INMS Component 2: Global & regional quantification of N use, flows, impacts & benefits of practices

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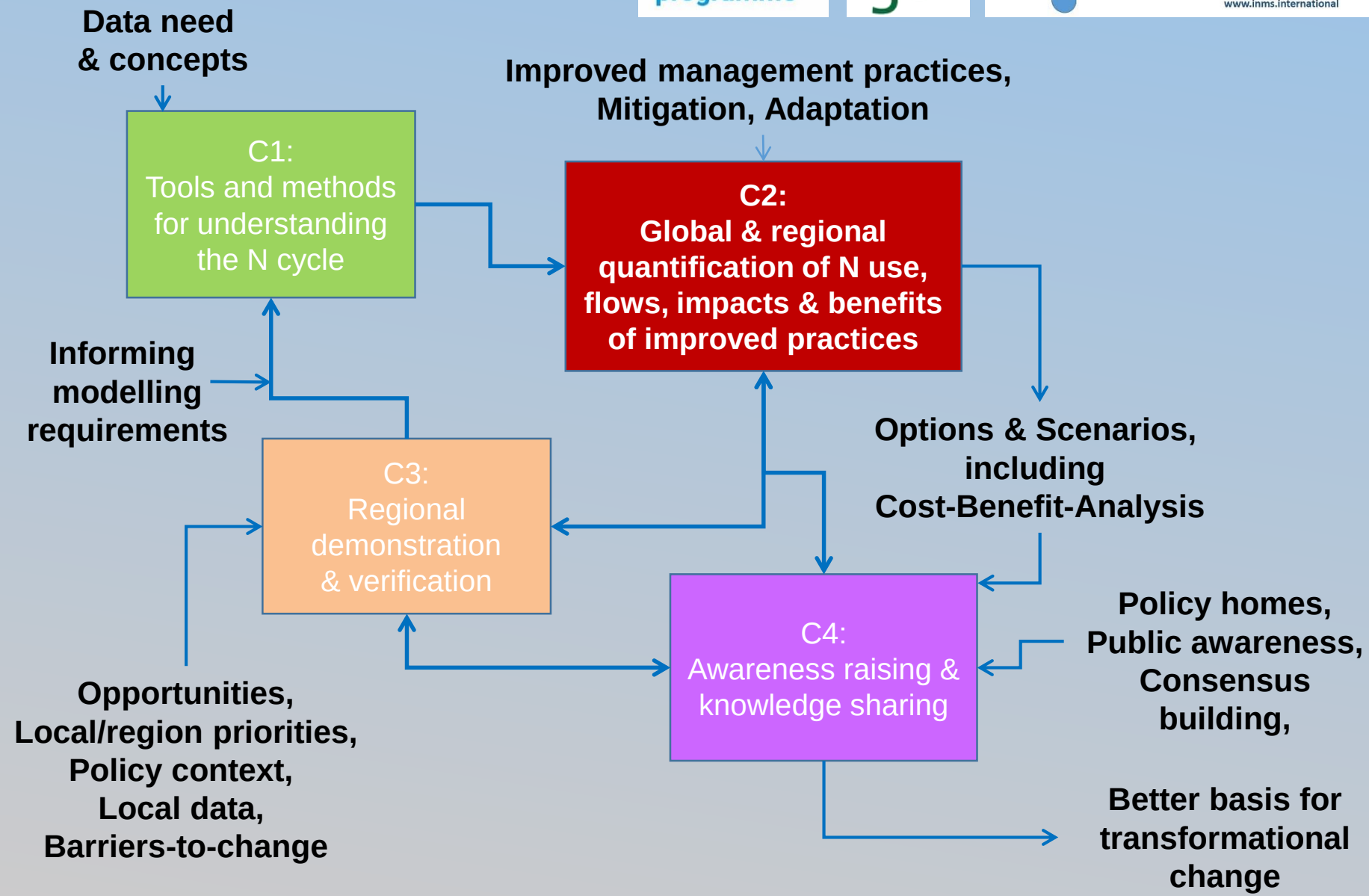
INMS 5 meeting 8 July 2020

Scope & Approach



Component 2
Quantification of N flows, threats & benefits
Wim de Vries / Jean Ometto

Activity 2.1
Quantifying N flows, threats and benefits at global and regional scales
De Vries/Boyer

Activity 2.2
Preparation of global assessment of N fluxes, pathways & impacts
Sutton/Howard

Activity 2.3
Integrating methods, measures & good practices to address N_r issues
Brownlie/Bleeker

Activity 2.4
Future N storylines & scenarios with management/ mitigation options & CBA
Winiwarter/Kanter

Activity 2.5
Collation & synthesis of experience & measures adopted by GEF and others
Bleeker/Walker

A2.1 (A1.5)/A2.4: Modelling/scenarios

- Modelling report: ready with all needed information on model use/protocol
- Modelling team ready: comparing IAMs and running scenarios
- INMS scenarios agreed upon: linked to existing SSP-RCP scenarios/ storylines with added new "N policies" (A2.4)

A2.3/A2.5: Measures

- Beta version of database is available on INMS website for A2.3.
- Collection of content underway
- Delivery is delayed but approach ready

A2.2: The INI book

- Draft table of content ready.
- Author teams under construction

Contents

Global scale integrated N assessment modelling

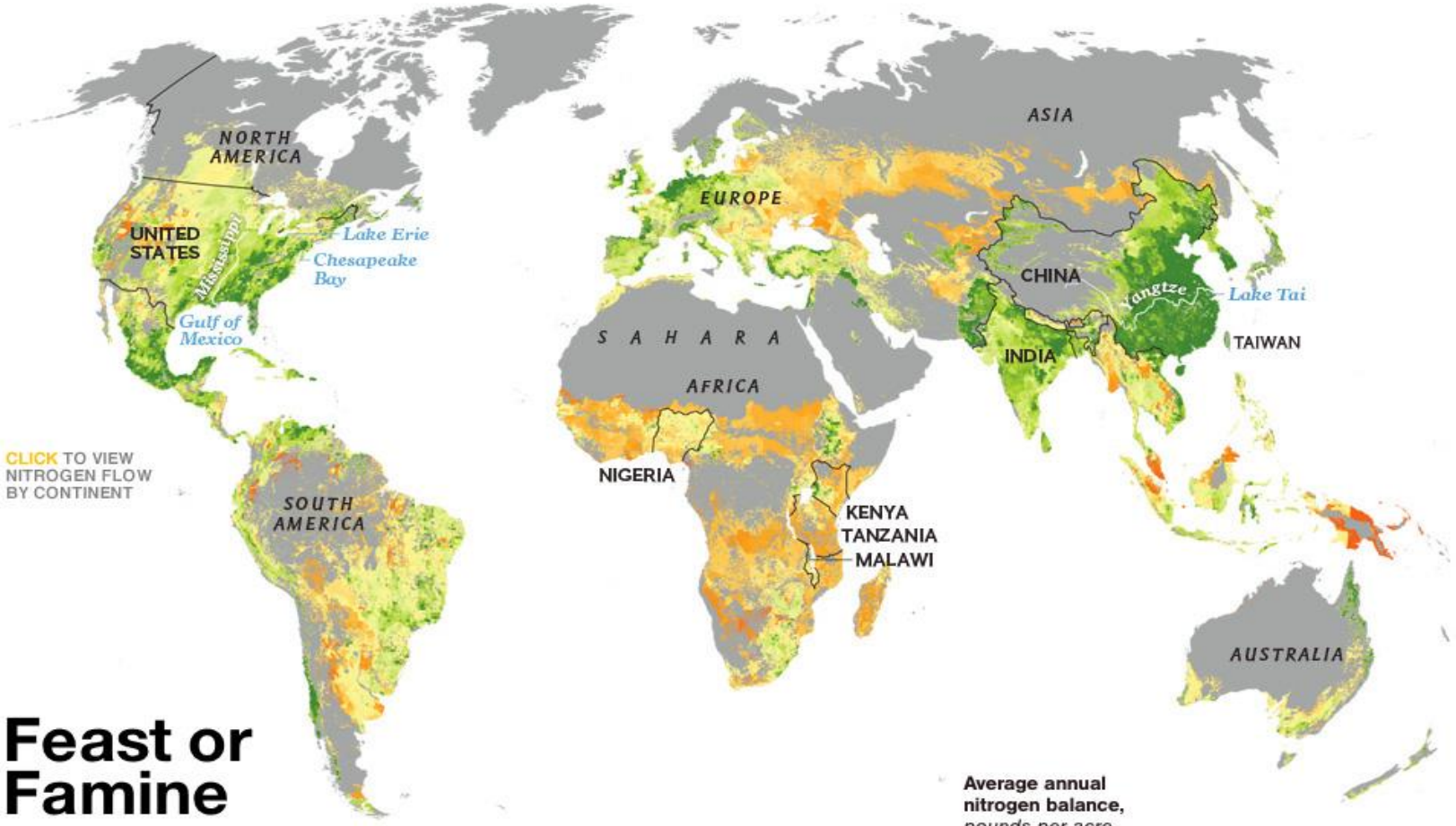
- The rationale: need for cost-benefit quantification of N policies
- The challenge: modelling interactions in the N cascade

