INMS agreements and workplan A2.1 & 1.5 Modelling protocol and discussion issues

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INMS meeting 18 April 2018, Edinburgh

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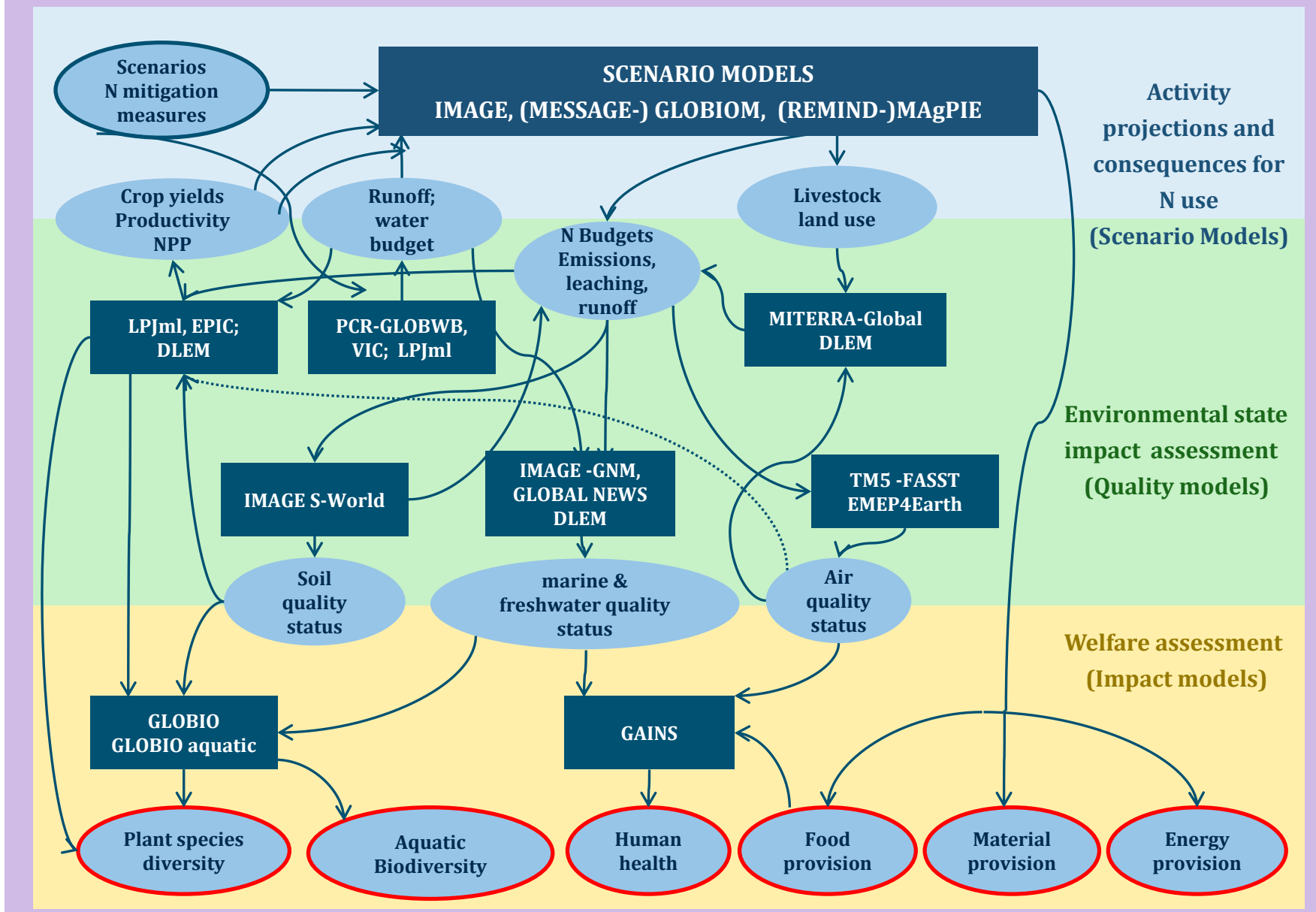# Protocol: Global scale Nitrogen modelling in view of benefits and threats

Protocol focuses on application of linked global N assessment models to quantify effects of

- socio-economic drivers (SSP-RCP scenarios)

- N mitigation policy storylines/management measures

on

- food production (benefits) vs

- quality of air, soil and water, and related human health, climate and biodiversity impacts (threats)

Aspects modelling protocol

- Approach and models involved

- Basic agreements: temporal/spatial resolution/extent

- Scenarios and N policy story lines

- Model outputs

- Model linkages, number of multi-model evaluations

# Multi model approach: involved models and linkages

Scenarios N mitigation measures

**SCENARIO MODELS
IMAGE, (MESSAGE-) GLOBIOM, (REMIND-)MAgPIE**

Activity projections and consequences for N use (Scenario Models)

Crop yields Productivity NPP

Runoff; water budget

N Budgets Emissions, leaching, runoff

Livestock land use

LPJml, EPIC; DLEM

PCR-GLOBWB, VIC; LPJml

MITERRA-Global DLEM

Environmental state impact assessment (Quality models)

IMAGE S-World

IMAGE -GNM, GLOBAL NEWS DLEM

TM5 -FASST EMEP4Earth

Soil quality status

marine & freshwater quality status

Air quality status

Welfare assessment (Impact models)

