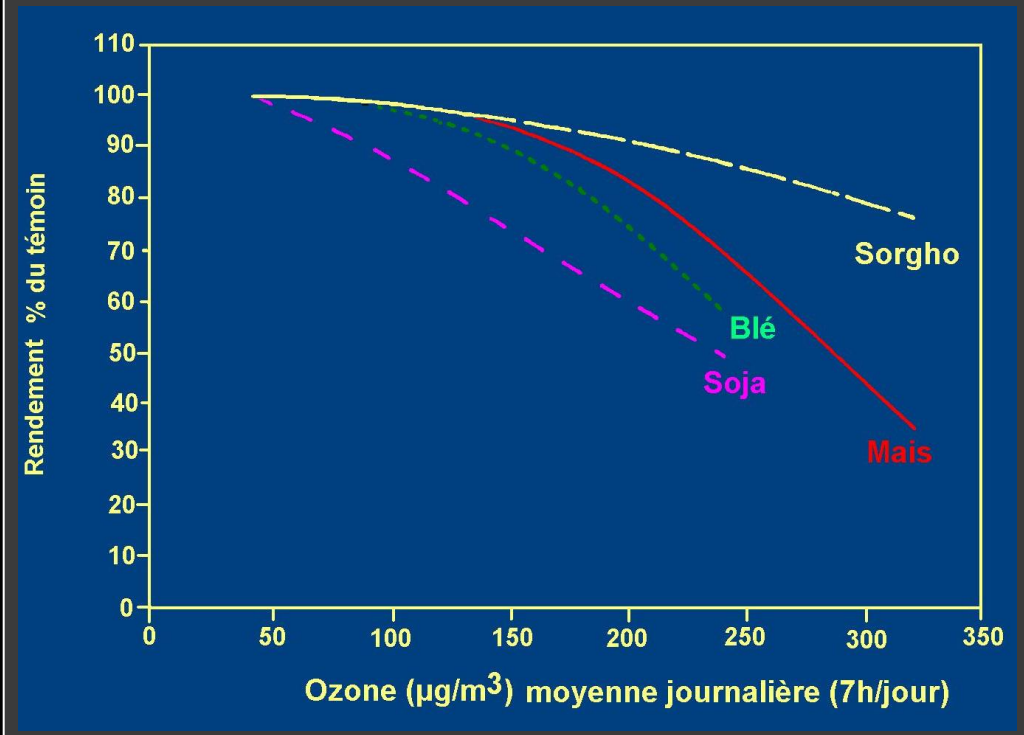
Makowski *et al.*

Threat : food security - ozone

Foliar damages



Agronomic impacts



