Activity 1.4: development of approaches for N threat-benefit valuation

April 2018

Hans van Grinsven, Baojing Gu

Component 1
Tools for understanding & managing the global N cycle *Baron / van Grinsven*

Activity 1.1
Devlpt of N system indicators
Winiwarter / Clark

Activity 1.2
Devlpt of N threat assessment methodology
Baron / Shibata

Activity 1.3
Devlpt methodology N fluxes and distribution
Beally/Hicks

Activity 1.4
Devlpt approaches N threat-benefit valuation
Van Grinsven / Baojing Gu

Activity 1.5
Flux-impact path models for assessment, scenarios
(de Vries / Winiwarter)

Activity 1.6
Examination barriers to better N management
Masso/Cordovil

INMS

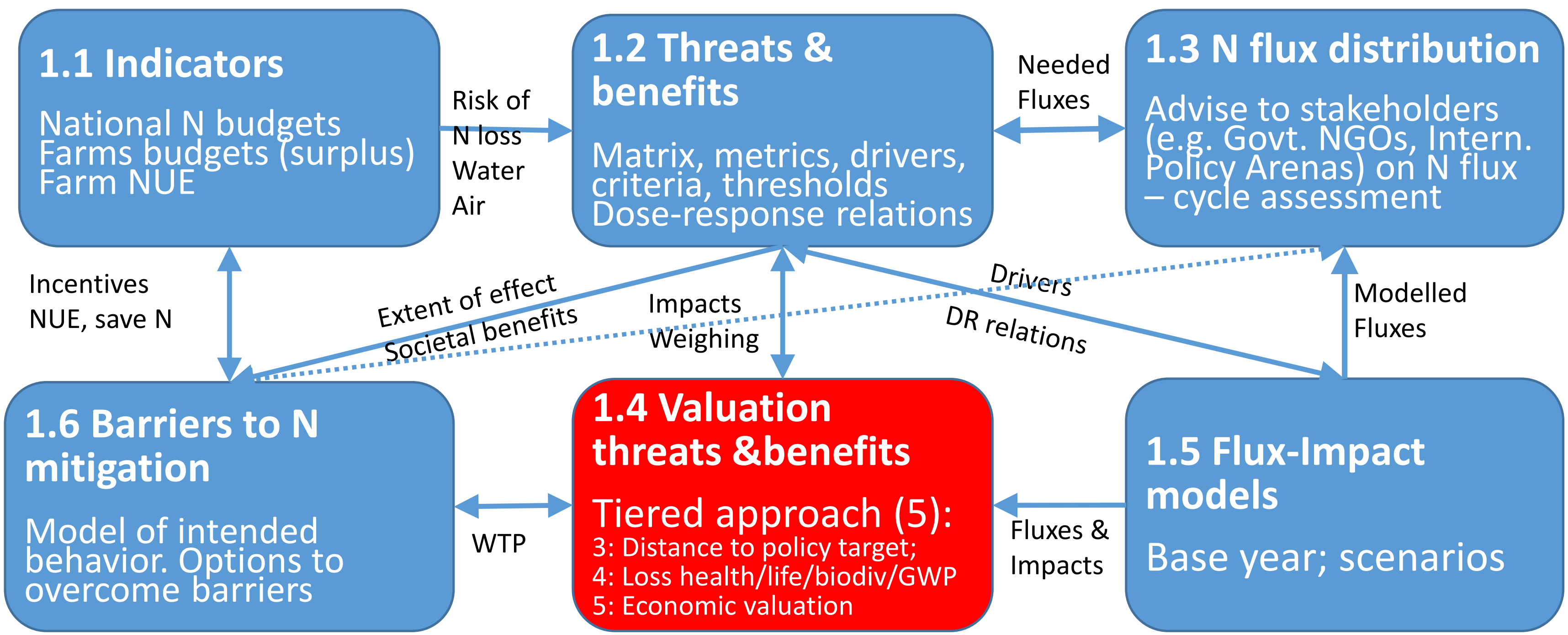
Summary of progress

- Teams formed
- Work plans written
- First deliverables
- Report outlines
- Some tuning issues
- No contracts
- Some delays

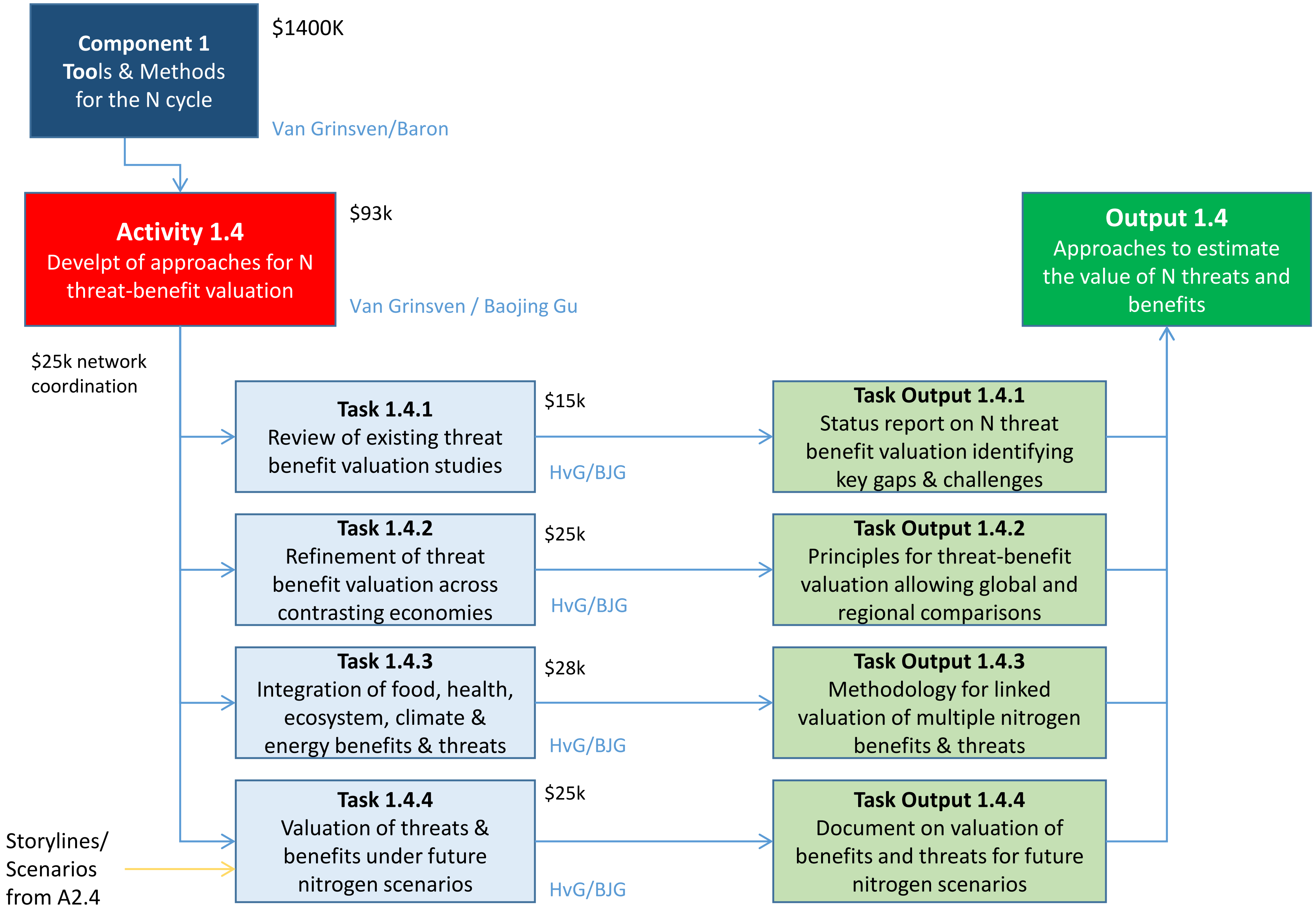
Some general concerns

- Commitment and engagement
  - new INMS team members; busy experts
  - Year 1 and 1st meeting for team building
- Linkage (time and content) to other activities
  - Balance between delivering methods and results
- Overhead for communication, administration
- Delayed contracts
- Budget flexibility – reserve funds

C1 – Linkage and interaction



Activity 1.4


Component 1
Tools & Methods
for the N cycle
$1400K
Van Grinsven/Baron
Activity 1.4
Develpt of approaches for N
threat-benefit valuation
$93k
Van Grinsven / Baojing Gu
Output 1.4
Approaches to estimate
the value of N threats and
benefits
$25k network
coordination
Task 1.4.1
Review of existing threat
benefit valuation studies
$15k
HvG/BJG
Task Output 1.4.1
Status report on N threat
benefit valuation identifying
key gaps & challenges
Task 1.4.2
Refinement of threat
benefit valuation across
contrasting economies
$25k
HvG/BJG
Task Output 1.4.2
Principles for threat-benefit
valuation allowing global and
regional comparisons
Task 1.4.3
Integration of food, health,
ecosystem, climate &
energy benefits & threats
$28k
HvG/BJG
Task Output 1.4.3
Methodology for linked
valuation of multiple nitrogen
benefits & threats
Storylines/
Scenarios
from A2.4
Task 1.4.4
Valuation of threats &
benefits under future
nitrogen scenarios
$25k
HvG/BJG
Task Output 1.4.4
Document on valuation of
benefits and threats for future
nitrogen scenarios

Activity 1.4: development of approaches for N threat-benefit valuation	17	2018				2019				2020				2021		
	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3
Task 1.4.1 **Review of existing threat benefit valuation studies**			R													
Task 1.4.2 **Refinement of threat benefit valuation across contrasting economies**						R										
Task 1.4.3 **Integration of food, health, ecosystem, climate & energy benefits & threats**						M			R							
Task 1.4.4 **Valuation of threats & benefits under future nitrogen scenarios**														R		
Monitoring and Evaluation					R				R				R			R

Progress Q4-17; Q1-18

- Core-team; multidisciplenary; global coverage
- Agreed workplan
- Agreed Outline for Status Report (Tasks 1, 2 and 3)
  - Propose to write one report; with partial deliveries per task
  - Joint high level paper results 1.2&1.4
- First “In Kind” and “In cash” contributions and new activities for global valuation
  - INPE-GPNM: CBA Case studie Pantanal Brasil
  - Univ Waterloo: Global Meta Analysis Aquatic impacts
  - Zhejang Univ: China Framework paper
  - PBL: intern started CBA Lake Victoria Basin
- Cooperation and joint workshop with A1.2 in Fort Collins (Sept. 10-13)