GLOBIO GLOBIO aquatic

GAINS

Plant species diversity

Aquatic Biodiversity

Human health

Food provision

Material provision

Energy provision

Modelling team

#	Model	Contact person/e-mail	Institute
1	IMAGE	Lex Bouwman	PBL
2	PCR-GLOBWB	Lex Bouwman	PBL
3	MAGPIE	Benjamin Bodirsky	PIK
4	LPJml	Christoph Muller;	PIK
5	GAINS	Wilfried Winiwarter	IIASA
6	GLOBIOM	Peter Havlik/David Leclere	IIASA
7	EPIC	Juraj Balkovič/Petr Havlík	IIASA
8	DLEM	Hanqin Tian	AU
9	CAPRI	Adrian Leip	JRC
10	EDGAR	Greet Maenhout	JRC
11	TM5	Frank Dentener/Rita van Dingenen	JRC
12	EMEP4Earth	Massimo Vienno	CEH
13	MITERRA Global	Jan Peter Lesschen	WUR
14	GLOBAL NEWS	Carolien Kroeze	WUR
15	WBM/VIC	Carolien Kroeze	WUR
16	ERSEM/NEMO	Icarus Allen/Jason Holt	PML, NOC
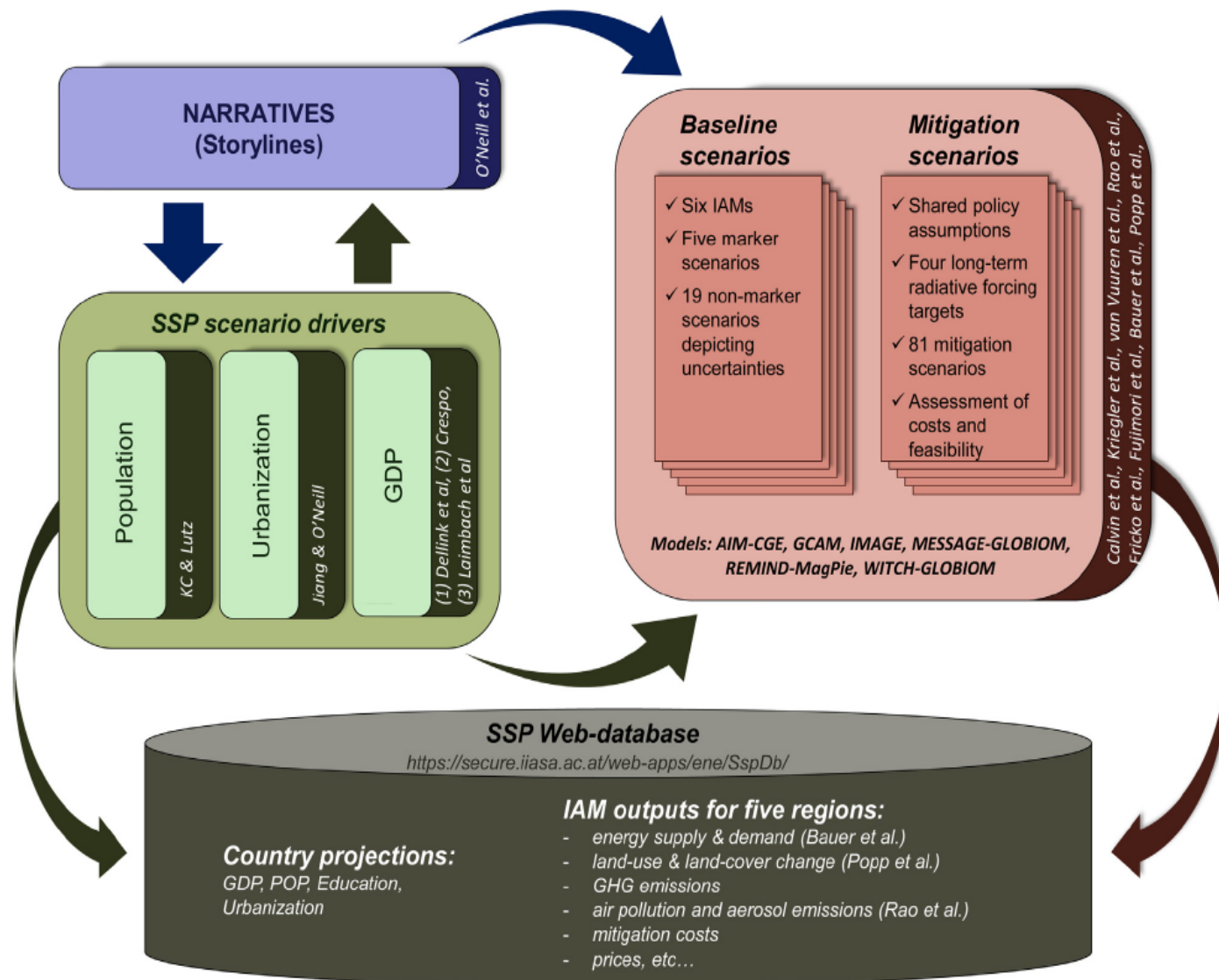
SSP-RCP scenarios, linked to IMAGE, GLOBIOM and MAgPIE are key in approach
Source: Riahi et al (2017)