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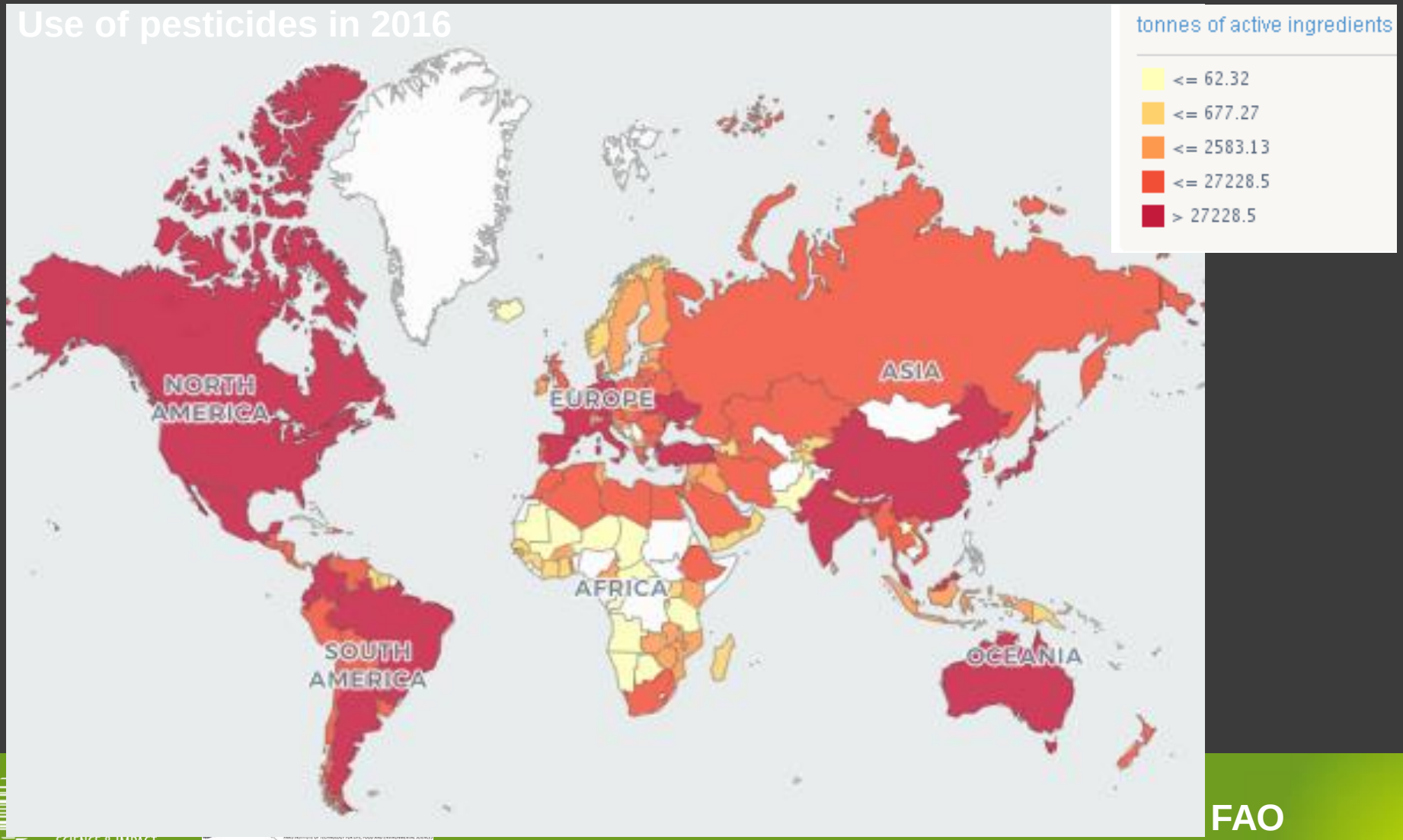
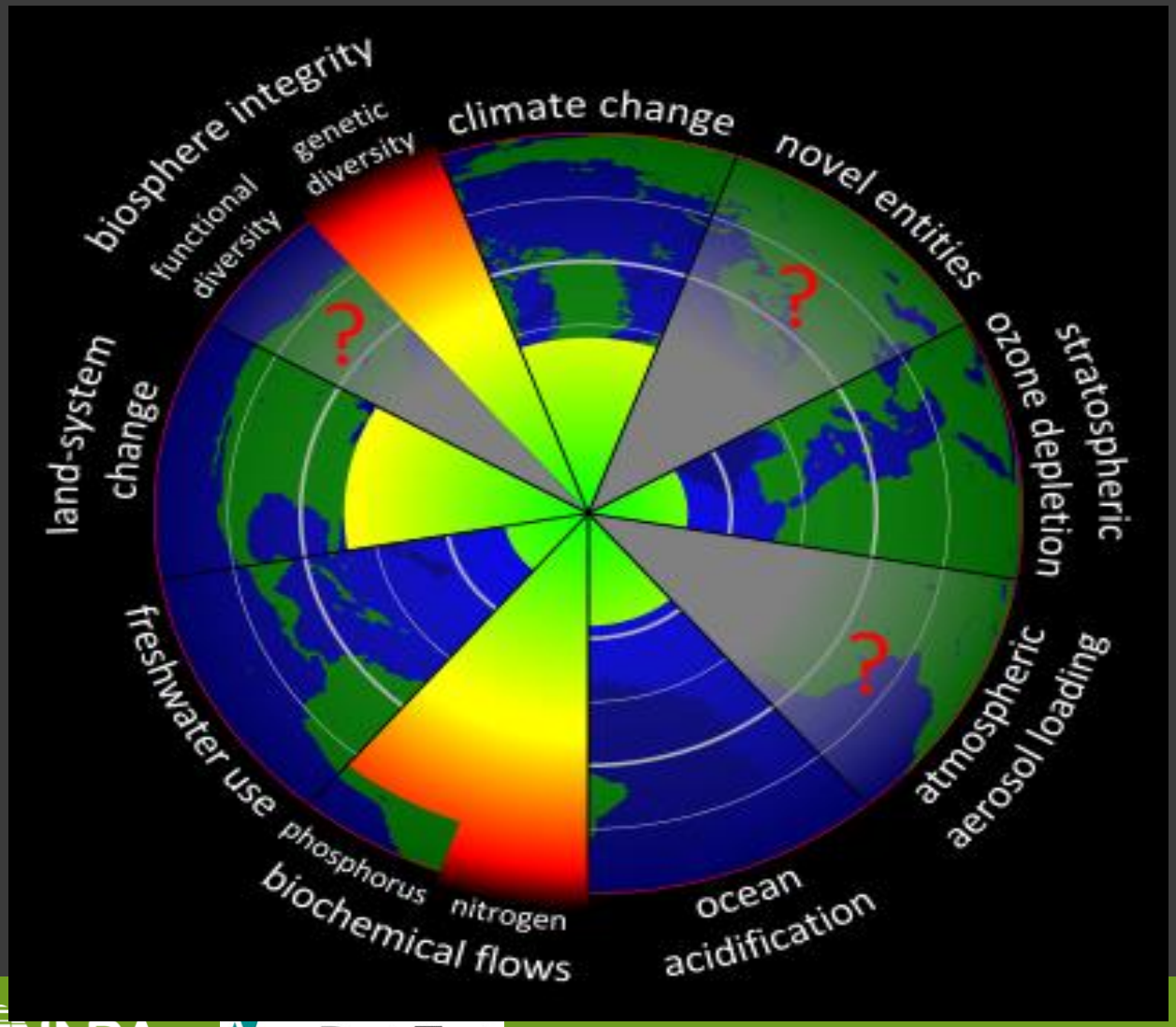
THREAT : BIODIVERSITY