INMS activity 1.4 Core team

Names	Region	Task and Expertise
• Baojing Gu	China	Co chair; integrated assessment
• Jane Compton •	USA	Ecosystem Service (ESS) valuation
• Roy Brouwer	Canada	Valuation theory, WTP surveys; meta analysis; valuation impacts water
• Berit Hasler • Heini Ahtiainen	Denmark Finland	Valuation Baltic (Marine); WTP surveys
• Hans van Grinsven	Netherlands	Chair: EU Cost Benefit; Unit cost method; Nitrate and health
• Arjan Ruijs	Netherlands	Environmental Economics; ESS valuation; CBA NEC
• Fredrick Mhina Mngube • Dieudonne Hatungimana	Africa	Demo Africa; Lake Victoria Basin. WTP Food security
• Felipe Pacheco • Jean Ometto	Brasil	Demo Latin America; Pantanal costing case study
• Biswajit Mondal • Tapan Adhyas	India	Demo South Asia; WTP Food security
• Niels-Axel Braathen	OECD	Health costs; valuation theory
• Mike Holland	UK-EU	ENA; ECLAIRE; Valuation EU health impacts, cost air pollution;
• Laurence Jones	UK-EU	ENA; ECLAIRE; Valuation impacts ESS and impacts terrestrial ecosystems
• Nicola Beaumont	UK-EU	Valuation of marine ESS
• Tai McClellan Maaz • Tom Bruulsma	IPNI	Benefits for agriculture and food

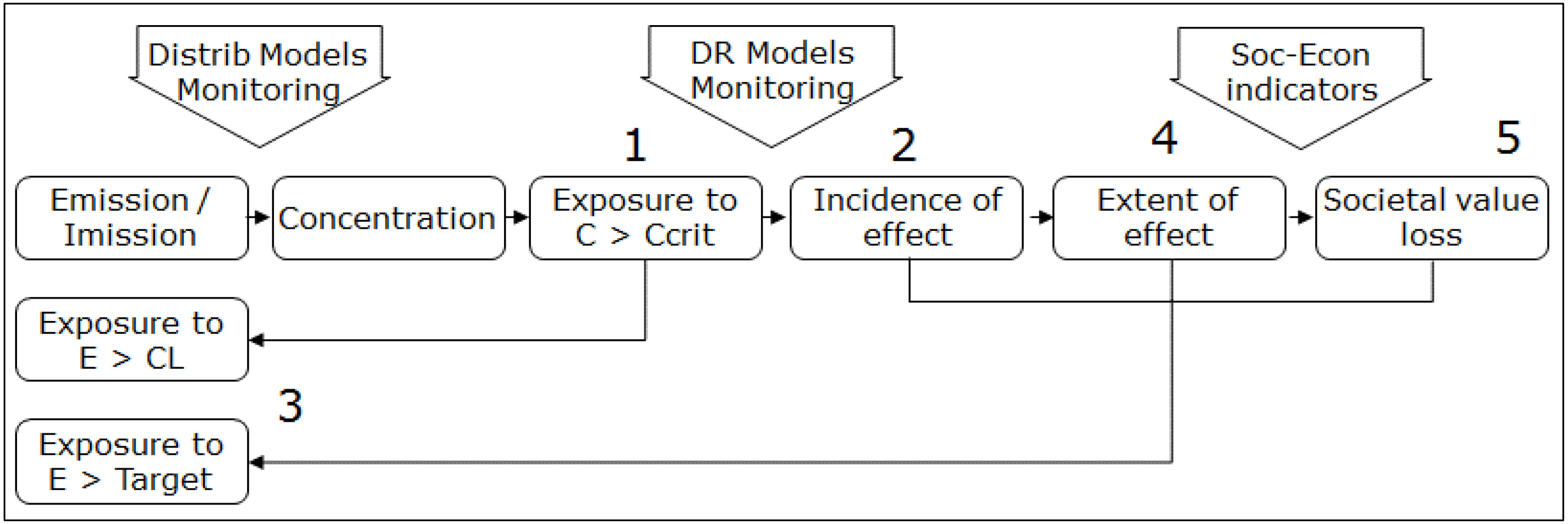
12 (+ 6) core members; multidisplinary; 5 continents; 13 male;

Priority issues for impact valuation in INMS 1.4

1. N runoff and marine eutrophication/HABs (UNEP GEF),
2. NH_3 and NOx emission to air and human health loss,
3. N fertilizer use and regional food security-sufficiency,
4. N deposition and C sequestration (Climate benefit),
5. N deposition and terrestrial eutrophication

6. Proxies for translating results EU, US to rest of world (GDP, population density, land cover)

Five Tier approach



- Tier 3: Distance to Policy targets
- Tier 4: Aggregated expression of N impacts
    - Disability Adjusted Life Years (DALY) for health;
    - Mean Species Abundance (MSA) for ecosystems;
    - Global Warming Potential (GWP) for climate
    - Food benefits: ratio of supply/demand of calories or protein (SDGs)
- Tier 5: express DALY, MSA, GWP in “€$£¥”: communicates well but most contested

Workplan 2018-2019
Tasks 1.4.1, 1.4.2, 1.4.3

- INMS Wiki N valuation literature database and classification
- Review and report existing threat benefit valuation studies (Chapters 1-4): identify gaps and priorities (in F Collins)
- Refine/adjust Tier 4 and 5 approach for developing economies
  - Pantanal, Lake Victoria B (India)
  - Metrics for Food benefits
  - Proxies for extrapolation of EU, US results
- Fill acknowledged gaps for valuation for Marine and Terrestrial ecosystem impacts
- Harvest existing meta-analyses; define and commission new meta analysis

1.4 Report Valuation of N threats and benefits across contrasting economies.

(One report: First draft Ch 1-4 Sept, 2018; 80% version end,2019)

1. Introduction (Grinsven and Gu)
2. Use for policy support and communication (Grinsven, Gu, Ruijs)
3. Principles of economic valuation of environmental pollution (Brouwer, Ruijs, OECD)
4. Status and review of current knowledge on valuation of impacts of N emissions (core team)
5. Case studies for developing economies (optional; Pantanal, L Victoria)
6. Proposed methodology for valuation of key N threats for contrasting economies (core team)
7. Guidelines for application impact valuation in Global N-assessment (base year, scenario)

3. Principles of economic valuation of environmental pollution (Brouwer, …)

- Dose Impact relations (Gu)
  - Emission – concentration
  - Exposure - Impacts
- Valuation (Brouwer, Ruijs, Hassler)
- Proxies to extrapolate impact values from high to low income countries (Gu, Grinsven)
- Benefits for agro-food sector (Grinsven, Ruijs, IPNI)
- Human Health (Holland, Gu, OECD)
- Ecosystems (Compton, Hassler, Jones, Beaumont)
- Climate change (Ruijs, Grinsven)
- References

4. Status and review of current knowledge on valuation of impacts of N emissions

- Benefits for agro-food sector (Grinsven, OECD)
  - Farm sector
  - Agro-food sector
- Human health (Holland, Gu, OECD)
  - Air pollution
  - Water pollution (Grinsven)
  - Food security and healthy nutrition
- Ecosystems (Compton, Hassler, Jones)
  - Terrestrial (Jones)
  - Fresh water (Mngube)
  - Marine (Hassler, Beaumont)
  - Ecosystem services (Ruijs))
- Climate change (Ruijs, Grinsven)
  - ETS
  - Valuation of future Impacts
- References

Suggestions next steps

- Harvest available material
- Involvement new partners
- Dedicated research to fill gaps
  - Impacts and regions
- Appointment of task leads

Optional slides for topics

- Unit cost methods for valuation
- WTP
- Case studies
- N benefit for agriculture
- Impacts on terrestrial ecosystems
- Baltic
- Health impacts: recent finding for
  - NH3 and PM
  - Nitrate drinking water

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Task 1.4.1 Review of existing threat benefit valuation studies				~~R~~ M	W	R											
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Task 1.4.3 Integration of food, health, ecosystem, climate & energy benefits & threats					W		~~M~~			R							
Task 1.4.4 Valuation of threats & benefits under future nitrogen scenarios															R		
Monitoring and Evaluation						R				R				R			R

Application of N cost – benefit assessments

- "*trick*" to weigh and add up Nr emissions; External costing
- deal with multiple source-form-impact nature of N pollution
- N-CBA's published for EU, USA, India, China (N cost 1-4% GDP)

Examples of application

1. Communicate relevance of N pollution – policy decision
2. Find optimum level of mitigation (incl. pollution swapping)
3. Find optimum level of N fertilization
4. Find optimum spatial configuration of N polluting activities
5. Translate external cost N pollution to price tag of diets / products

N policy making: weighting of competing claims on environment

- Conflict of values and interests for incomparable issues
- Prioritization is a societal/political process; never a fully objective process
- Integrated approach combines quantitative and qualitative assessment and stakeholder dialogues

Five Tier approach – five metrics

Tier 1: Exceedance of effect criteria for environmental emissions or quality

- Exceedance of air and water quality standards (MPR, NOEC, CL)

Tier 2: Impacts of nitrogen pollution on health and environment

- Incidence of respiratory illness, cancers, frequency and extent of harmful algal blooms, or effects on biodiversity or forest vitality

Tier 3: Achievement of internationally or nationally agreed policy objectives

- To show effect of policies or interventions; “Distance To Policy Target”

Activity 1.4 focus on Tiers more meaningful for society, general public

Tier 4: Life expectancy, nature experience/recreation, ecosystem functioning, services

Tier 5: Expression as loss or gain of prosperity or welfare; in economic or monetary units