Example application SSP1, SSP2 and SSP5 with climate change in Baltic sea region
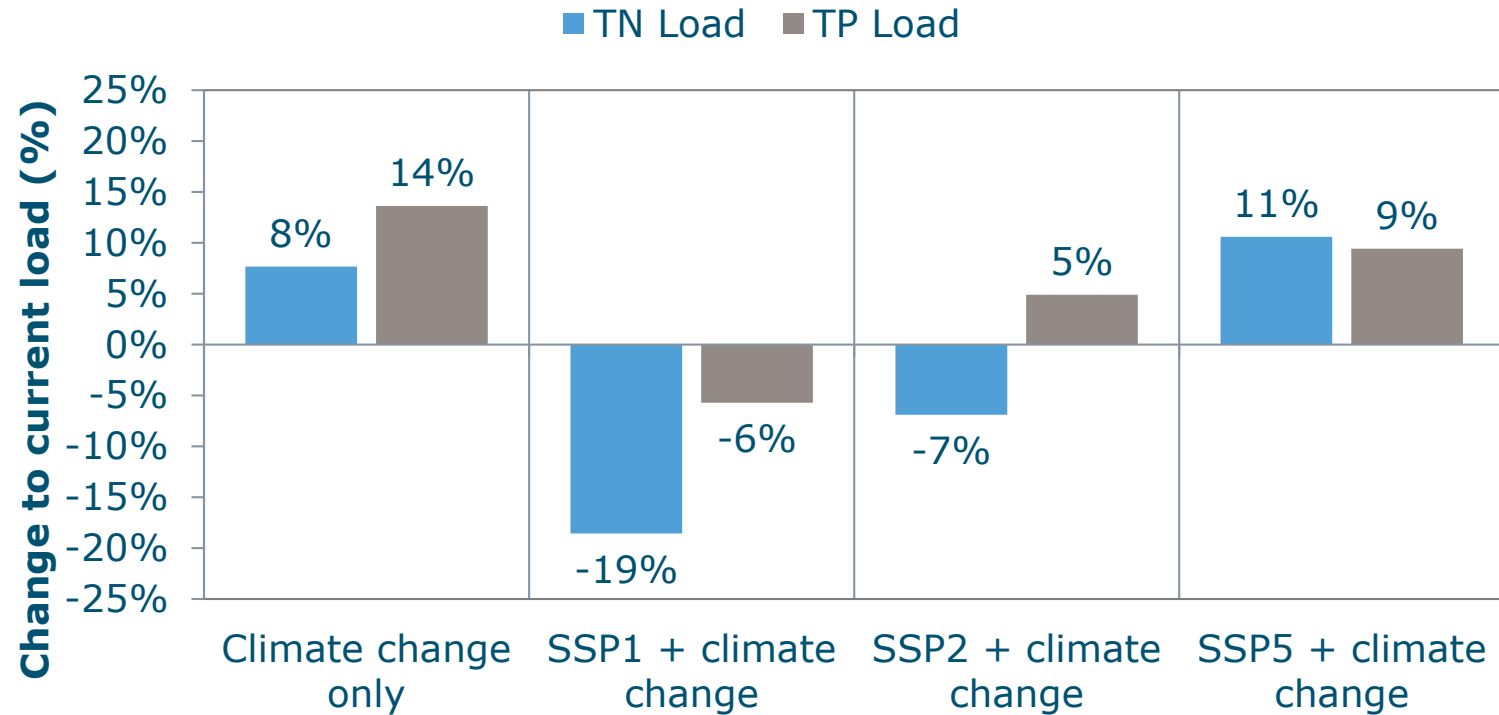
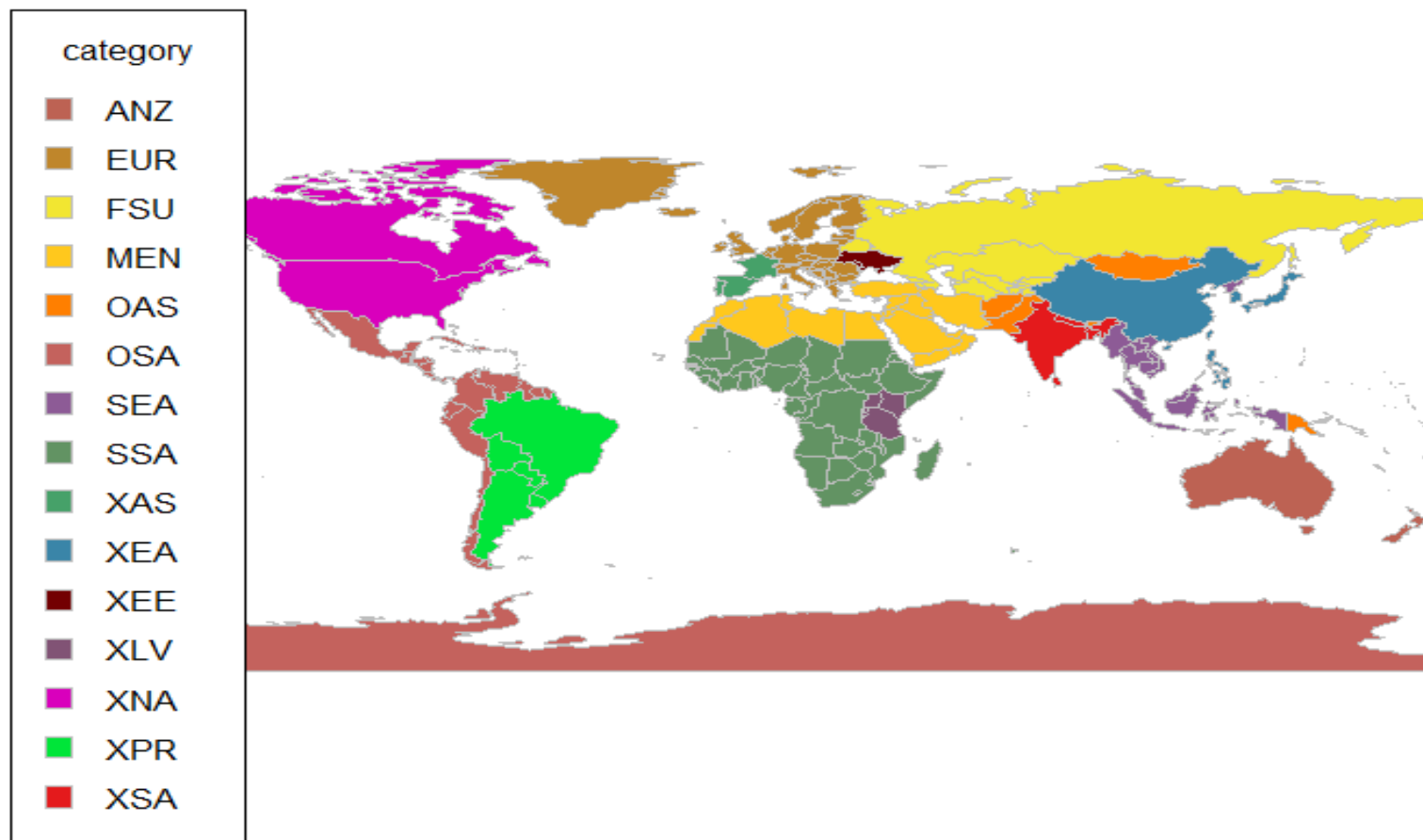Source: BONUS Soils2Seas: Final Policy Brief .