INA part C: Global integrated assessment across the N cycle

- Outline and links to INMS modelling
- Examples of model results
  - Present (and past) N impacts
  - Future N impacts in response to scenarios and measures

Interaction between models and demo-regions; planning

Benefits: food and feed production



Feast or Famine

Nearly half the people on the planet wouldn't be alive if not for the abundant food made possible by nitrogen fertilizer. Yet its benefits have not reached everyone. In sub-Saharan Africa, where 239 million people go hungry in a year, crops fail as soil is stripped of nutrients, and farmers can't afford to buy fertilizer. Elsewhere overuse pollutes waterways and releases greenhouse gases.

JEROME N. COOKSON AND LAWSON PARKER, NGM STAFF
SOURCE: PAUL C. WEST, INSTITUTE ON THE ENVIRONMENT, UNIVERSITY OF MINNESOTA

Threats of N use in agriculture: Impacts on air, soil and water quality: health, climate and biodiversity

Biodiversity impacts

N outputs: harvested crops

Climate change impacts

Atmosphere

NH_3 N_2O NO_X N_2

Atmosphere

NH_3 N_2O NO_X N_2

N inputs:
N fertilizer
N fixation
N deposition

Crop production

feed

manure

Animal production

N outputs: milk, meat, eggs

NH_4^+ $\mathbf{NO_3^-}$ DON N_{part}

NH_4^+ NO_3^- DON N_{part}

Ground water & surface water

In addition: Impacts of (industrial) N emissions on air quality and human health

Impacts of (industrial) N emissions on air quality and human health

- NO_x emissions lead to ozone (O_3) formation in troposphere (*70%*): UNEP estimated 1 million premature respiratory deaths globally:
  - India: 400,000
  - China: 270,000.
  - Africa: /Europe/US; 50,000

- NO_x and NH_3 emissions contribute to particulate matter (*20%*): WHO estimated 7 million premature deaths globally due to lung cancer, pulmonary diseases, respiratory infections etc.

The impacts of nitrogen (INMS) on SDGs

Translating SDGs to N flux indicators in simplified model system: critical N inputs

SDG	N flux	Indicators		
		Current	Target	Distance to target
2 Zero hunger	*Production indicators*			
	N uptake/crop yield	Current	Potential	Potential-current
	N Inputs	Current	Needed	Needed-current
	Environmental indicators			
	N Losses			
15 Life on Land	• NH_3-N emissions	Current	Critical	Current - critical
13 Climate action	• N_2O-N emissions	Current	Critical	Current - critical
6 Clean water	• N leaching	Current	Critical	Current - critical
14 Life below water	• N runoff	Current	Critical	Current - critical
	N Surplus	Current	Critical	Current - critical
	N Inputs	Current	Critical	Current - critical
	Efficiency indicators			
12 responsible production	N use efficiency (NUE)	Current	Optimal	Optimal-current

Global scale integrated N assessment modelling in view of benefits and threats

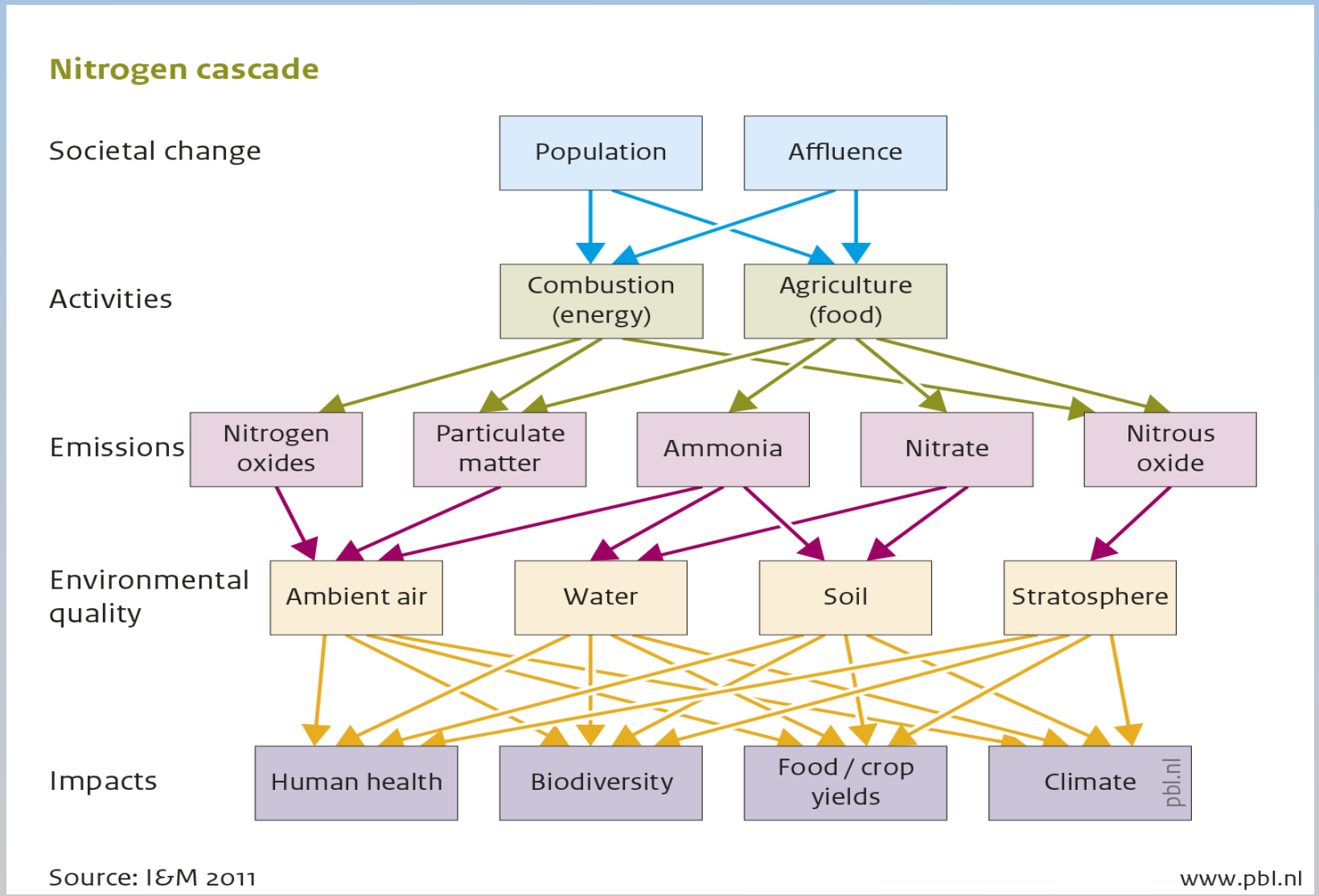
A global integrated nitrogen assessment model needs to quantify effects of N management (N policies) on:

- food, feed and fiber production (benefits)
- quality of air, soil and water, and related human health, climate and biodiversity impacts (threats)

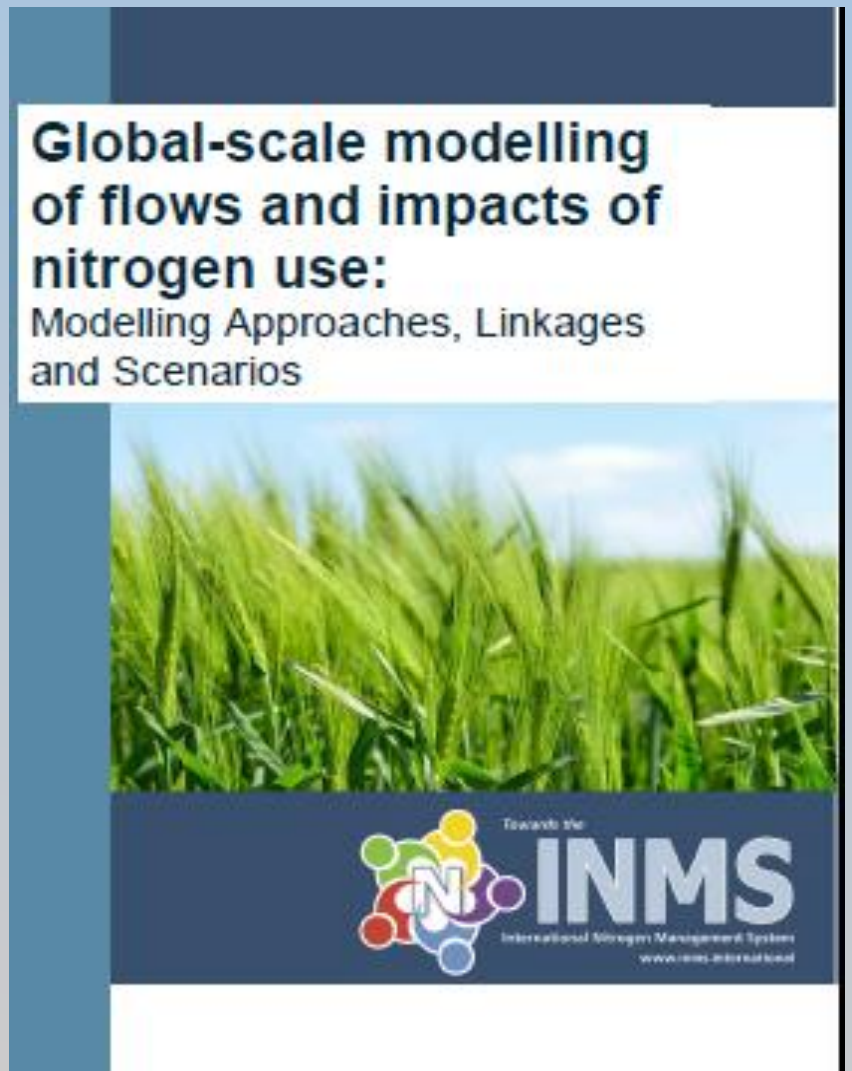
while

- being linked to socio-economic drivers (scenarios)
- accounting for variations in climate, soils, crops.