Threats : Planetary boundary exceedance



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TRANSITION TO A

NON-FOSSIL-FUEL
N-P-EFFICIENT
BIODIVERSITY PROTECTIVE
HEALTHY

WORLD

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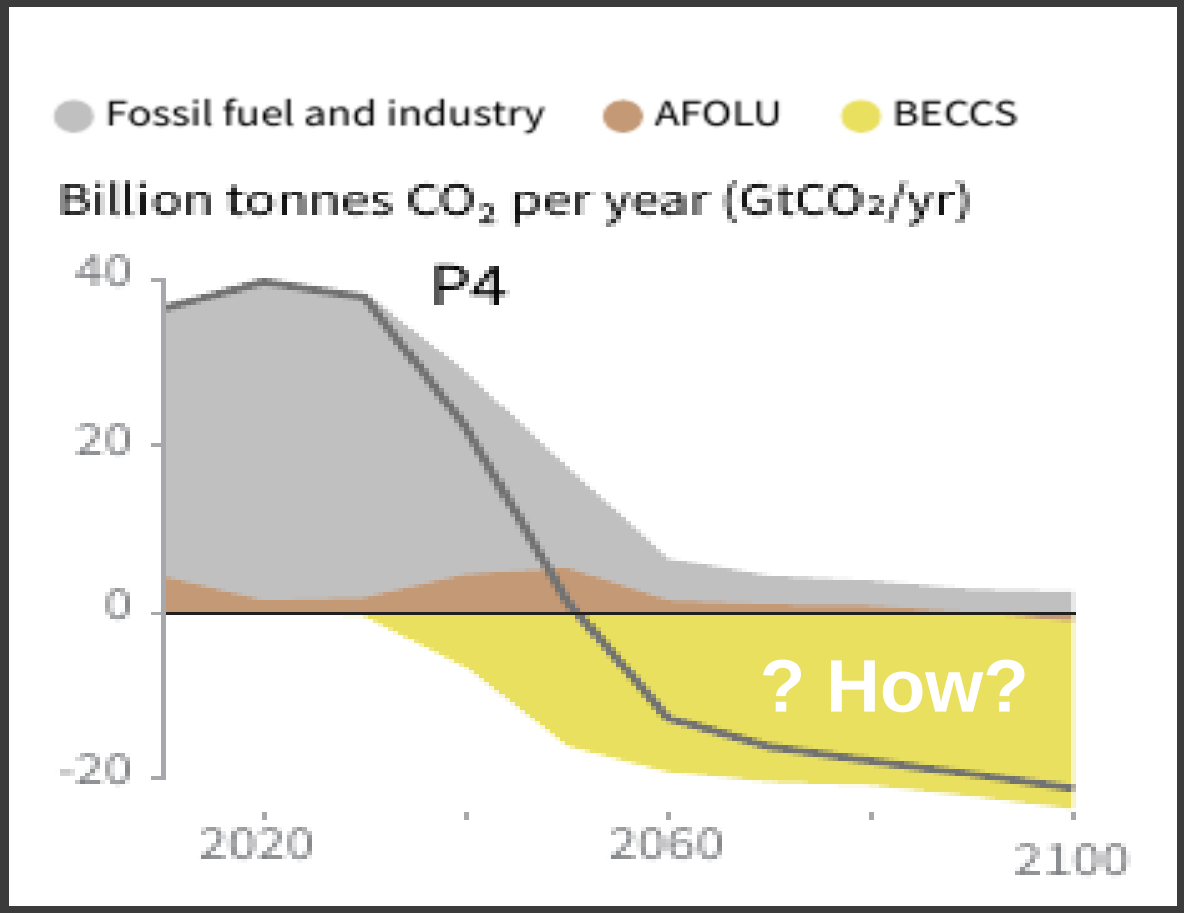
Transition to a non-fossil-fuel world