Basic agreements: temporal and spatial resolution/extent

- *Base year: 2010*

- Spatial extent: World

- *Spatial resolution: Continental regions and 0.5° by 0.5° degrees*

- Temporal extent: 1970-2050 (2100 for selected outputs)

- Temporal resolution: periods 1970, 1985 and *2005, 2010* in the past and 2030, 2050 and 2100 (for selected outputs) in future.

- *Data Exchange by model intercomparison files .mif (csv files of a specific format) files for continental regions and netcdf files for 0.5*0.5°*

Discussion issues

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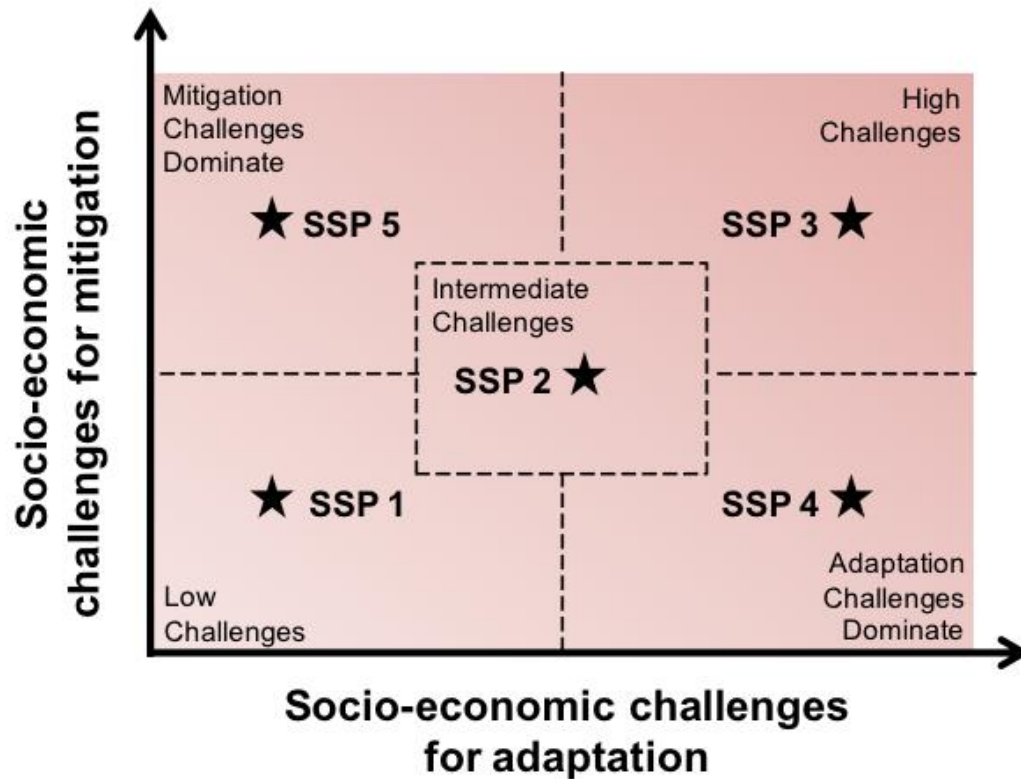# Scenarios in three parts: SSP, RCP and SPA

Representative concentration pathways (RCPs)

Radiative forcing

Shared socioeconomic Pathways (SSPs)

Shared Policy assumptions (SPAs)