Global scale integrated N assessment: challenge to model the N cascade



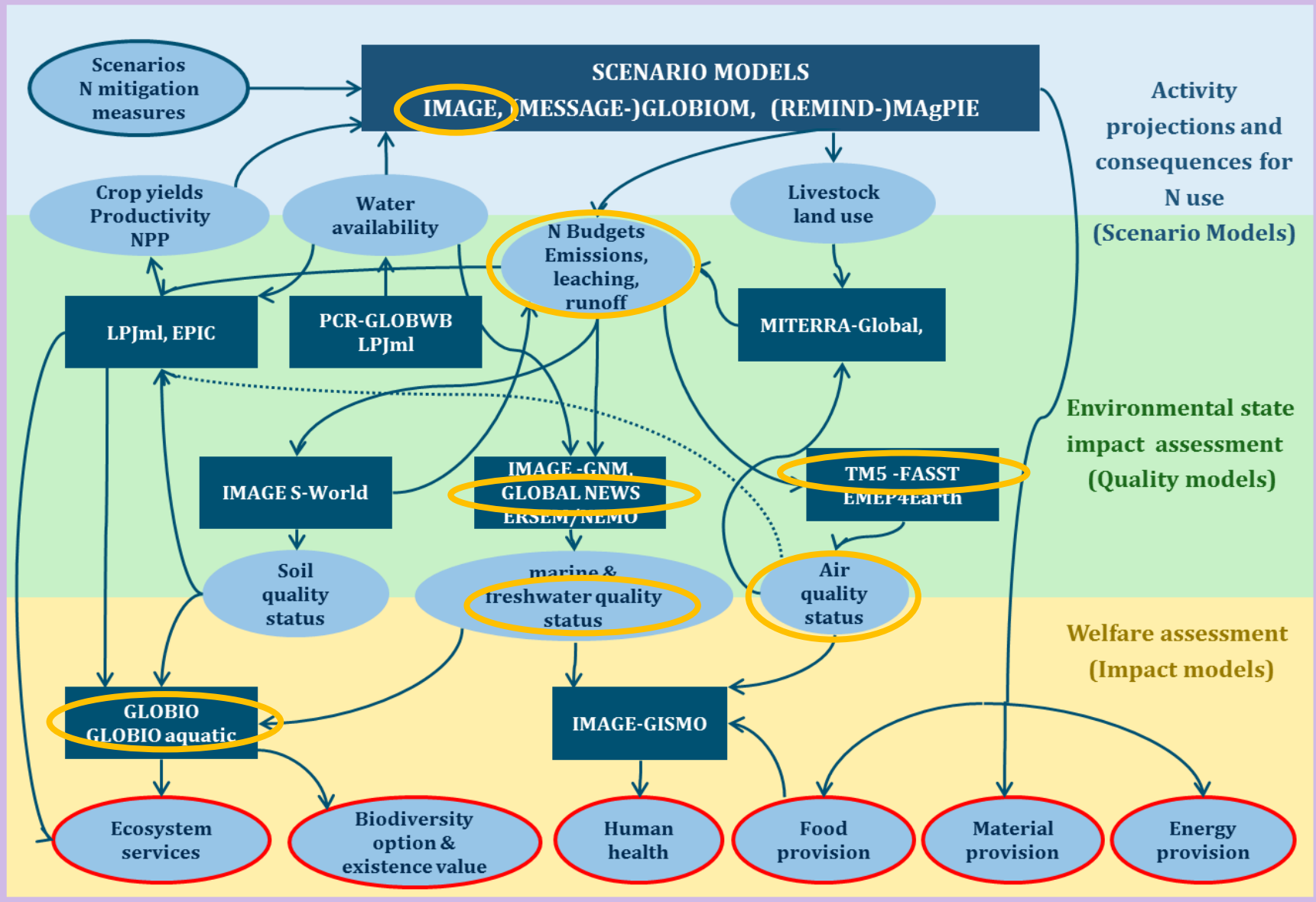
INMS global scale modelling approach



First INMS report: describes global scale modelling approach

- modelling approach, including needed models and model linkages to simulate N benefits and threats.
- modelling protocol on: (i) models involved, (ii) base year used (2010), spatial and temporal extent and resolution, (iii) scenarios used, (iv) model outputs and (v) model linkages.
- Database platform for the INMS model inputs and outputs.

Multi model approach: involved models and linkages



Status and Planning

Three integrated assessment models, IAMs (IMAGE, MAgPIE, GlOBIOM)

- Paper submitted to Nature Communications which gives a comparison of major N inputs and N outputs of the IAMs but also of FAO and IFA
- Results, during a historical period up to 2010 (2010 is base line year), show huge differences in N manure inputs and N uptake.
- INMS scenarios (SSP1, SSP2 and SSP5 with N policies) implemented in all three IAMs and results on future N budgets (and river N exports for IMAGE-GNM) are (near) ready.

Other models

- Results for base year (2010) are all ready
- All models are working on evaluation of scenarios (in different stages)
- TM5-FASST air quality model is used to calculate air quality impacts in response to various scenarios: results used for Cost benefit Analysis

Model results are part of chapters in INA part C

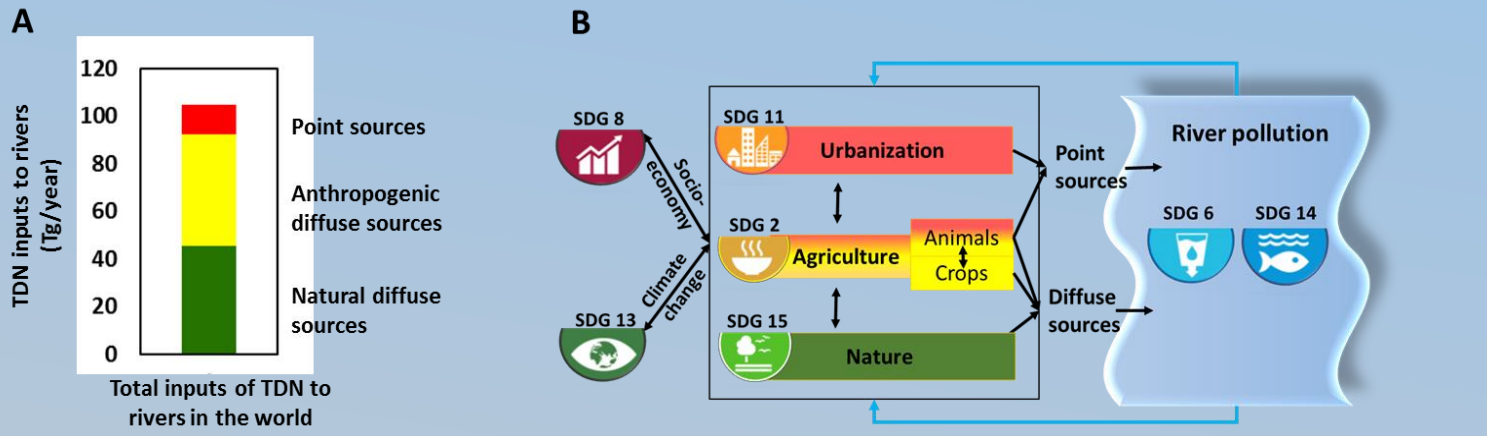
Impacts will be described by presenting current status and predictions up to 2050 (2010) based on WAGES

- Starting with *total N budgets*. C10

- **W**ater quality: linked to aquatic (marine) eutrophication C11
- **A**ir quality: linked to health C12
- **G**reenhouse gas emissions: linked to climate C13
- **E**cosystems: linked to terrestrial and aquatic biodiversity C14
- **S**oil: linked to soil N budgets (input, uptake, losses to air and water) and related soil acidification C15

- Finalizing with *cost-benefit analysis* C16

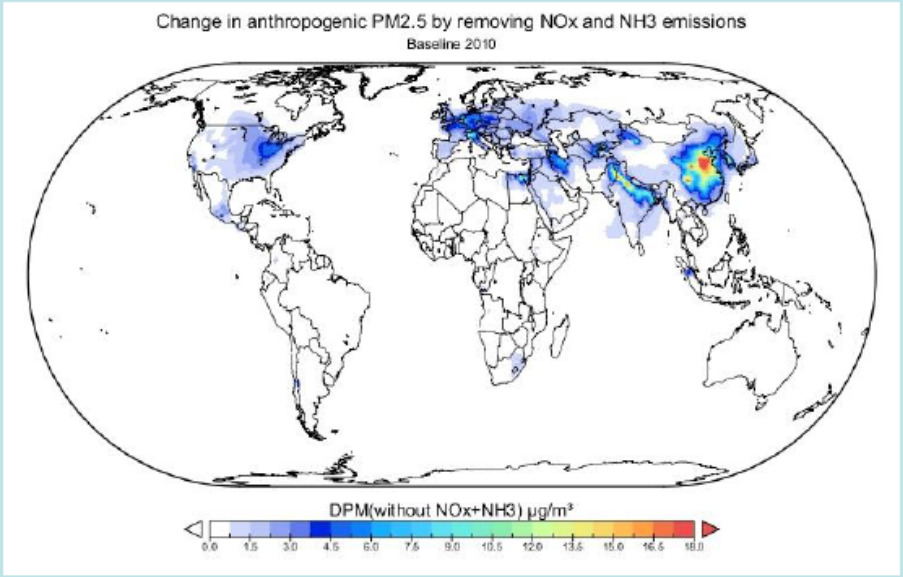
Example Chapter 11: Water quality assessment with Global NEWS