IPCC 1.5° special report (2018)

BECCS : Bio-energy with carbon capture and storage

AFOLU : Agriculture, Forestry and Other Land Uses

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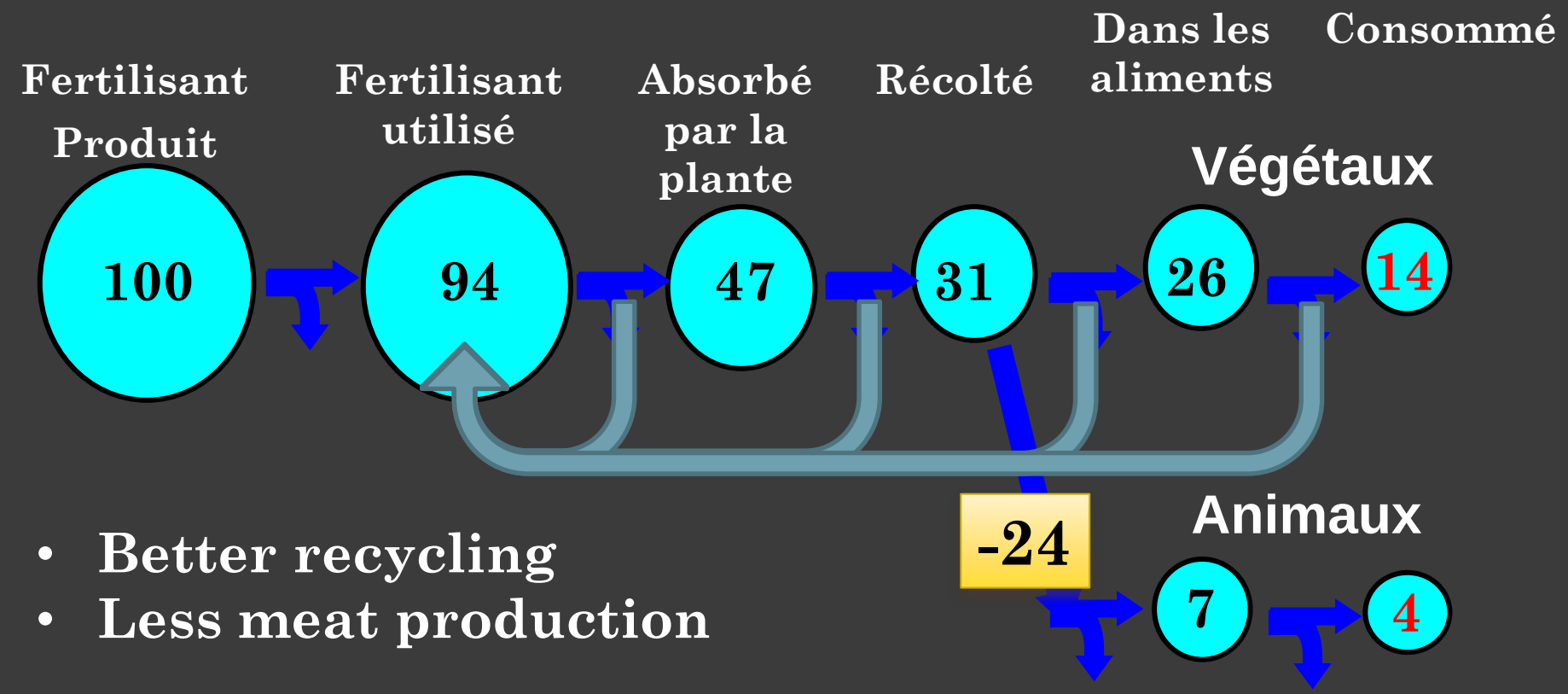
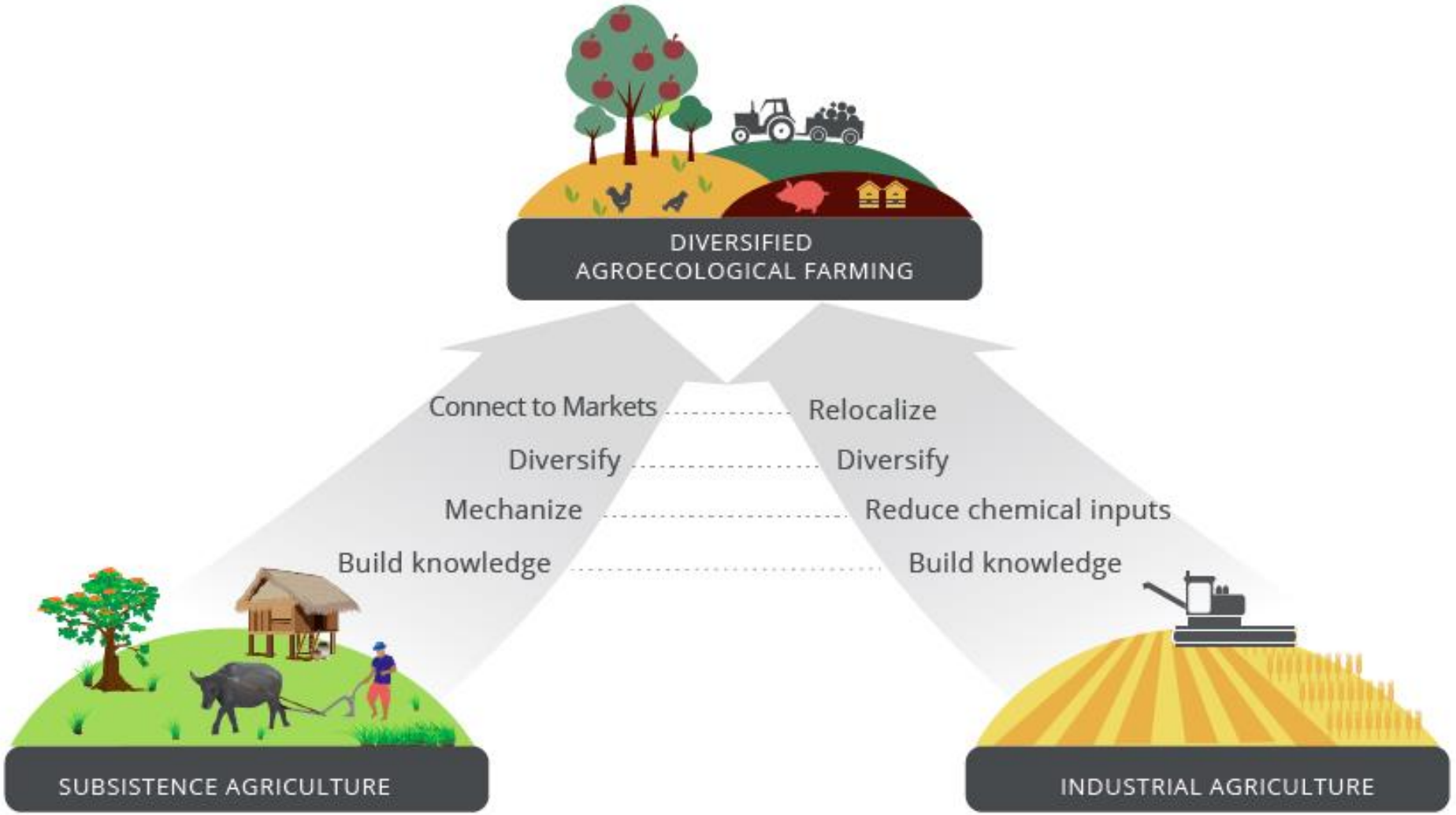
TOWARDS A BETTER USE OF NITROGEN