Socio-economic reference pathway

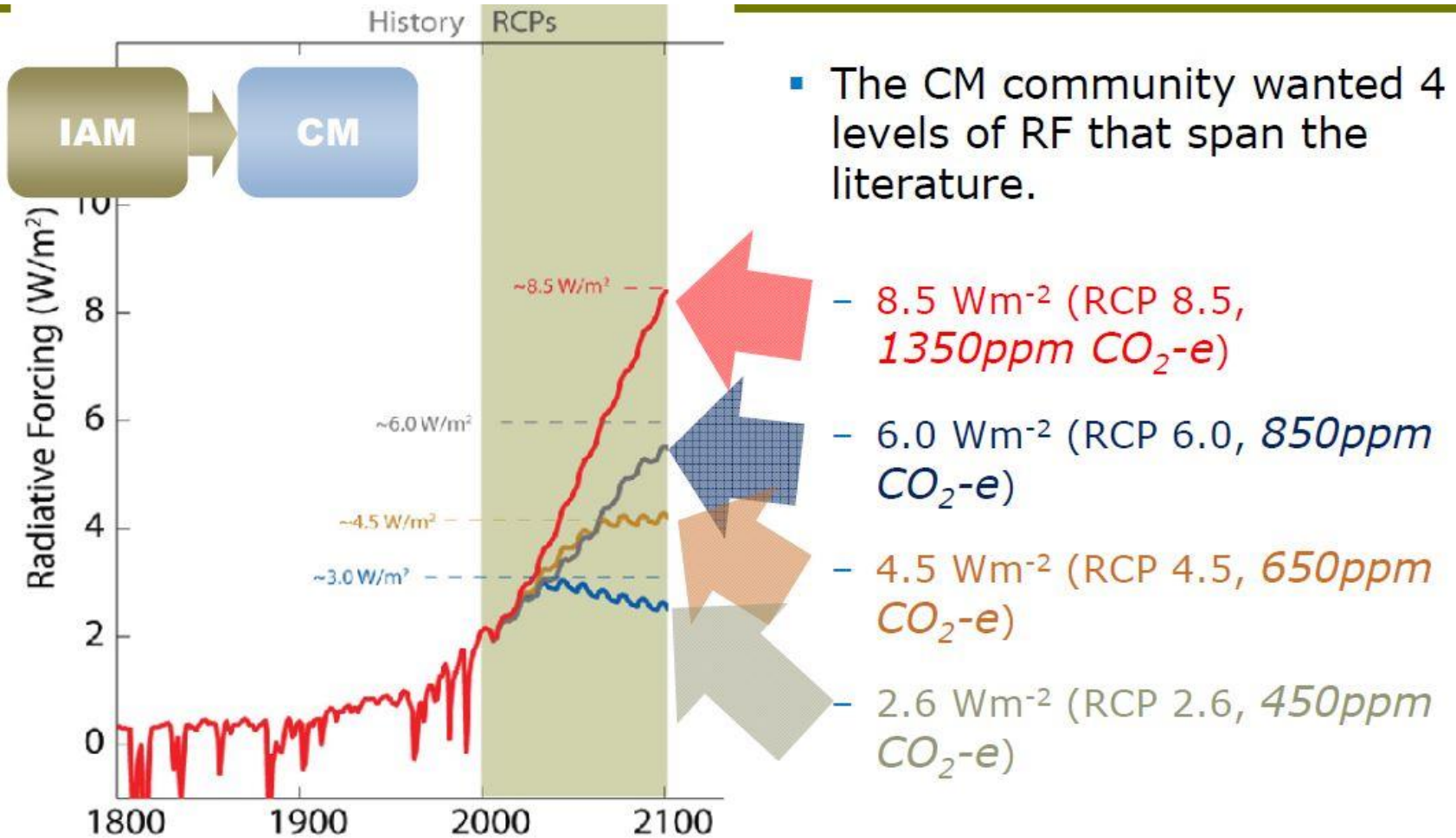Targeted N policy Storylines/measures

Policy-context
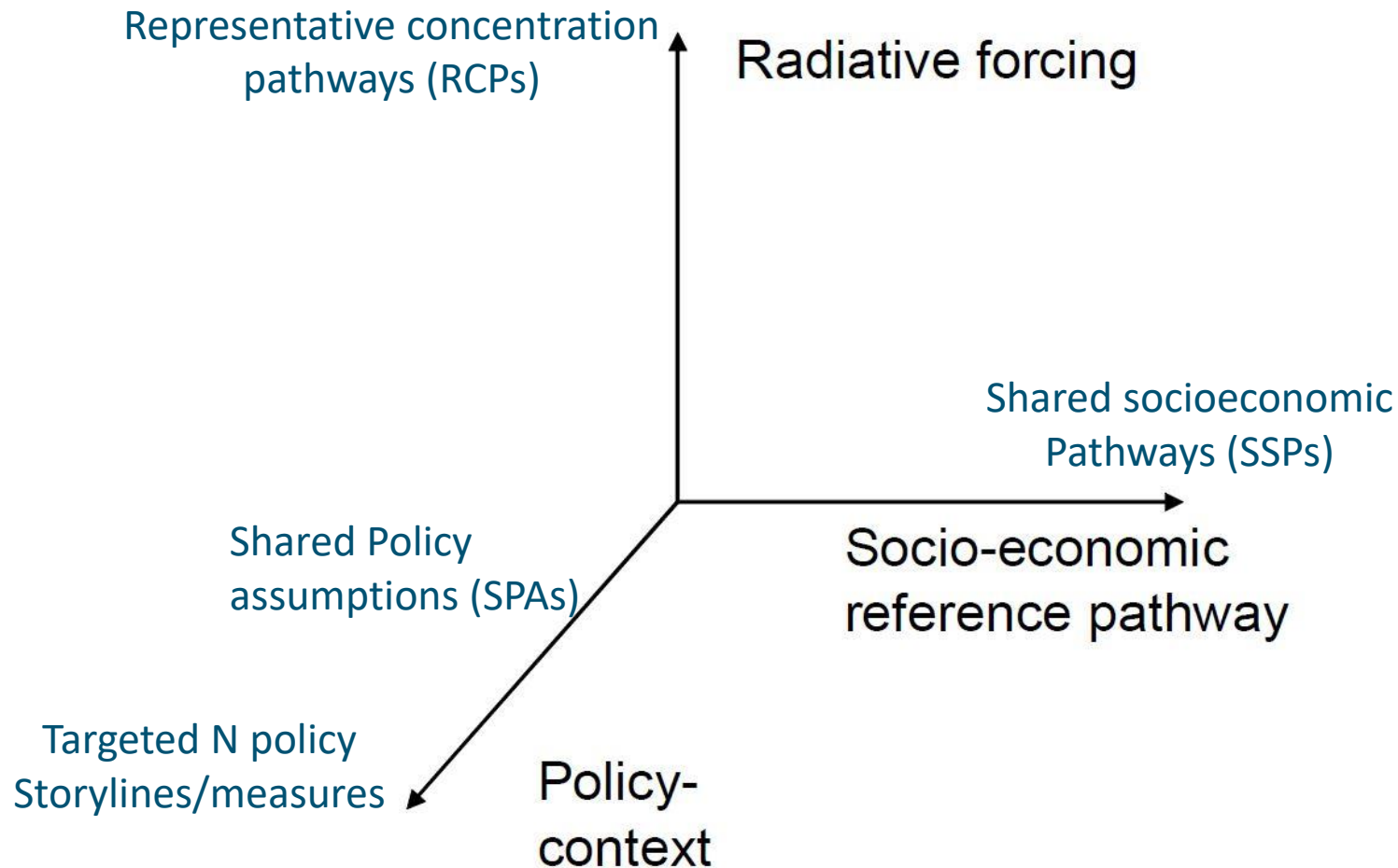
Source: Van Vuuren et al (2017)