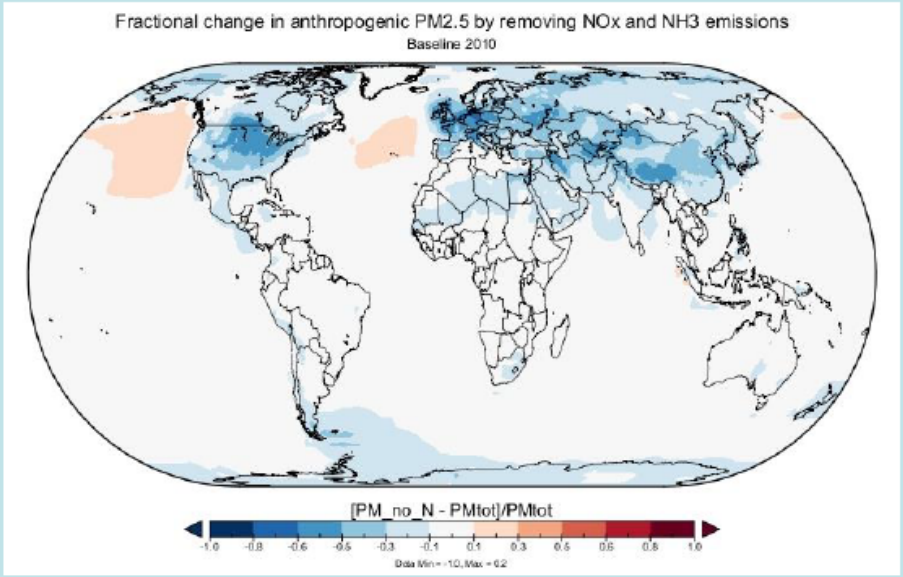
Strokal et al. (2020; INI Berlin proceedings)

Example Chapter 12: Air quality assessment with TM5-FASST

Absolute change in PM2.5 by removing NO_x and NH_3 emissions



Fractional change in **anthropogenic** PM2.5 by removing NO_x and NH_3 emissions



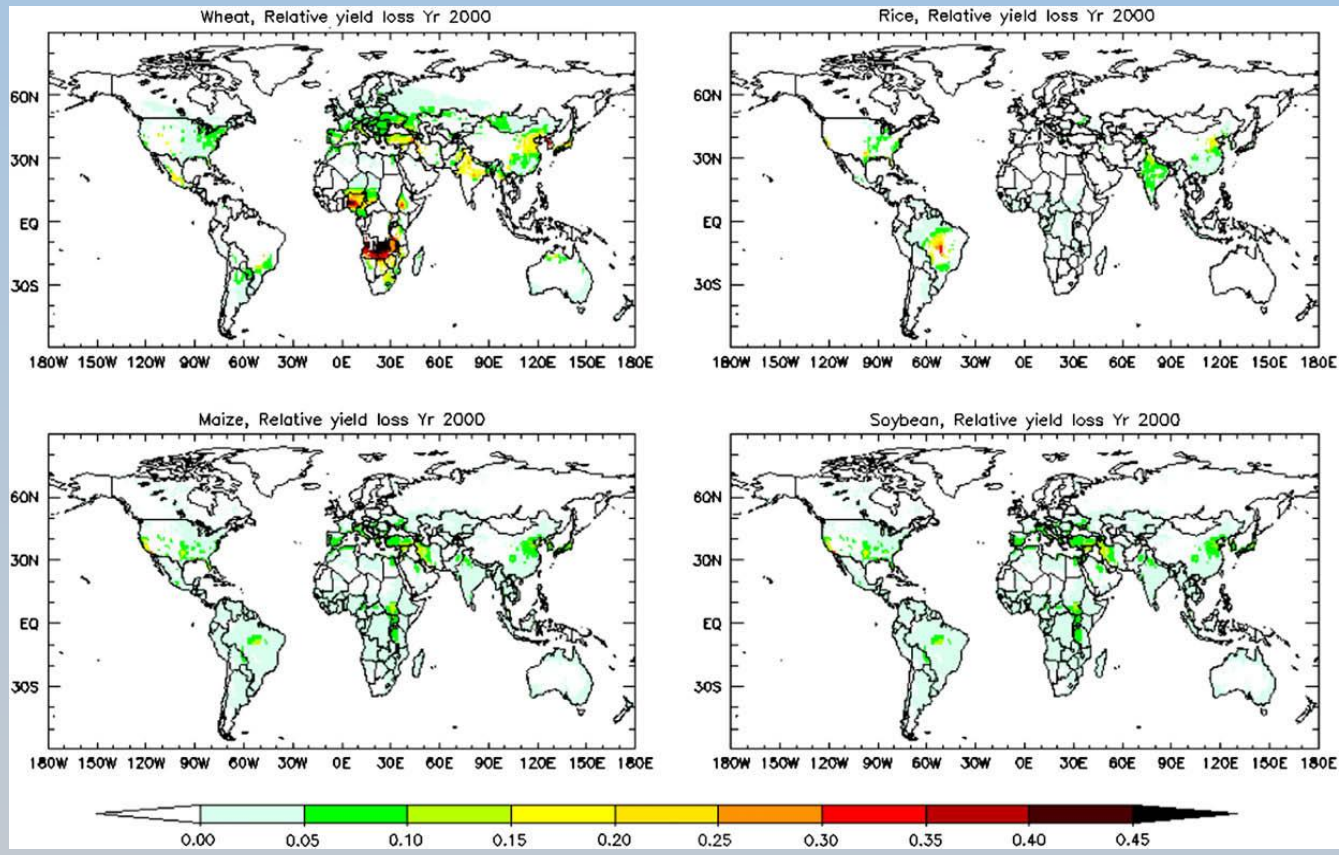
Impacts of NO_x and NH_3 emissions on $PM_{2.5}$ affecting health: Van Dingenen et al. (2019)

Example Chapter 12: TM5-FASST: Assessment of ozone impacts on global food production

- Estimated global relative yield losses due to ozone is 3-16%

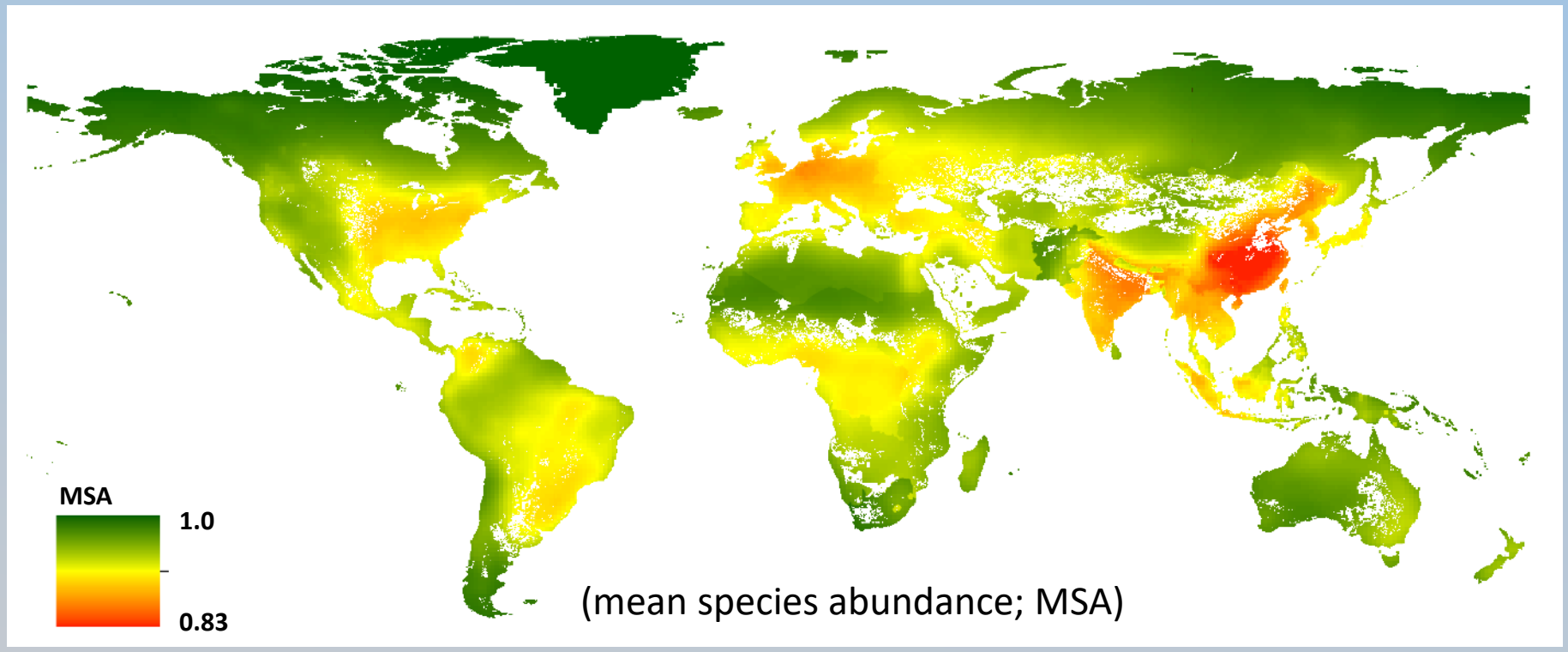
Global economic damage:

- 10–18 billion Euro
- About 40% of loss in China and India



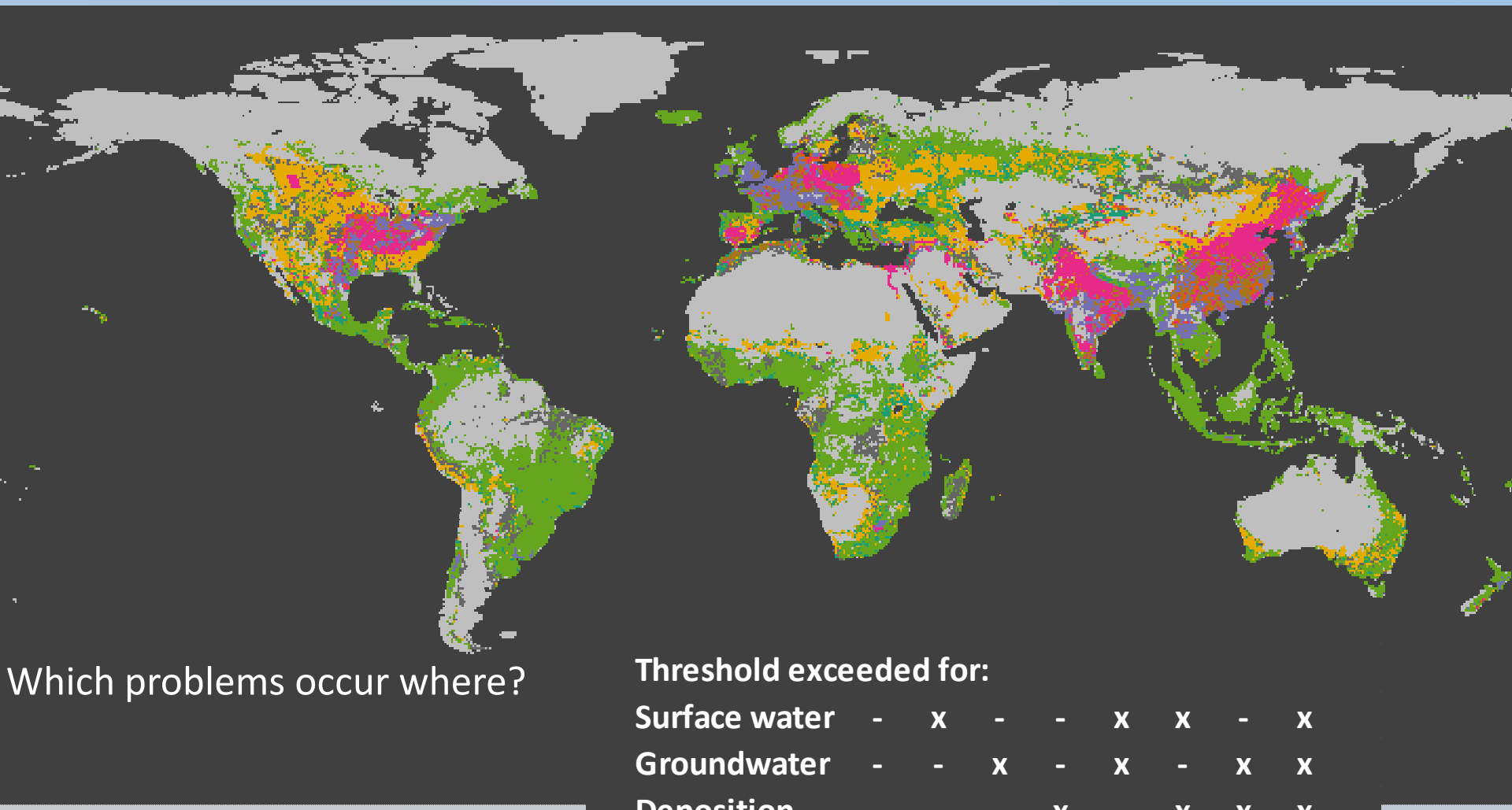
Van Dingenen et al. (2009)

Example Chapter 14: GLOBIO: Impacts of N deposition (year 2015) on biodiversity



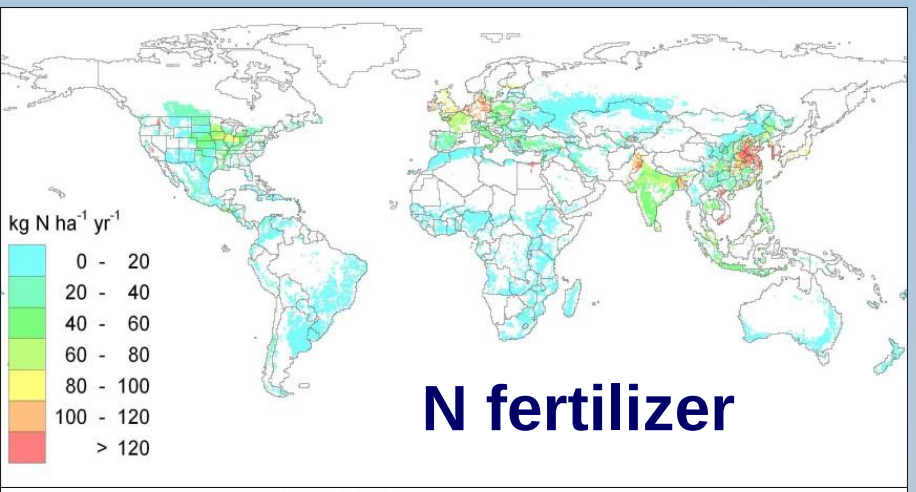
Schipper et al (in prep)