Environmental impacts of nitrogen
4 N compounds, 3 impact categories

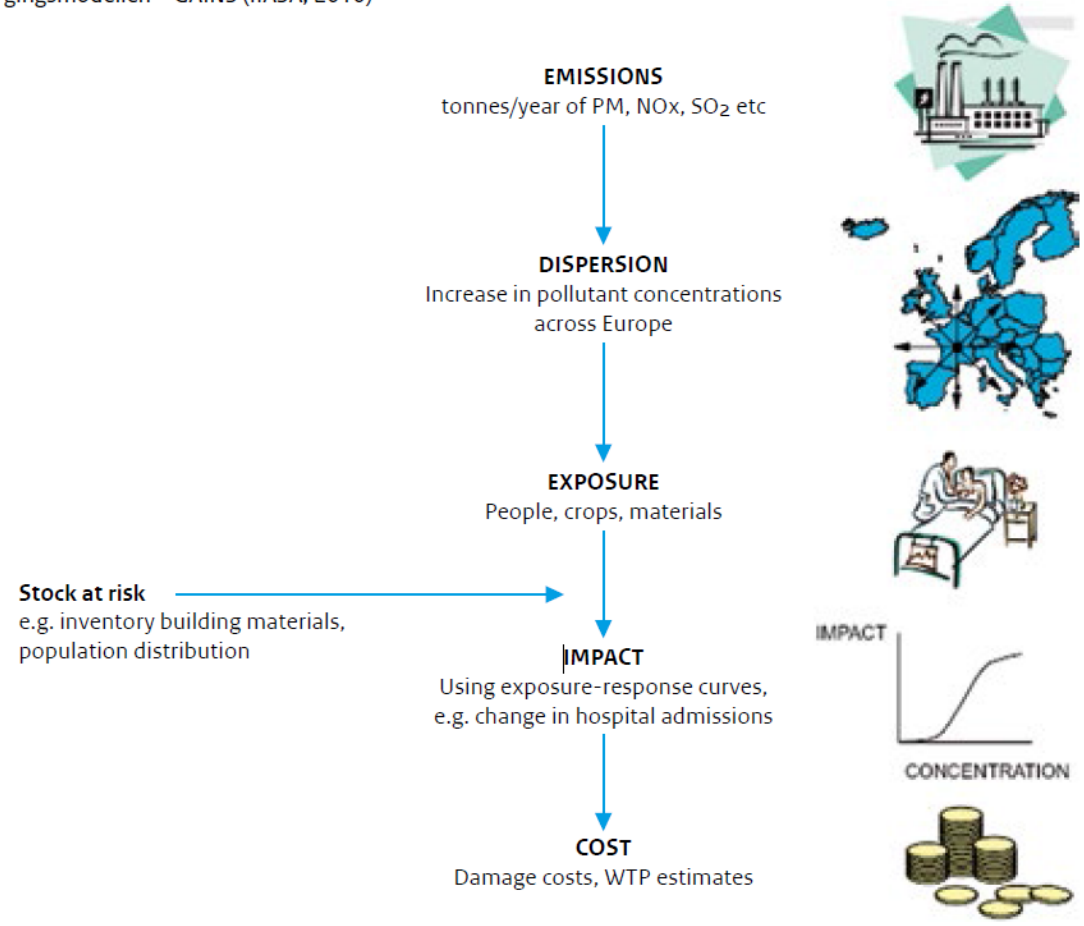
	Human health	**Ecosystems**	**Climate**
NOx-air	Cara, Cancers *mainly via ozone*	Eutrophication Acidification	*?Carbon-sequestration?* *?cooling particles?*
NH_3-air	Cara, Cancers *?weak causality?*	Eutrophication Acidification	*?Carbon-sequestration?* *?cooling particles?*
N (NO_3)-water	Cancer (colon) *?weak epidemiology?*	Aquatic Eutrophication	*?Carbon-sequestration?*
N_2O-air	Skin cancer, cataract		GHG-balance

Environmental impacts of nitrogen
4 N compounds, 4 impact categories

	Human health	**Ecosystems**	**Climate**	**Food**
NOx-air	Cara, Cancers *mainly via ozone*	Eutrophication Acidification	*?Carbon-sequestration?* *?cooling particles?*	Crop damage *mainly via ozone*
NH_3-air	Cara, Cancers *?weak causality?*	Eutrophication Acidification	*?Carbon-sequestration?* *?cooling particles?*	N loss can reduce yield
N (NO_3)-water	Cancer (colon) *?weak epidemiology?*	Aquatic Eutrophication	*?Carbon-sequestration?*	N loss can reduce yield
N_2O-air	Skin cancer, cataract		GHG-balance	Climate driven yield change
N-fertilizer			GHG-balance	Yield increase

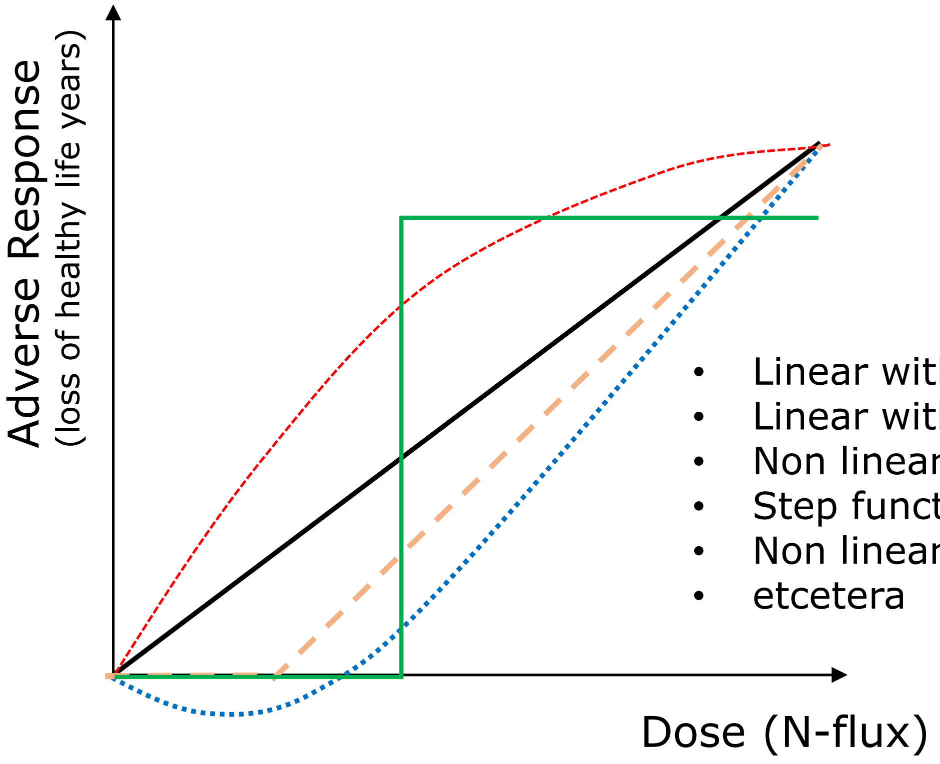
Principal steps of an impact - pathway - cost analysis

Figuur 10 Schematische weergave van het afwegingskader voor Europese luchtkwaliteit Integrale afwegingsmodellen – GAINS (IIASA, 2010)



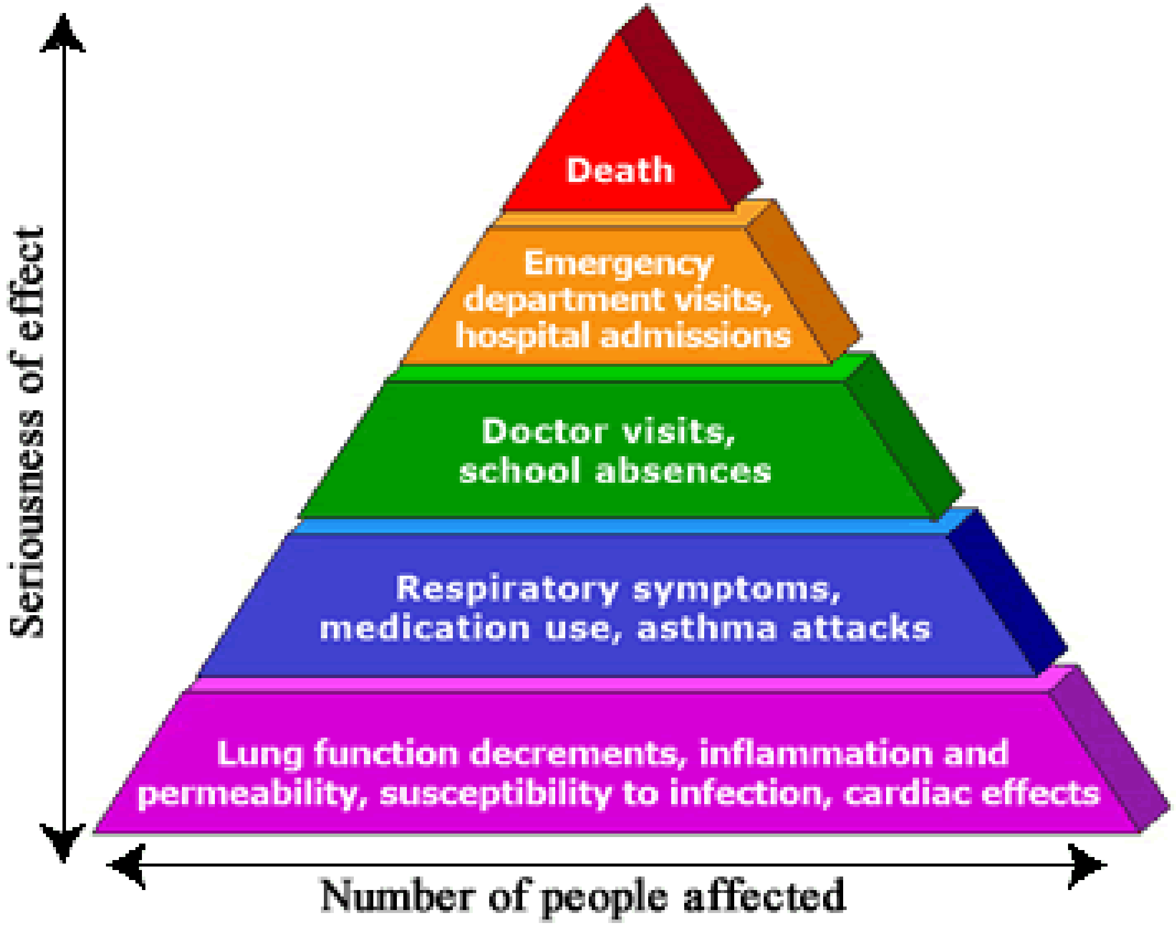
IIASA (2010)