- Better recycling
- Less meat production

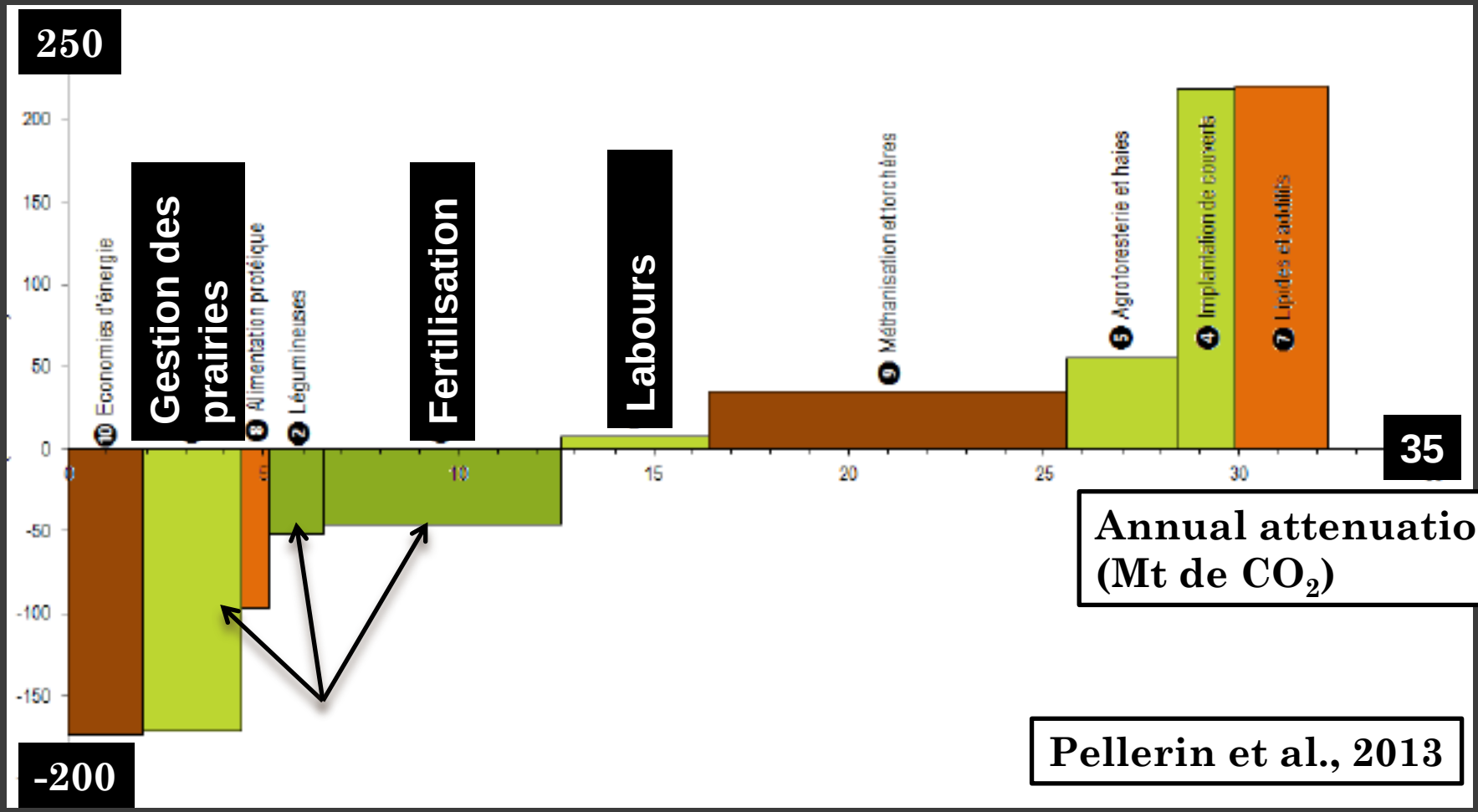
TRANSITION TOWARDS AGROECOLOGY



TRANSITION TOWARDS AGROECOLOGY

- Use **biotic interactions**, **self-regulations** and biodiversity rather than pesticides
- Exploit non-renewable resources very carefully and **promote recycling**
- **Combine indigenous knowledge and scientific outputs**
- Bind actions at plot, farm, landscape and food system to **find solutions ecologically, socially and economically affordable**
- Help famers to find their **own finely tuned systems**

AT WHICH COSTS



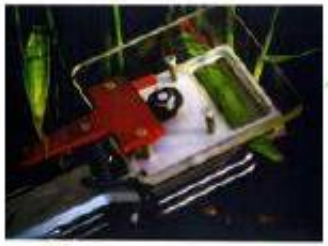
UPCOMING CHALLENGES

1. Characterise the impacts
   - On climate, health, food production, biodiversity
2. Predict future changes

- Require
  - Measure reactive trace gases and aerosol fluxes
    - Under real conditions to quantify and provide validation
    - Under controlled conditions to understand and provide wider range of conditions
  - Model reactive trace gases and aerosol fluxes
    - In a changing world (climate, land use, fuel-transition)