The SSP scenario approach

SSP1. Sustainable Pathway
SSP2. Moderate Pathway
SSP3. Rocky Road
SSP4. Regional Pathways
SSP5. Taking the Fast Road

Source: O Neill et al (2017)

Four RCPs

- The CM community wanted 4 levels of RF that span the literature.
  - 8.5 Wm^{-2} (RCP 8.5, *1350ppm CO_2-e*)
  - 6.0 Wm^{-2} (RCP 6.0, *850ppm CO_2-e*)
  - 4.5 Wm^{-2} (RCP 4.5, *650ppm CO_2-e*)
  - 2.6 Wm^{-2} (RCP 2.6, *450ppm CO_2-e*)

Linkage between SSPs and radiative forcing levels as compared to RCPs

Scenario	Radiative forcing 2100	Best fit RCP
SSP1	5.0	RCP 4.5
SSP2	6.5	RCP 6.0
SSP3	6.8	RCP 6.0
SSP4	5.7	RCP 6.0
SSP5	8.3	RCP 8.5

Source: IMAGE results: Lex Bouwman, pers. Comm.

SSP linked to RCPs: defining needed policies

- The final element in the Scenario Matrix Architecture is the **Shared Climate Policy Assumptions (SPAs)**

- **SPAs define**

  - What policies?

  - Who mitigates? and when?
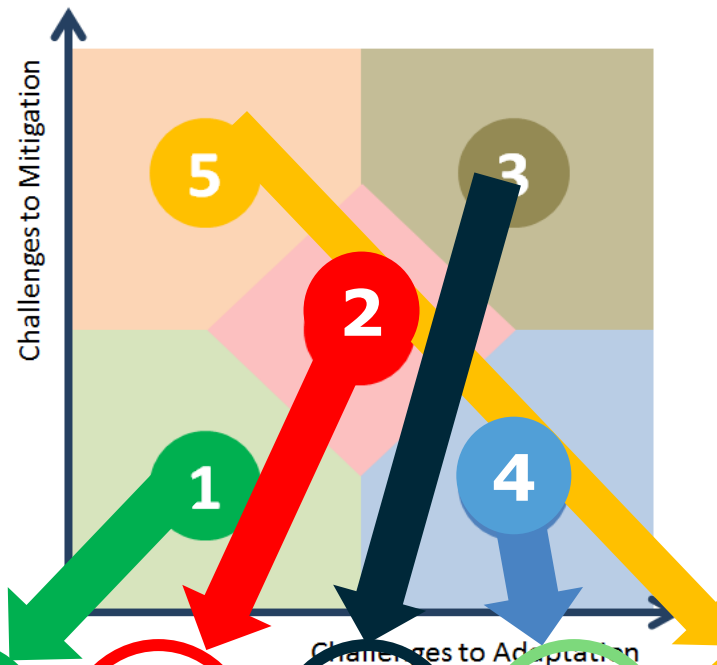
		SSP 1	SSP 2	SSP 3	SSP4	SSP5
	Reference	X	X	X	X	X
RCP Replication	8.5 Wm^{-2}					**X**
	6.0 Wm^{-2}	X	**X**	**X**	**X**	X
	4.5 Wm^{-2}	**X**	X	X	X	X
	2.6 Wm^{-2}	X	X			X

SPAS

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Which SSP-RCP-N policy scenarios? Suggestions based on New York meeting

Scenario name	SSP Scenario	RCP scenario	**Additional N policy storylines**
Sustainability	SSP1	RCP4.5	Not included
Fossil fueled development	SSP5	RCP8.5	Intermediate ambition level
Fragmentation	SSP3	RCP6.0	Low ambition level
Mitigation	SSP1	RCP2.6	High ambition level
Business as usual	SSP2	RCP6.5	High ambition level

Example of nutrient focused SSP1 and SSP5 descriptions for Baltic sea region

SSP1, Sustainability	SSP5, Fossil-fueled development
• Population in the region and globally peaks and starts to decline after 2050 • Rapid urbanization • Gradual move towards less resource intensive lifestyles	• Global population peaks in 2050, population in the Baltic Sea region increases steadily • Rapid urbanization • Resource and energy intensive lifestyles prevail
• Increased plant based diet • High N efficiency, high share of local & organic products • Reduced agricultural land cover & livestock	• Increased meat and dairy products in diet • Globalised, export oriented sector, intensification • Increased livestocks => expansion of agricultural land cover
• Tertiary treatment becomes the standard • Separation of rainwater and sanitation • Advanced on-the-site treatment common in rural areas	• New investments made to serve growing urban areas • focus on human health rather than environmental quality • Some upgrading due to technology spill-overs
• Sustainable fisheries with high quality products • Circular economy in aquaculture • Small-scale, low impact fishes promoted • Avoidance of habitat damaging gear and bycatch	• Large-scale fishing focusing on maximising profits • Habitat destructive gear and bycatch allowed • Industrial scale development of freshwater and marine aquaculture with no nutrient focus

Extension of two extreme global futures to the Baltic Sea region. The global futures translate to developments in the regional drivers of agricultural nutrient loading, wastewater treatment and the fisheries

Source: BONUS BALTICAPP policy brief 1: Exploring plausible Baltic Sea futures.