Examples of simple dose response functions forimpacts of N pollution

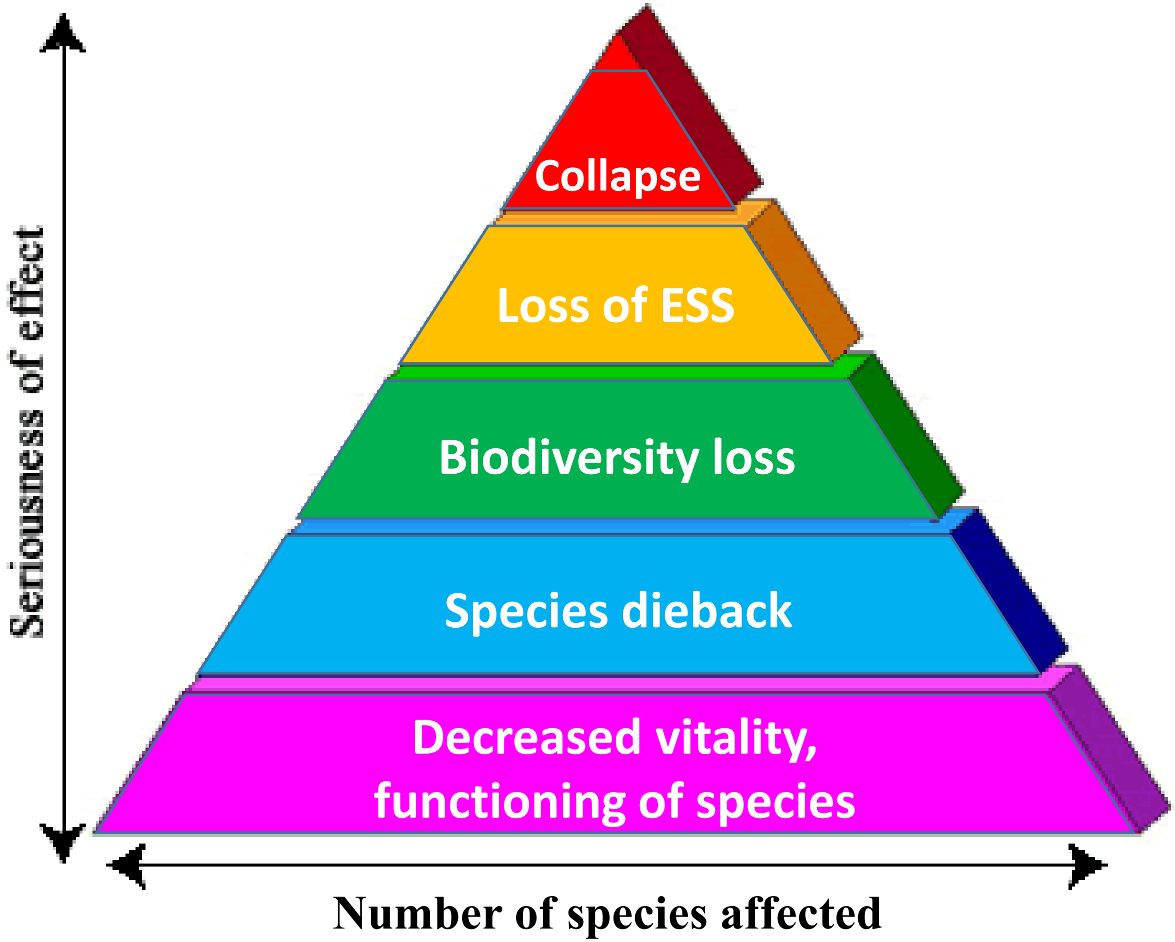


- Linear with no threshold (air pollution & heatlh)
- Linear with threshold (biodiversity)
- Non linear (biodiversity)
- Step function (nitrate & health)
- Non linear with benefits (nitrate & health)
- etcetera

Pyramid of health impacts of air pollution (5 metrics)



Pyramid of ecoystem impacts of N pollution?

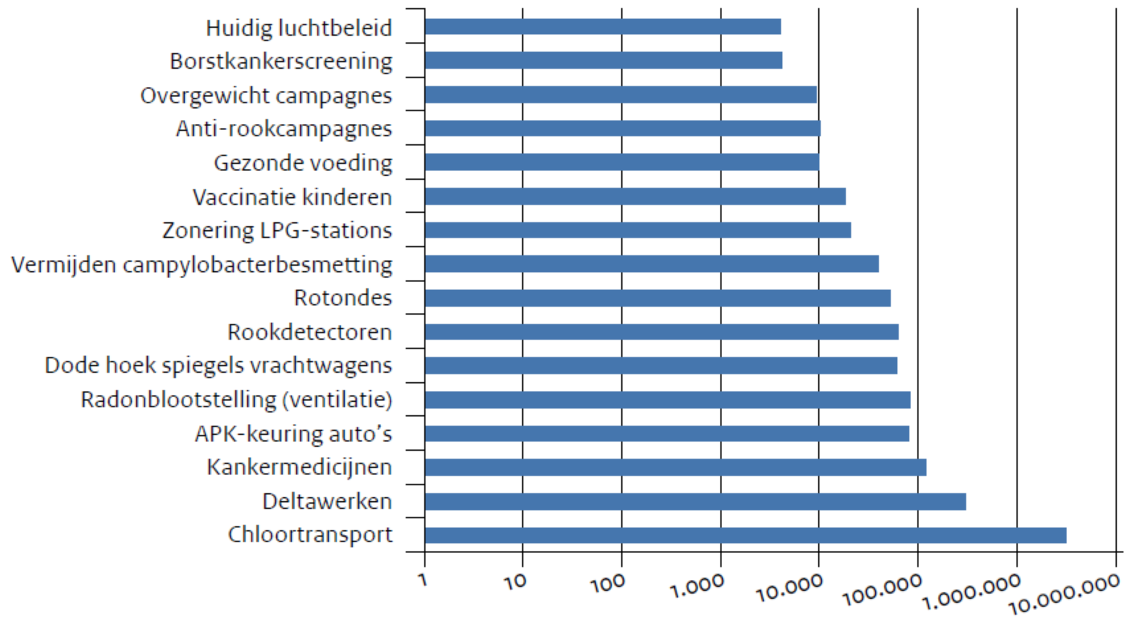


Revealed WTP for gained life year

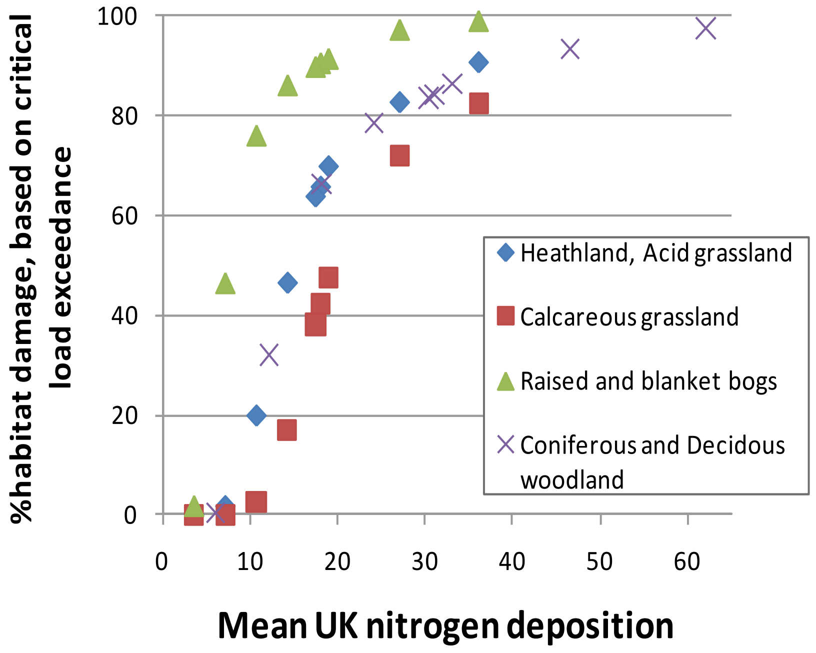
3,000 to
3,000,000 €

(EU 40,000 €)

Figuur 11 Illustratie van de uitkomsten van afwegingen voor verschillende beleidsterreinen: achteraf gebleken waardering voor een gewonnen levensjaar in euro's (logaritmische schaal)



Example: N response curve ecosystem damage



<u>Non linear with threshold</u> (Critical N load ≈10 kg N ha^{-1} yr^{-1})

External cost based on critical load exceedance

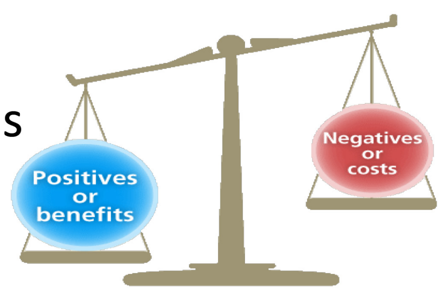
Jones et al (2013)

The economic value of N damage/benefit in ENA

Standard economic concepts and methods for valuation

Key is **willingness to pay approach** (WTP)

- Health impacts
  - WTP (stated) to reduce the risk of premature death
  - WTP (stated) to reduce pain and suffering
  - Costs for real economy: medical treatment, lost labor productivity
- Ecosystems impacts
  - WTP (stated) to restore ecosystem damage
- Climate impacts
  - WTP (revealed) to reduce greenhouse gas emissions
- Benefits for food and bioenergy production
  - Added economic value



Calculation of costs and benefits of N pollution by Unit Costs

1. Determine societal cost or benefit of N related impact
2. Determine contribution of N to impact
3. Determine cost per unit of N emission for impact (UC)
    - UC = [Result 1] x [Result 2] / [N emission]
4. Extrapolate to determine N costs, eg.
    - Change of N emissions
    - For other regions

Unit cost method
N-Cost = Price x Emission

	Health	Ecosystem	Climate	Total
	euro/kg N_r	euro/kg N_r	euro/kg Nr	euro/kg N_r
NO_x -N to air	10-30	2-10	-9 - 2	3-42
NH_3-N to air	~~2~~8–20*	2-10	-3 - 0	1-30
N_r to water	0-4	5-20		5-24
N_2O-N to air	1-3		4-17	5-20

X

	Emission EU27
Year 2008	Mton (Tg)
NO_x -N to air	3.2
NH_3-N to air	3.1
N_r to water	4.6
N_2O-N to air	0.8

Climate benefits of N

* *NH_3 health risk via sec. PM:*

- *European Commission 2013,*
- *Brunekreef et al., Lancet 2016*

Unit N (marginal) costs between 1995 and 2005 of different Nr - threats in EU based on WTP

Effect	Emitted nitrogen form	Emission/ loss to	Estimated cost € per kg N_r emitted,
Human health (PM, NO_2 and O_3)	NO_x	Air	10 – 30
Ecosystems (eutrophication, biodiversity)	N_r runoff , deposition	Surface Water	5 – 20
Human health (particulate matter)	NH_3	Air	2 – 20
Climate (greenhouse gas balance)	N_2O	Air	4 – 17
Climate**	NOx	Air	-9 - 2
Climate**	NH_3,	Air	-3 – 0
Ecosystems (eutrophication, biodiversity)	NH_3 and NO_x	Air	2 – 10
Human health (drinking water)	N_r (nitrate)	Groundwater	0 – 4
Human health (increased ultraviolet radiation from ozone depletion)	N_2O	Air	1 – 3
Crop damage (ozone)	NO_x	Air	1 – 2