Time Scales and Spatial Scales

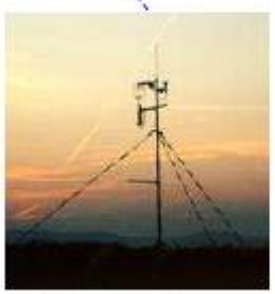
branch cuvette



leaf cuvette

soil/vegetation chamber

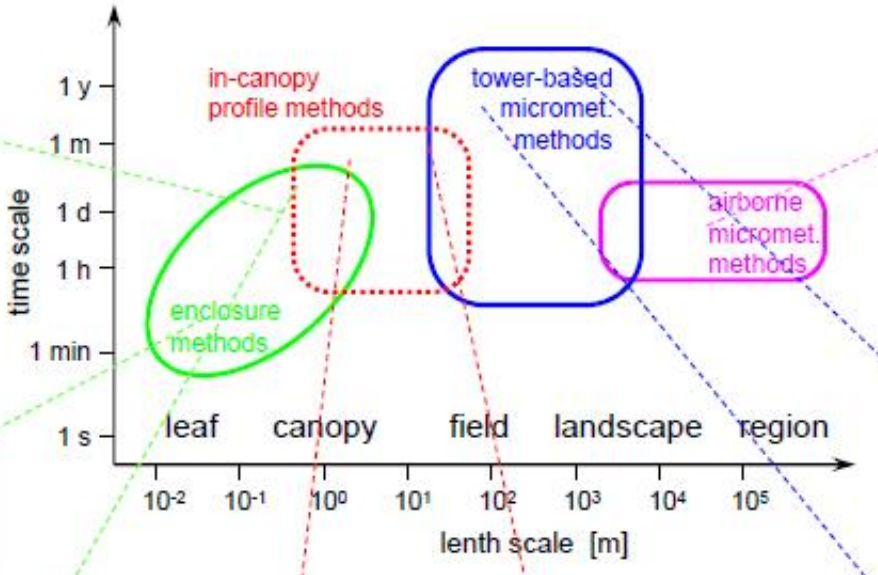
in-canopy profiles

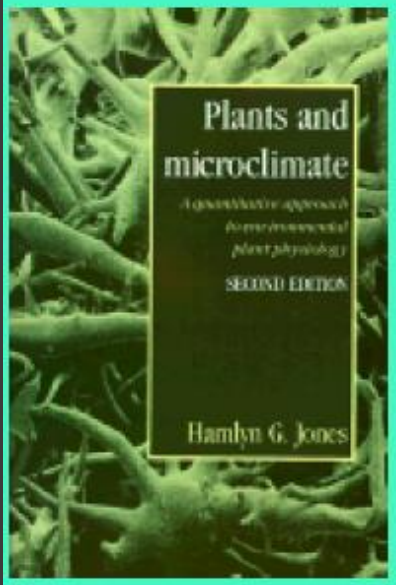


micromet. above agricultural crops

boundary layer micromet. method

micromet. above forest

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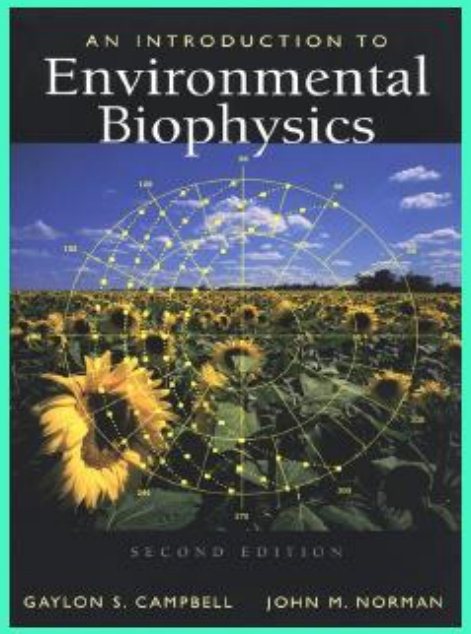
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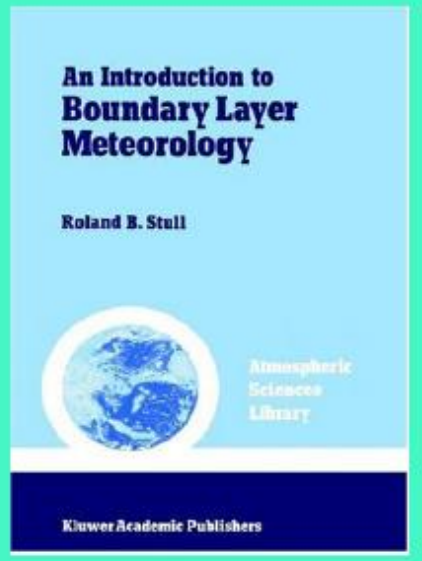
An Introduction to
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Roland B. Stull
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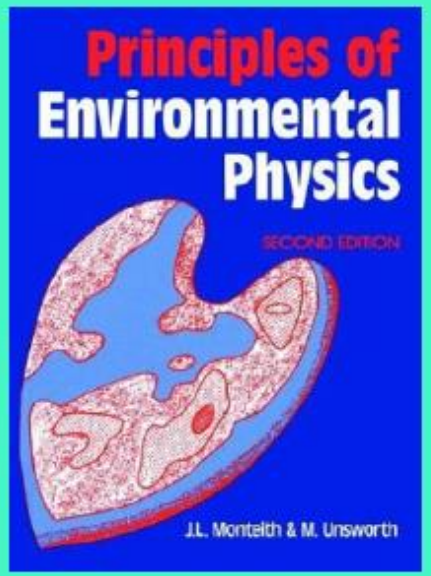
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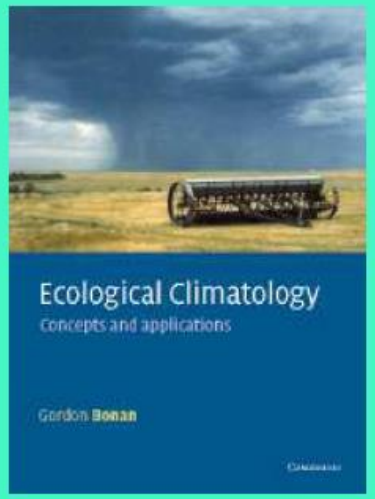
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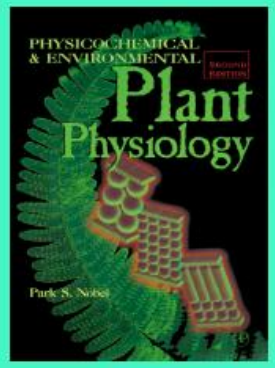
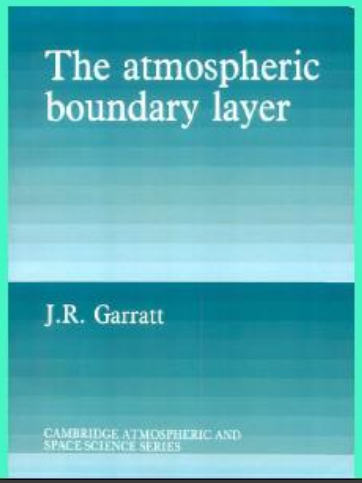