Example of N assumptions in storylines in SSP1, SSP2 and SSP5 in Baltic sea region

Changes in:	SSP1 Sustainable development	SSP2 Middle of the road	SSP5 Fossil fuelled development
Agricultural land use	- 10%	0%	+ 10%
Livestock density	- 50%	0%	+ 50%
Manure nitrogen efficiency	+ 10%	+ 5%	- 10%
Applied effective nitrogen	- 5%	0 %	+ 5%
Atmospheric deposition of N	-40%	-30%	-15%
Urban wastewater	-35% / -40%*	-20% / -25%*	-16% / -23%*
Rural wastewater	-30% / -30%*	-17% / -17%*	1% / -23%*

Source: BONUS Soils2Seas: Final Policy Brief .

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Discussion issues scenarios (models)

- Do we limit scenario-models, predicting scenario impacts on N sources, to IMAGE, MADRAT/MAgPIE and GLOBIOM/GAINS? (*CAPRI used in internal link with TM5-FASST?*)

- Do we agree with the suggested story lines: which SSPs do we include and which RCPs do we couple to the SSPs?

- Which GCM model results of the different RCPs do we take to include climate change impacts on spatial patterns of temperature and precipitation?

Discussion issues N policy story lines

- What are the additional N policy storylines for each scenario in terms of

  - N energy emission measures

  - food loss

  - waste recycling

  - NUE increase by placement of fertilizers/manure with the right type, at the right amount, right time and right place (4 R strategy).

- NB: note that dietary change is already in the SSPs

Model outputs: Main drivers/N sources

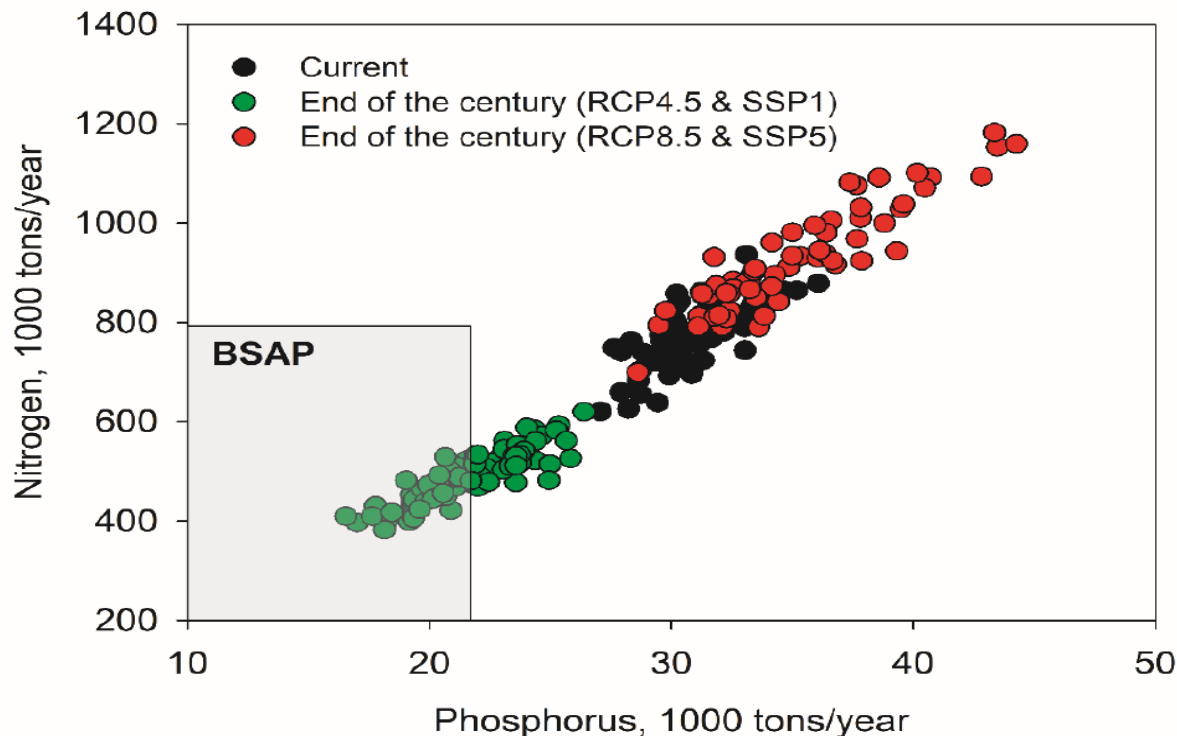| Model outputs	IMAGE	Mag-PIE	GLO-BIOM	MI-TERRA	LPJml	CAPRI	GAINS	ED-GAR	TM5-FAST	EMEP4 Earth	Global NEWS
Drivers of N sources/N fate											
• Energy emissions	x					x	x	x			
• cropping patterns/ crop areas	x	x	x			x					
• herd size/animal numbers	x	x	x			x					
• Climate parameters: rainfall, temperature	x					x					
N sources											
• N fertilizer and N manure input	x	x	x			x					
• N deposition/N fixation to non-agricultural systems	x					x					
• Point N sources	x	x				x					

Model outputs: productivity, N fate; air quality

Model outputs	IMAGE	Mag-PIE	GLO-BIOM	MITER RA	LPJml	CAPRI	GAINS	EDGAR	TM5-FAST	EMEP4 Earth	Global NEWS
Growth/NPP											
• crop/grass yield	x				x						
• NPP/forest yield	x				x						
N fate agricultural land											
• N uptake crops/ grassland	x	x	x	x		x					
• N (NH_3, N_2O, NO_x, N_2) emissions	x	x	x	x		x					
• N leaching and N runoff	x	x	x	x		x					
Air quality indicators	x										
• N deposition	x								x	x	
• AOT40, POD	x								x	x	
• N- PM2.5, N- PM10	x								x	x	

Model outputs: indicators for water quality, biodiversity and health

Model outputs	IMAGE	Mag-PIE	GLO-BIOM	MITER RA	LPJml	CAPRI	GAINS	EDGAR	TM5-FAST	EMEP4 Earth	Global NEWS
Water quality indicators											
N groundwater	x										
N river export	x										x
ICEP index	x										x
Biodiversity indicators											
• terrestrial diversity index	x										
• Aquatic diversity index	x										
Health indicators											
• DALY etc							x?				