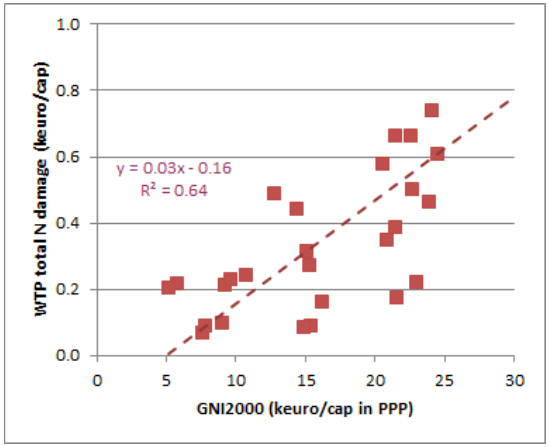
- *Cooling effects*

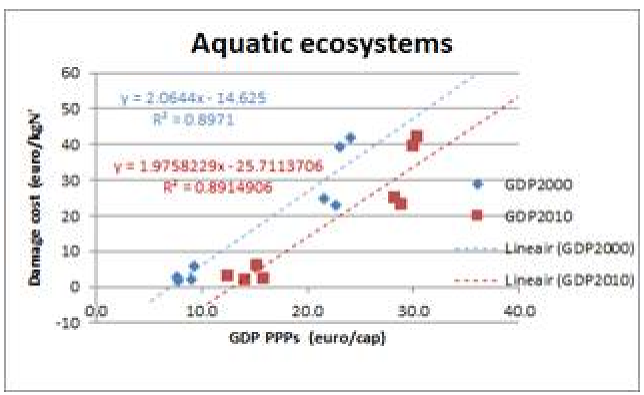
Source Grinsven et al, ES&T 2013

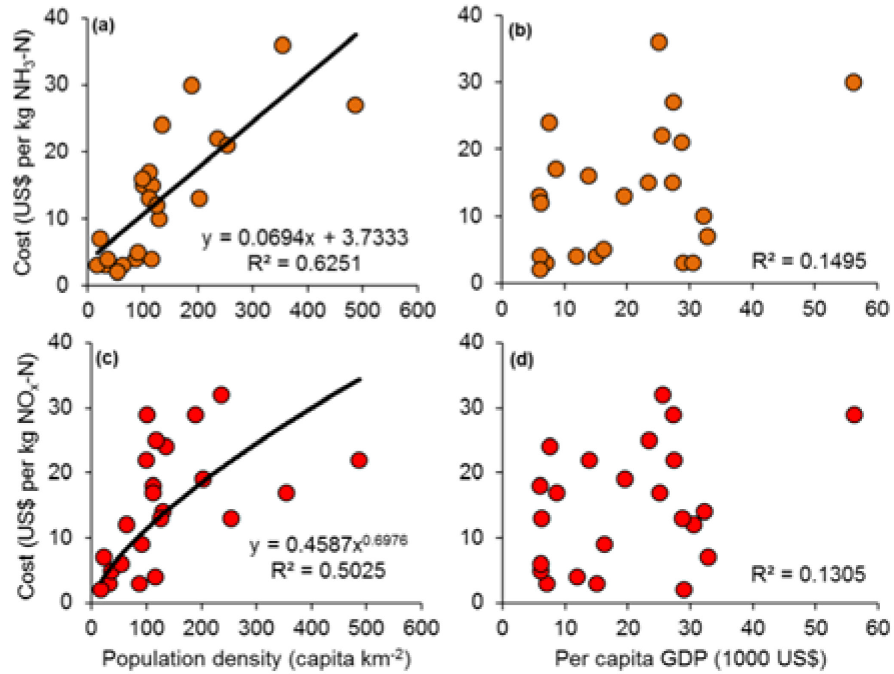
Data sources for N impact monetarization ENA 2011

Domain	Component	Source
Health,	NOx-air, NH3 air	EXTERNE (2005)
	NO3-water	Grinsven et al 2010, De Roos et al 2003
	N2O (ozone layer)	Struijs et al. 2010
Terrestrial ecosystems	NOx, NH3	NEEDS, 2006; Christie 2006
Aquatic ecosystems	N-water	Söderqvist & Hasselström, 2008 (Baltic) AQUAMONEY
GHG balance	N2O-stratosp	CO2-price Emission Trading System

Proxies to extrapolate ENA results to Global



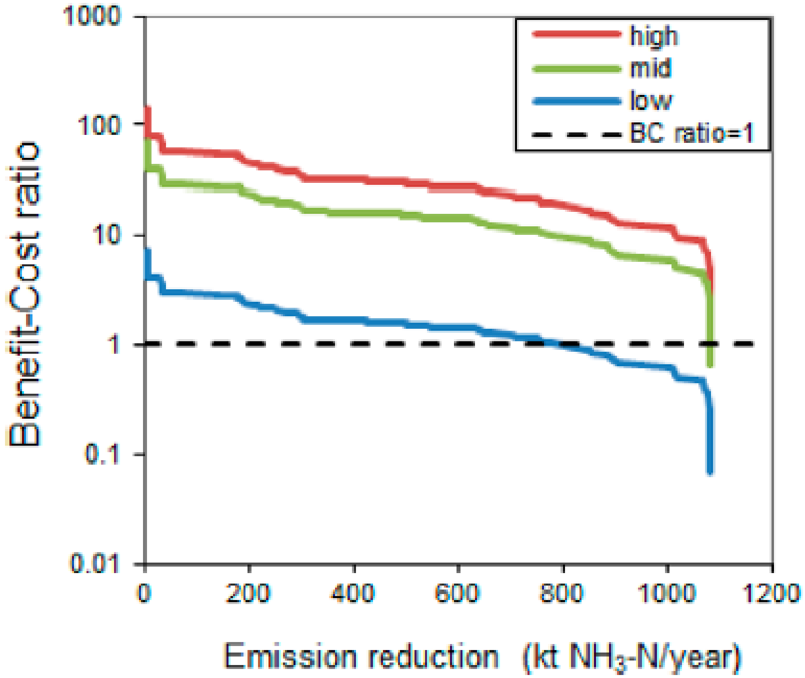


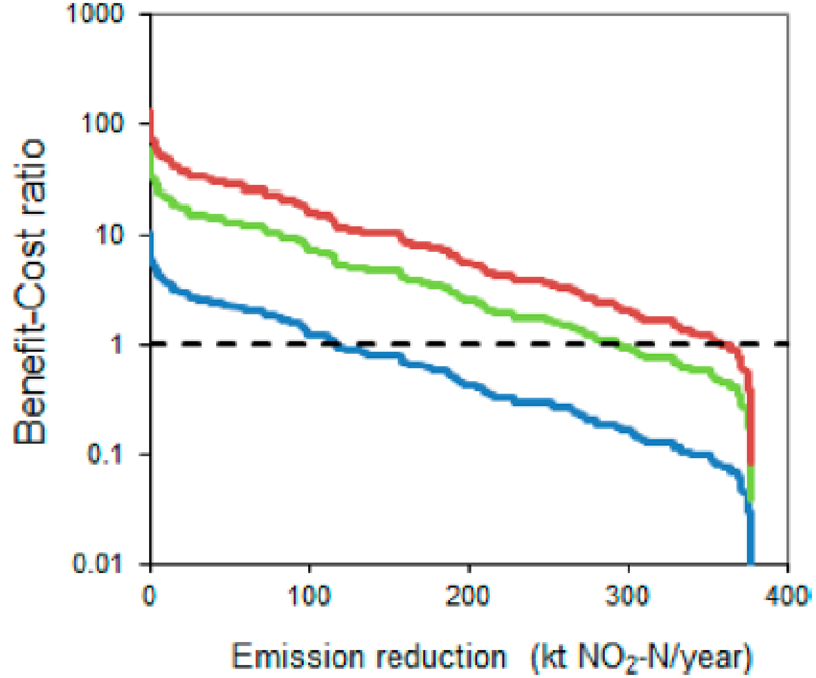


First estimate of global cost of N damage 200 to 2000 billion US dollars (ONW, 2013)

Tool to help **find optimum mitigation**

(additional to cost minimization as in e.g. GAINS)





N-CBA's based on Unit Cost Methods published for EU, USA, India, China

(N pollution cost all around 1-4% GDP)

Cost of N pollution in India

- 2000: 17 bio USD/yr; - 2015: 75 bio USD/yr (3.5% GDP)

GDP scaled Unit N Costs ENA

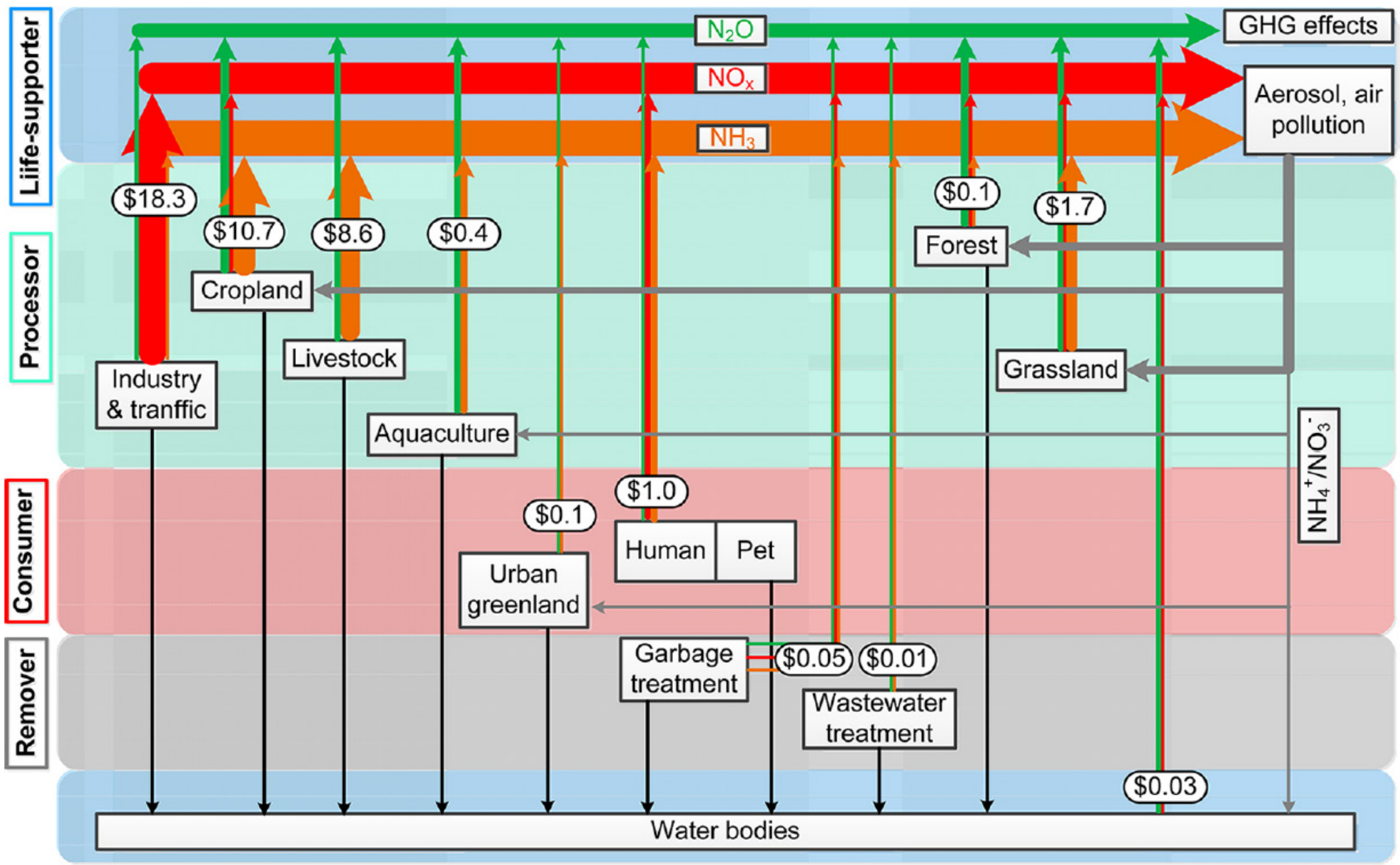
Table 2.1 Summary of Reactive Nitrogen Emissions in India for 2000 and 2015 With a First Indication of the Societal Costs of N_r Pollution per unit N and Scaled up to the Country