PHYSICOCHEMICAL
& ENVIRONMENTAL
Plant
Physiology


The atmospheric
boundary layer
J.R. Garratt
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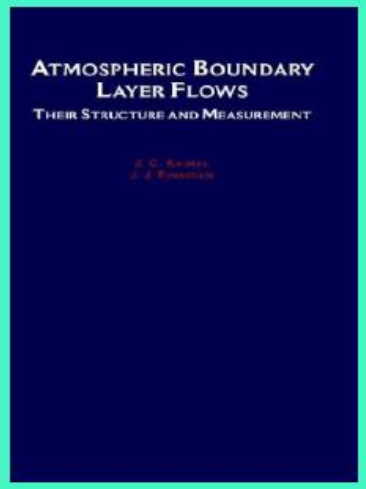
ATMOSPHERIC BOUNDARY
LAYER FLOWS
THEIR STRUCTURE AND MEASUREMENT

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(aller dans l'onglet Productions / Cours)

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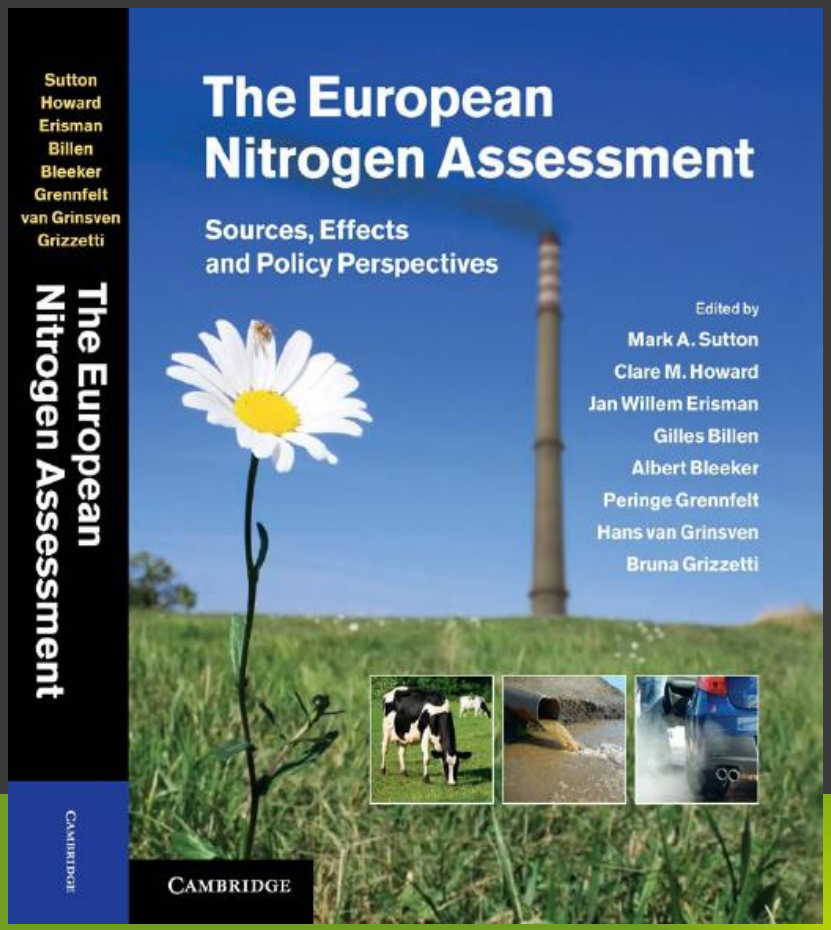

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