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Example of application SSP1-RCP4.5 and SSP5-RCP8.5 to Baltic sea region

Source: BONUS BALTICAPP policy brief 1: Exploring plausible Baltic Sea futures.

Number of multi-model evaluations
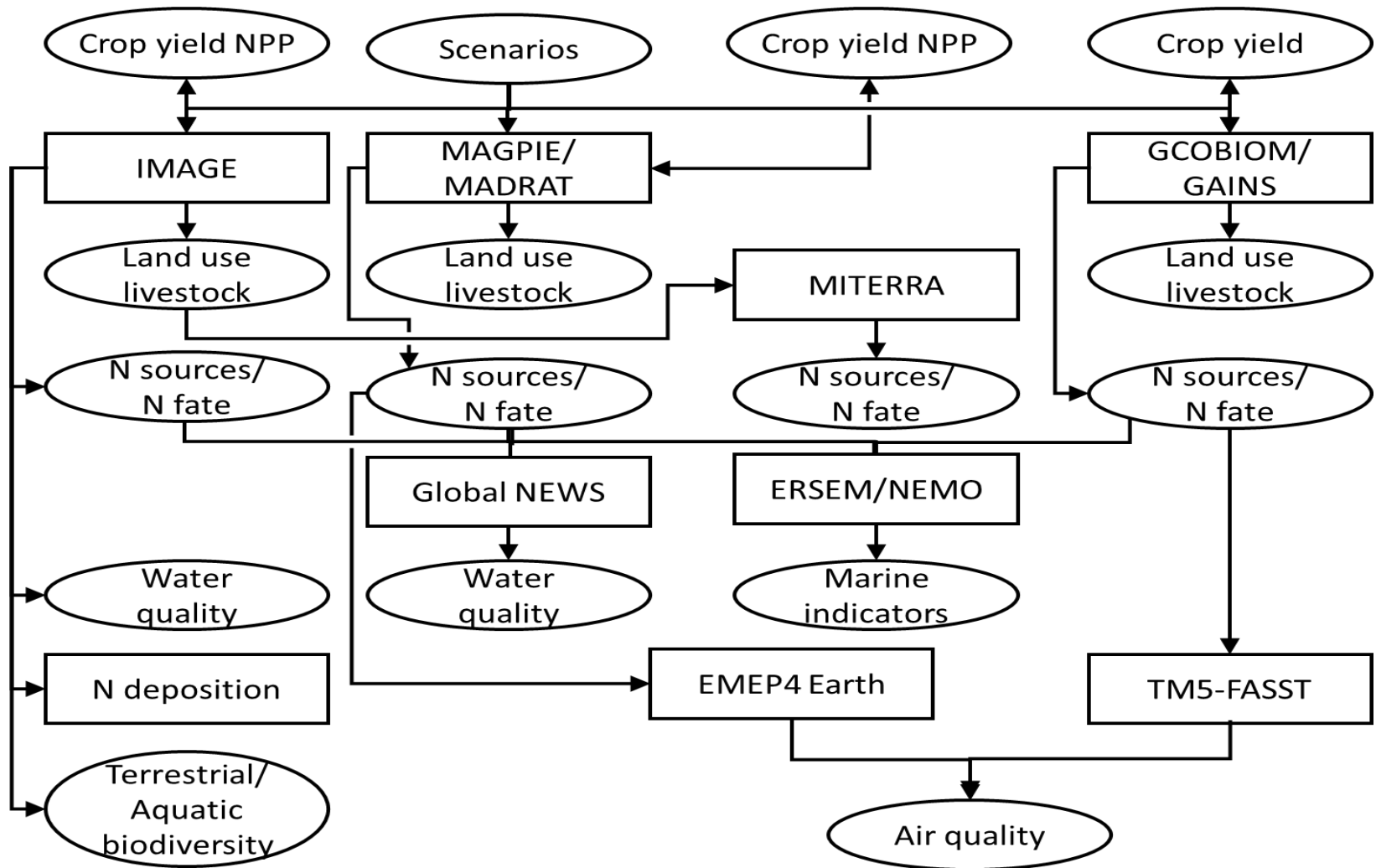
Number of multi-model evaluations

- N sources: IMAGE, MADRAT/MAgPIE and GLOBIOM/GAINS (3 outcomes)

- N budgets: IMAGE, MADRAT/MAgPIE, GLOBIOM/GAINS and MITERRA Global (4 outcomes)

- Air quality: EMEP4Earth (using results of MAgPIE/MADRAT)? (1 outcome). Separate TM5-FASST-CAPRI?

- Water quality: IMAGE-GNM; Global NEWS linked to IMAGE, MADRAT/MAgPIE and GLOBIOM

- Terrestrial and Aquatic Biodiversity: IMAGE (1 outcome of each)

- *Is human health impact included in any model (GAINS)?*

Discussion issues

Water quality/runoff

- Is updating and re-calibration to 2010, with new input data from an IAM foreseen in Global NEWS?

Air quality and crop yield/NPP

- Are deposition/air quality outputs input to crop growth models (LPJml, EPIC)?

- Which deposition/air quality outputs are related to Net Primary production predicted by LPJml in IMAGE-Magpie?

Questions?