Year: 2000	Emission	Health costs[a]	Ecosystem costs[a]	Climate costs[a]	Total costs[a]	Health costs	Ecosystem costs	Climate costs	Total costs
N losses	Mt N/year^{-1}	USD kg^{-1} N				Billion USD year^{-1}			
N_r to water	5.6[b]	0.1	1.1	–	1.2	0.5	6.4	–	6.9
NH_3 to air	5.0[c]	1.1	0.2	–	1.3	5.7	0.9	–	6.6
NO_x to air	1.6[c]	1.7	0.2	–	1.9	2.7	0.3	–	3.0
N_2O to air	0.4[c]	0.2	–	0.9	1.0	0.1	–	0.4	0.5
Total									17.1
Year: 2015	**Emission**	**Health**	**Ecosystem**	**Climate**	**Total**	**Health**	**Ecosystem**	**Climate**	**Total**
N losses	**Mt N year^{-1}**	**USD kg^{-1} N**				**Billion USD year^{-1}**			
N_r to water	7.5	0.3	3.6	0.0	3.9	2.3	27.1	-	29.3
NH_3 to air	6	3.6	0.6	0.0	4.2	21.6	3.6	-	25.2
NO_x to air	3.2	5.4	0.6	0.0	6.0	17.3	1.9	-	19.2
N_2O to air	0.5	0.6	0.0	2.7	3.3	0.3	–	1.4	1.7
Total									75.4

Sutton et al in Abrol, Adhyas et al (2017)

Cost of N in air pollution China 2008

- 19–62 billion USD/yr 0.4–1.4% of GDP
- 52–60% NH3 emission 39–47% NOx emission

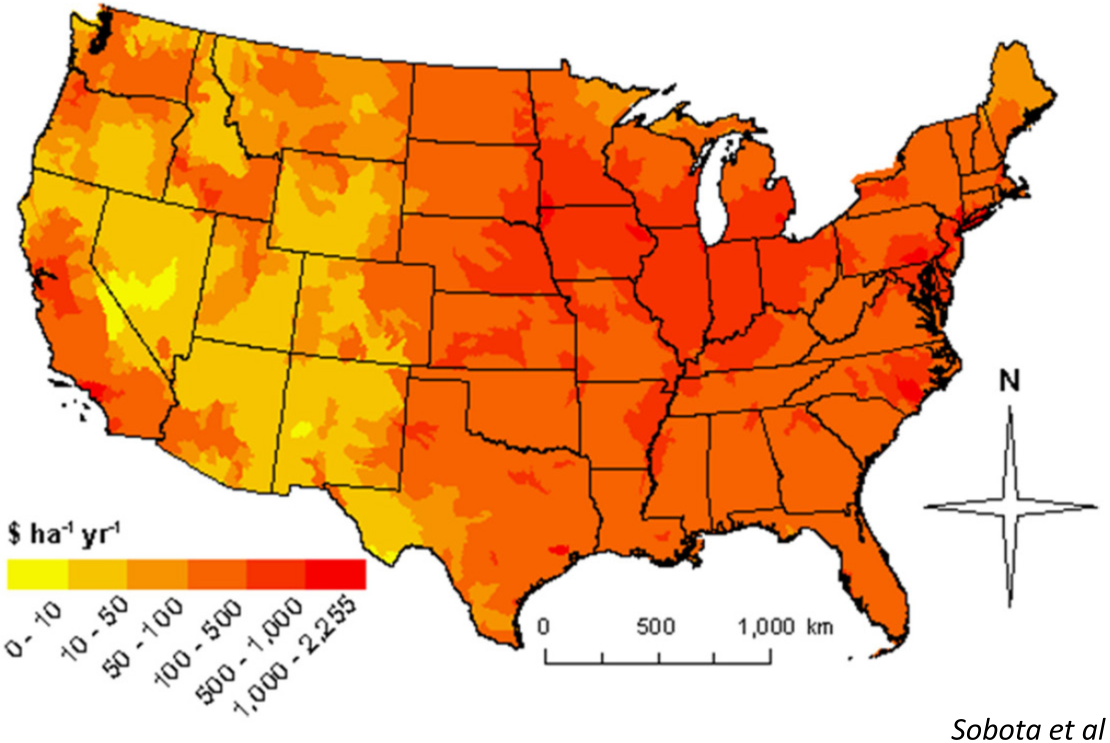


Gu et al 2012

Cost of N pollution USA around 2000

- 210 bio USD/yr (range 81–441
- 1-3% GDP; - agri N share 75%

potential damage costs per watershed

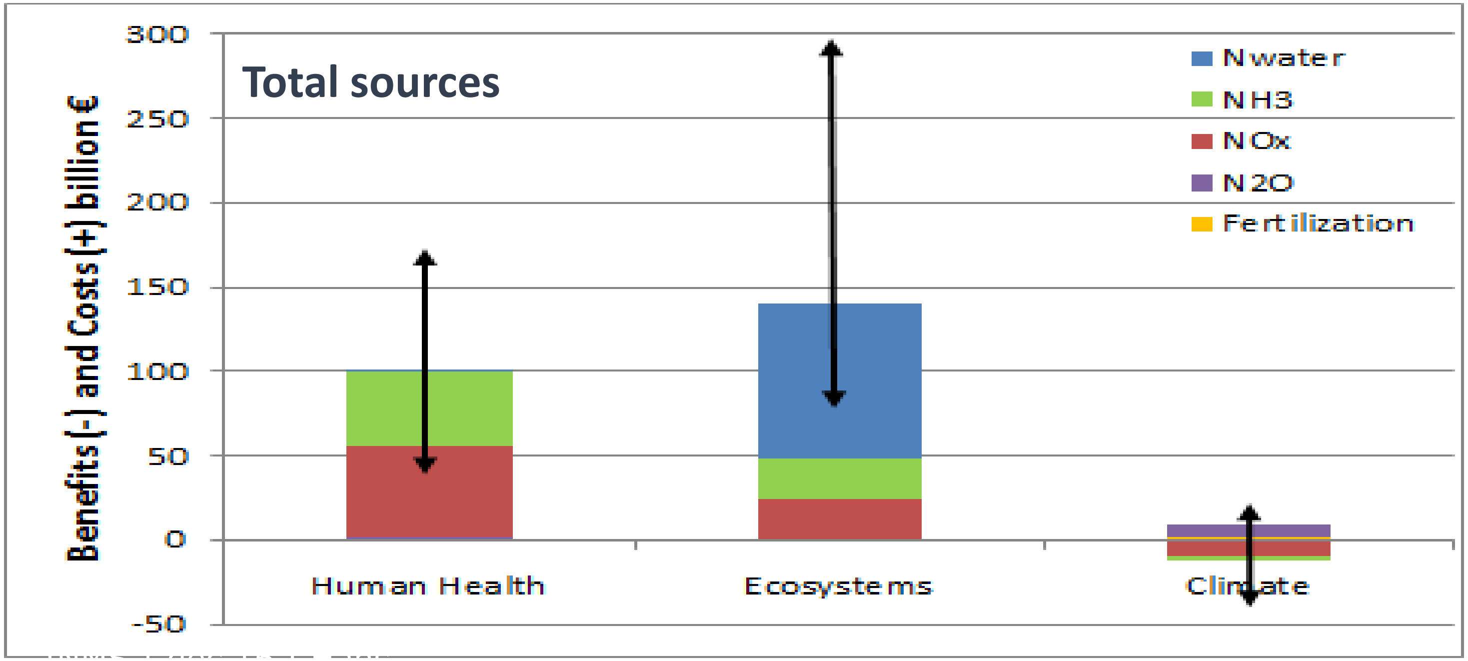


Sobota et al 2015

European Union 2008

N pollution cost:
75-485 billion euro/yr
150-1150 euro/capita
1-4% GDP loss

Large uncertainties
Contributions NO_X, NH_3 and N_{water} (NO_3) similar
Health Impacts
$NO_X \approx NH_3 \gg NO_3 > N_2O$

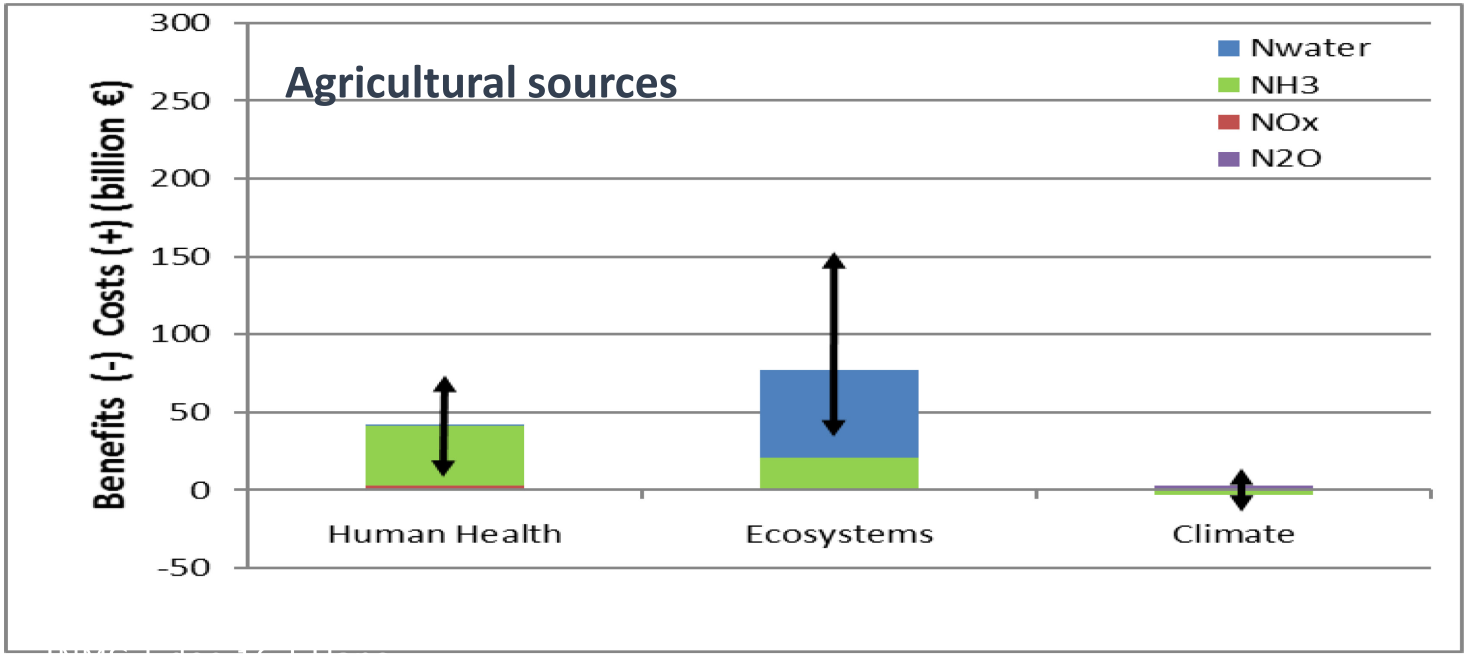


(*Grinsven et al., ES&T 2013; Our Nutrient World, 2013*)