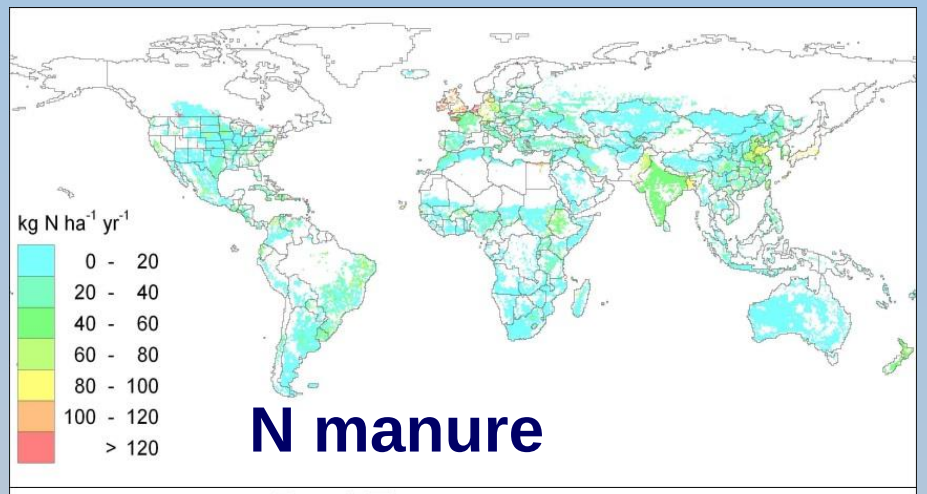
Example Chapter 14: Predicted critical load exceedances using IMAGE

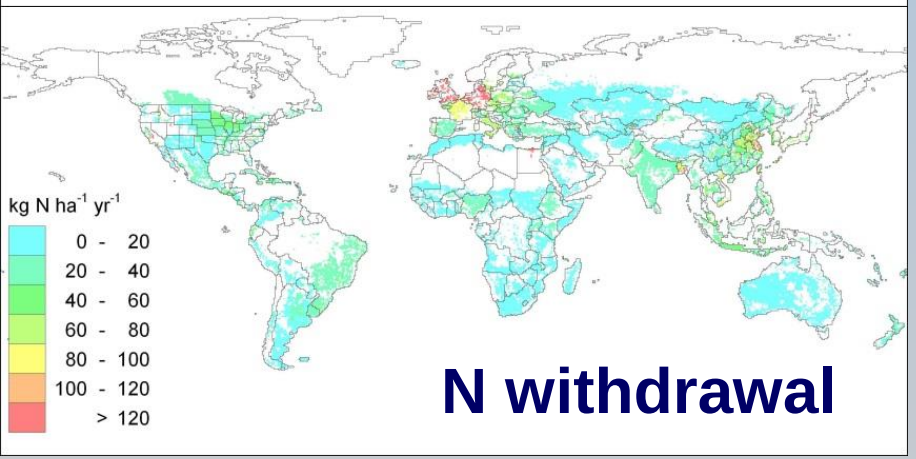


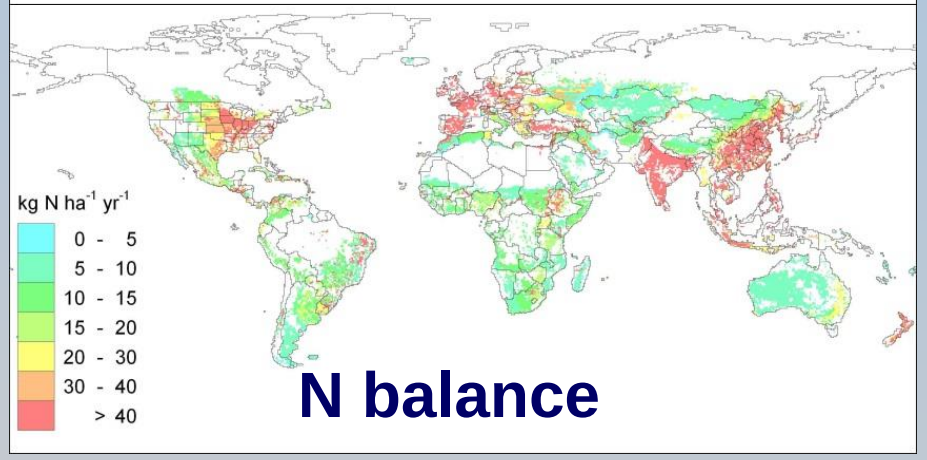
Schulte-Uebbing et al (in prep)

Example Chapter 15: Soil N budget results with IMAGE









Bouwman et al. (2019)

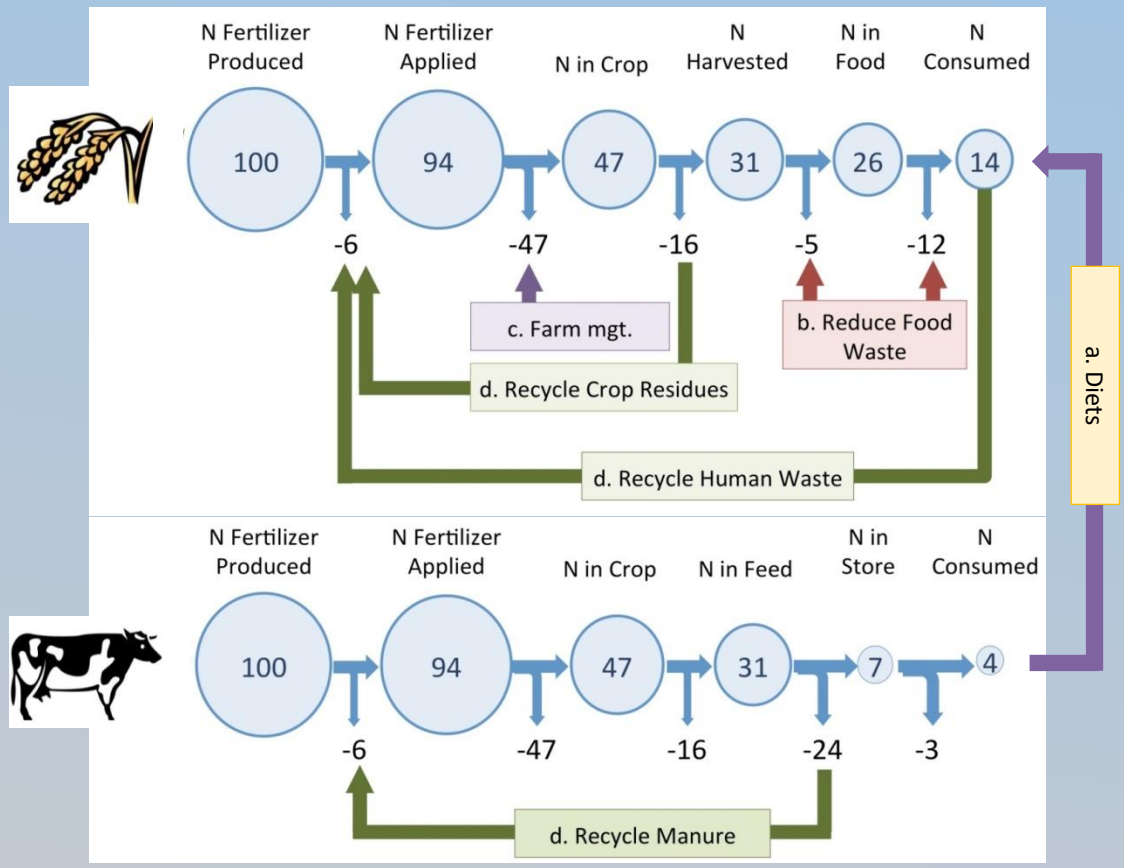
Challenge ahead: systematic evaluation of scenarios and N mitigation measures

We use existing global scenario's, i.e. SSPs and RCPs, including dietary change propositions.