European Union 2008

N pollution cost:
35-230 billion euro/yr
(half of total)

Fifty-fifty due to NH_3 and N runoff
Health Impacts
$NH_3 \gg NO_X > NO_3 > N_2O$



(Grinsven et al., ES&T 2013; Our Nutrient World, 2013)

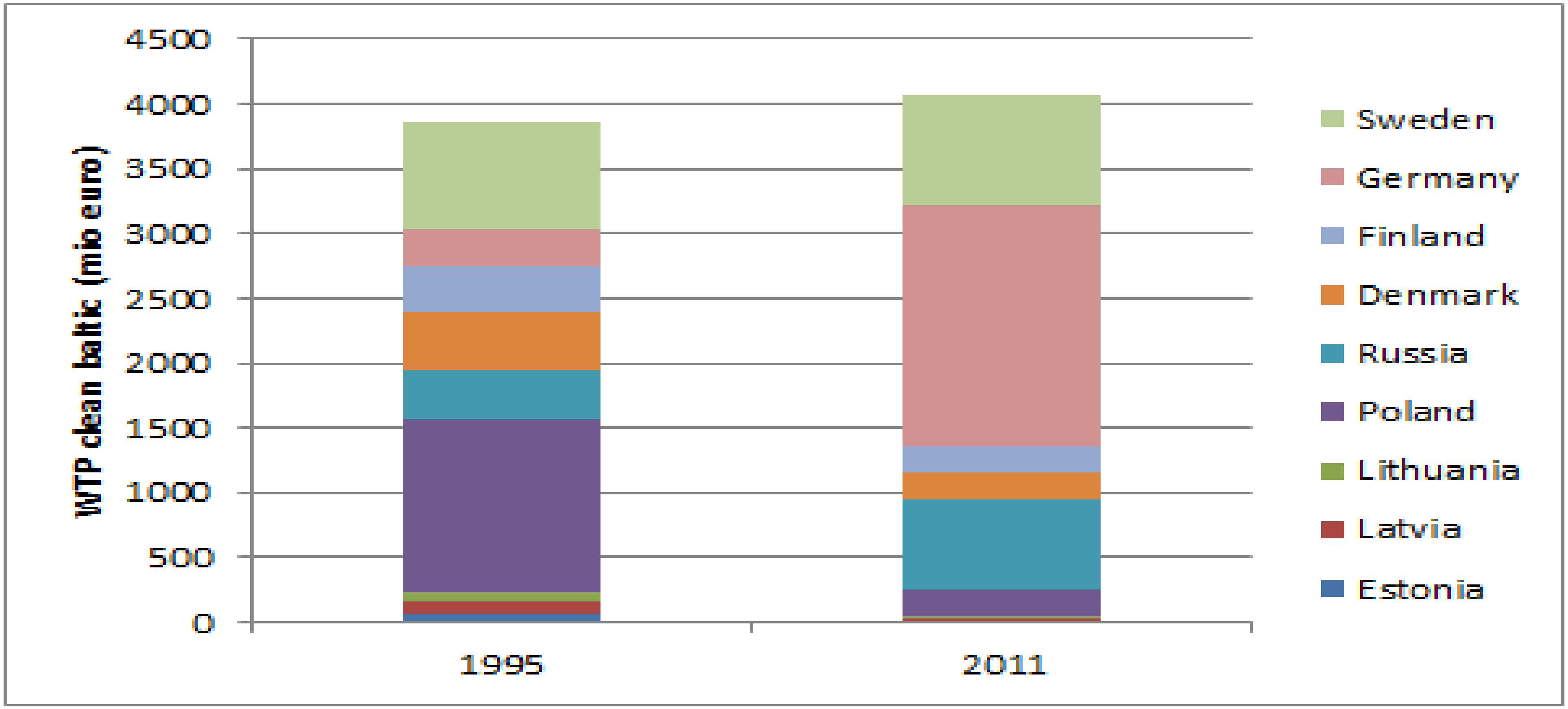
Summary Biodiversity Benefit EU28

	CLE 2025	MFTR 2025	Net benefit 2025	ENA 2008 Ter Ecosys
		billion €/yr		
WTP	3.2-9.5*	2.3-6.8	0.9-2.6	13-63#
WTP ppp	2.7-8.0	1.9-5.6	0.8-2.5	
Repair cost	9.1	6.4	6.4	
Revealed regul. cost	54.8	65.0	9.2	

*Based on UK WTP of 80-240 €/ha (Christy et al 2006; 2010); 10-30 €/household Maas (2014)
#Based on EU unit cost of 2-10 €/kgN (Ott et al 2006)

(ECLAIRE FP7; 2015)

WTP survey clean Baltic



Results change over time

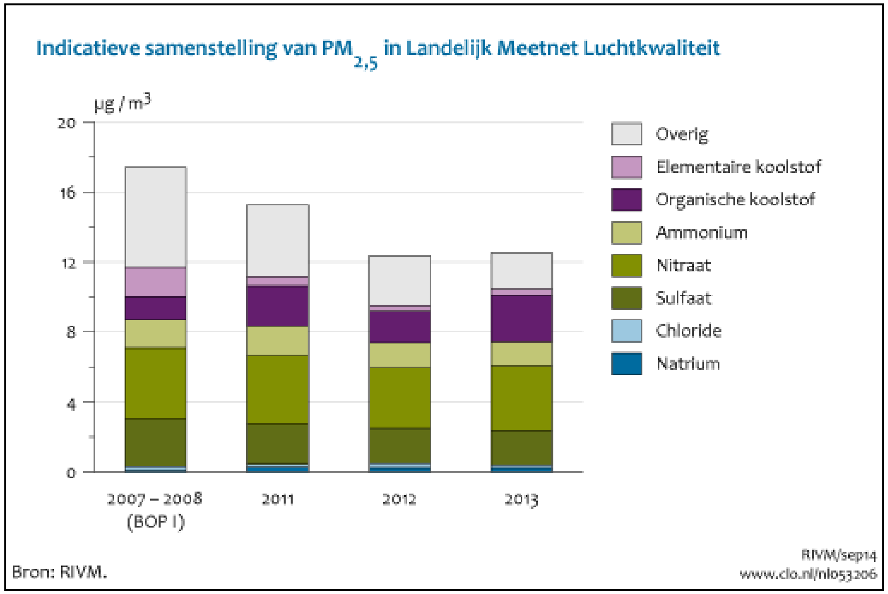
(Athiainen et al., 2014)

Recent findings: Health impacts ammonia- nitrate aerosols

Secondary inorganic aerosols (SIA): **Epidemiological** studies have frequently found these to be associated with adverse health effects. This is **not consistent** to findings from controlled **laboratory** studies.

EU Air Quality policy considers SIA equally harmful as primary PM

- EU: ≈ 30% of $PM_{2.5}$ as N - SIAs
- Netherlands ≈ 50%



Health benefit of reduction of agricultural emissions

- Due to its strong contribution to the $PM_{2.5}$ mass, control strategies in NH_3 emissions could possibly reduce the mortality attributable to air pollution

Mortality attributable to air pollution (1000 people/yr) and effect of three scenarios with agricultural emissions reductions of 50% and 100%

Region	REF		REF_50		REF_75	
	average	range	average	range	average	range
Europe	277	(148–414)	225	(107–361)	176	(66–313)
North America	54	(21–100)	38	(11–81)	26	(6–65)
South Asia	778	(410–1140)	753	(396–1107)	750	(395–1102)
East Asia	1381	(607–1929)	1275	(553–1812)	1195	(514–1719)
World	3155	(1523–4603)	2905	(1375–4313)	2739	(1280–4123)

(Pozzer et al, 2017)

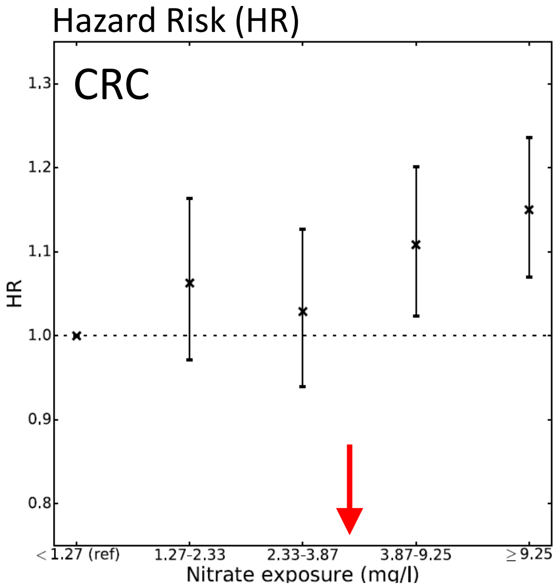
Recent findings: health loss below 25 mg/l NO_3 drinking water

Espejo-Herrera et al. (2016); Spain:

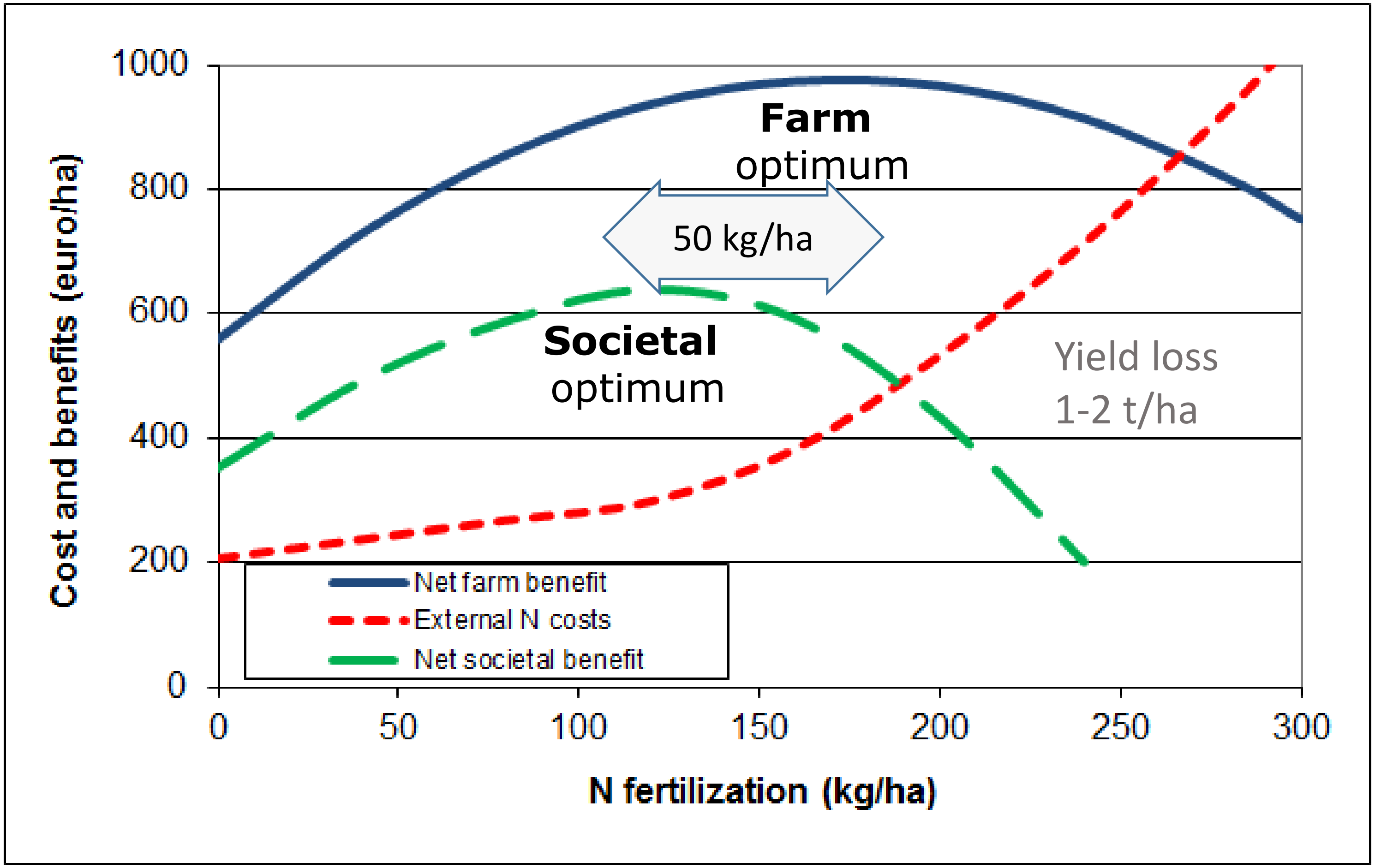
- ≈1.5-fold increased risk for colon cancer if drinking water nitrate >8.6 mg/L and rectum cancer >4.3 mg/L

Schullehner (2018); Denmark

- Reconstruction of nitrate exposure 1970-present combining nitrate monitoring & modelling and medical records
- Statistically significant increased risks at drinking water levels above 3.87 mg/L NO_3
- Lower effect threshold does not mean more CRCs



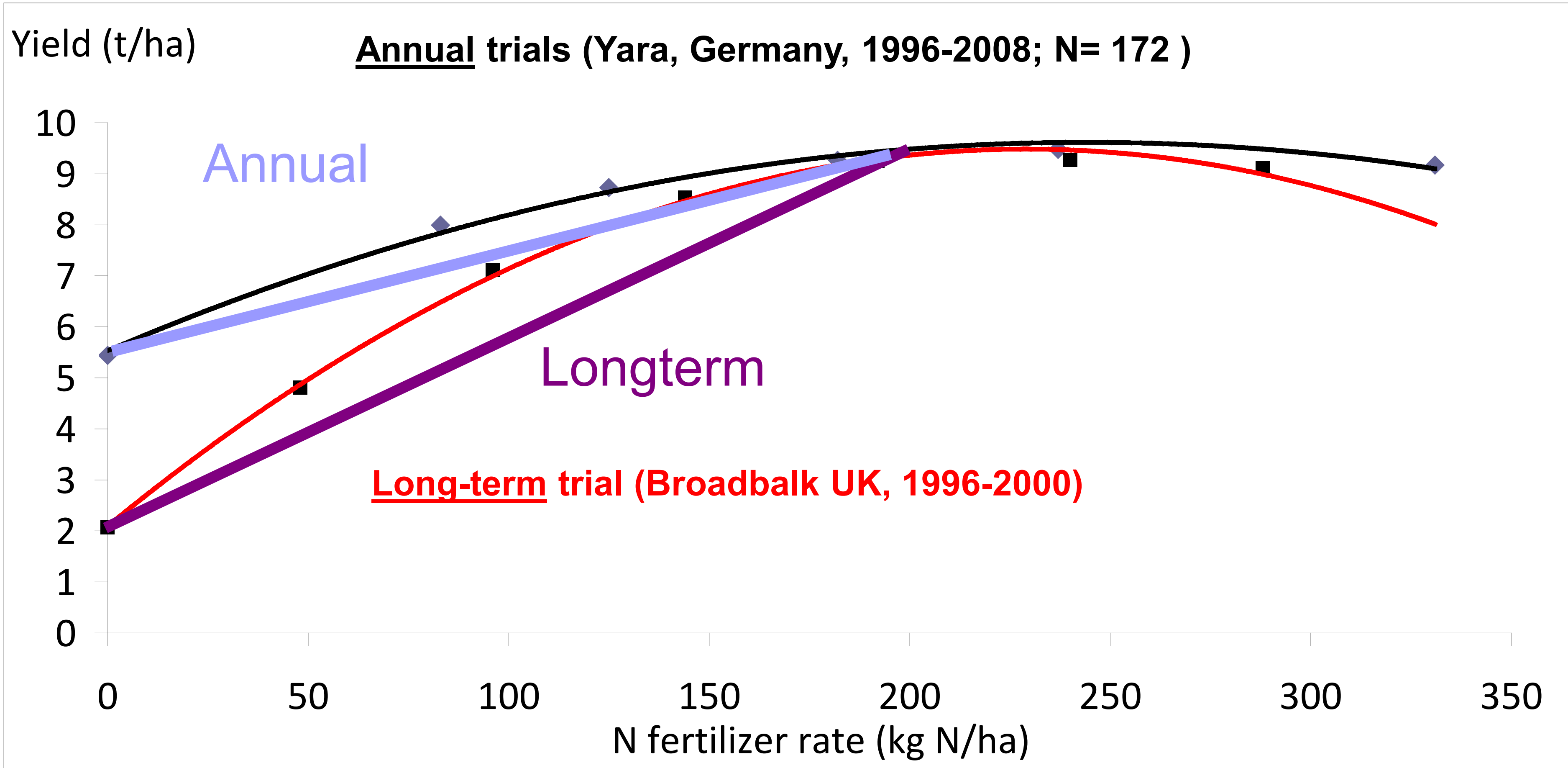
Optimum N fertilization, accounting for external N costs



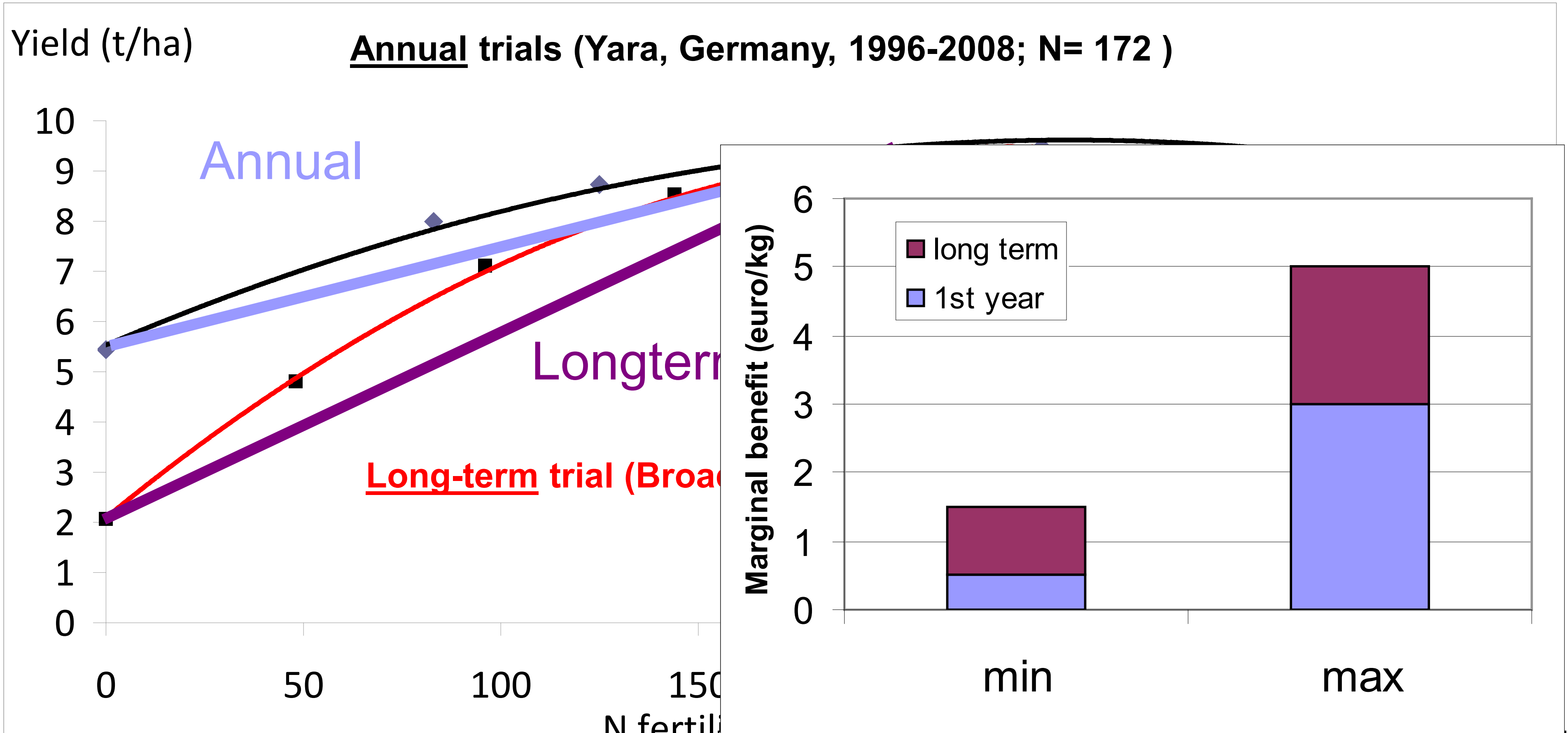
Wheat
Northwest
Europe

Grinsven et al, 2014

Marginal direct Nr benefits for farmer



Marginal direct Nr benefits for farmer



2-7 € wheat / € fertiliser-N