We assess separate N mitigation policies related to

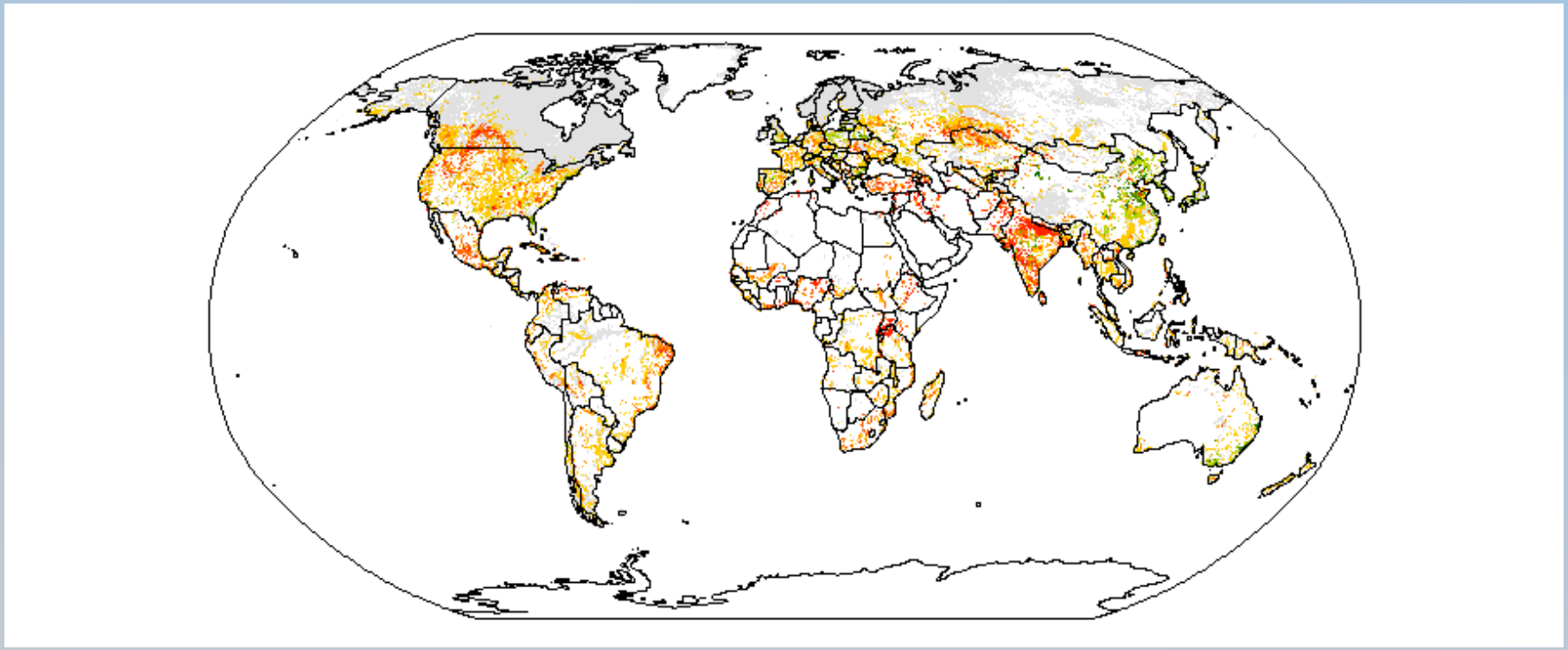
- enhanced (animal, plant, human) waste recycling
- improved nutrient management.

Measures: A2.3 and A2.5
Scenarios: A2.4



Examples of scenario results

Change in harmful algal blooms in lakes (2010 -> 2050) in response to SSP2 scenario



Deterioration in many regions due to increased N and P loading as well as temperature rise.

Janse et al (in prep)

Result of Integrated model assessments: part C of the INA book

- Current status of N uses on soil, air and water quality and thus on biodiversity, human health and climate

- Evaluate impacts (costs and benefits) of scenarios and N related N policies/measures (management) on air, soil and water quality for:
  - food/feed supply
  - Biodiversity, human health and climate

Basis is result of coupled models evaluating scenarios (population growth, dietary patterns, bioenergy use) and N policies/measures

Interaction modelling and demo-regions

Questionnaire send to Contact persons of demo regions asking for:

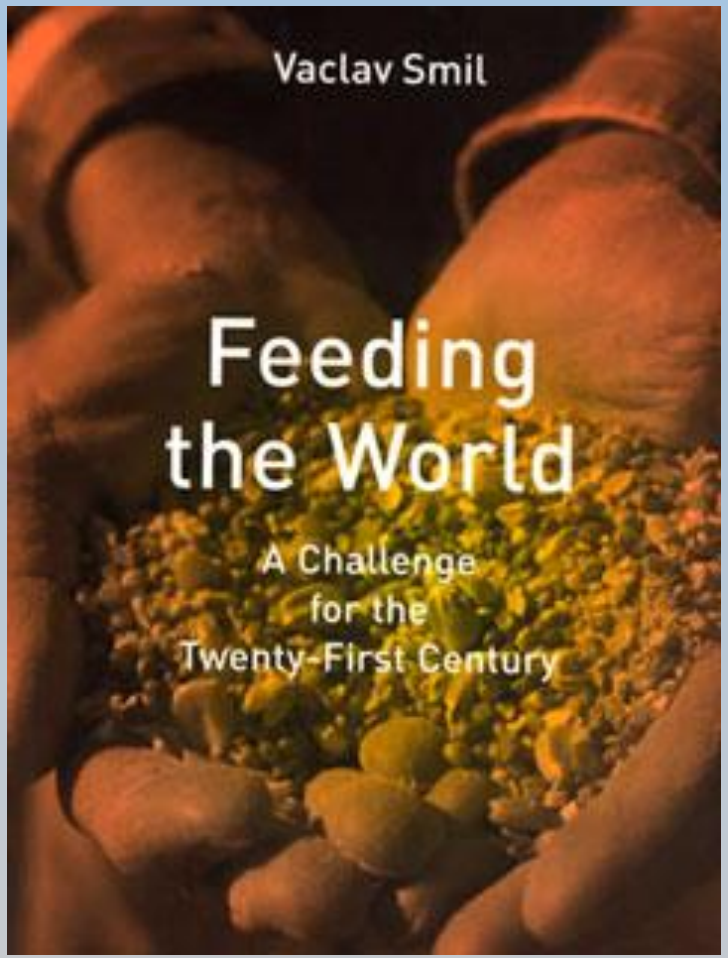
- interested in a full N budget for their region by IAM models
- more detailed data on inputs for assessing N budgets for region
- Validation data on N concentrations in air, ground water and/or surface water.

Region	Interest	Input data	Monitoring data
*) North America	Yes	N inputs + uptake	Air, ground/surface water
*) Western Europe	Yes	N inputs + uptake	Air, ground/surface water
*) East Africa	Yes	N inputs + uptake	Air, ground/surface water
*) Eastern Europe	Yes	N inputs + uptake	Air, surface water
*) South Asia	Yes	N inputs + uptake	Air, ground/surface water
*) East Asia: China and Japan	Yes	No	Air
*) Latin America: La Plata Basin	Yes	N inputs + uptake	Air, ground/surface water

Agenda meeting Component 2

- A1.5/A2.1. Introduction C2 and modelling: Wim de Vries
- A 2.4 Scenarios: Ecolex database: David Kanter
- A 2.3 Measures & good practices: Will Brownlie
- A 2.5 Experience & measures adopted by GEF: Sarah Walker/ Albert Bleeker
- A2.2 Status and planning of INA book: Clare or Mark:
- Overall discussion

Questions?


Vaclav Smil
Feeding the World
A Challenge for the Twenty-First Century