GCRF Sustainable futures for the Costa Rica dairy sector – training workshop, CATIE, 5-6th October 2017

Ammonia emissions from agriculture: impacts, sources and mitigation

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ROTHAMSTED RESEARCH

BBSRC bioscience for the future

Lawes Agricultural Trust

Overview

- Introduction
  - Reactive N
  - Impacts and effects
  - Emission process

- Emission sources
  - Agricultural
    - Livestock housing
    - Manure storage
    - Manure and fertiliser application
    - Outdoor livestock

- Potential mitigation

Global demands

Figure 2.3 World population: 1950-2010 and projections (three variants)

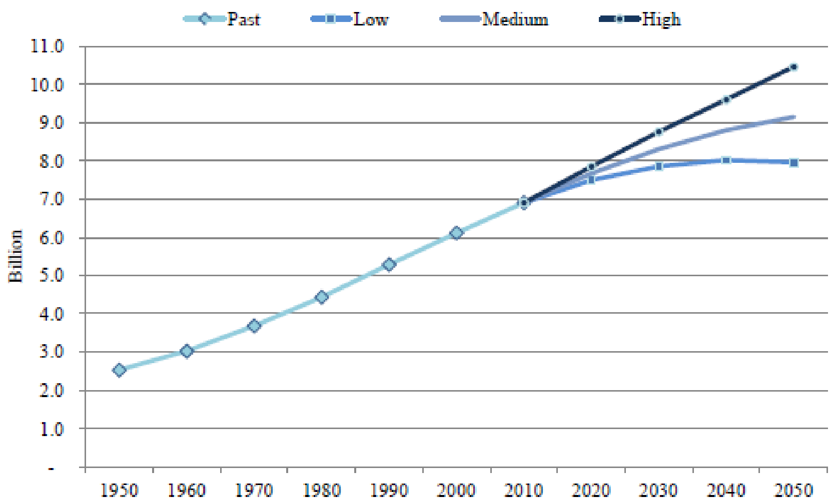


Figure 1.1 Per capita food consumption (kcal/person/day)

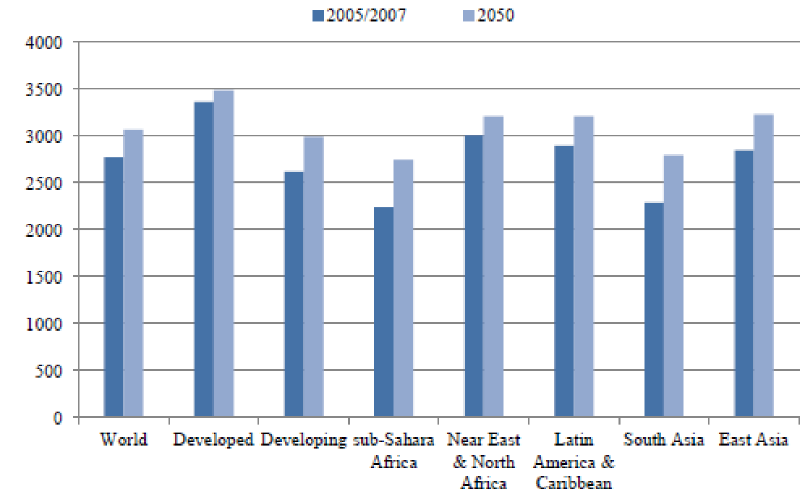
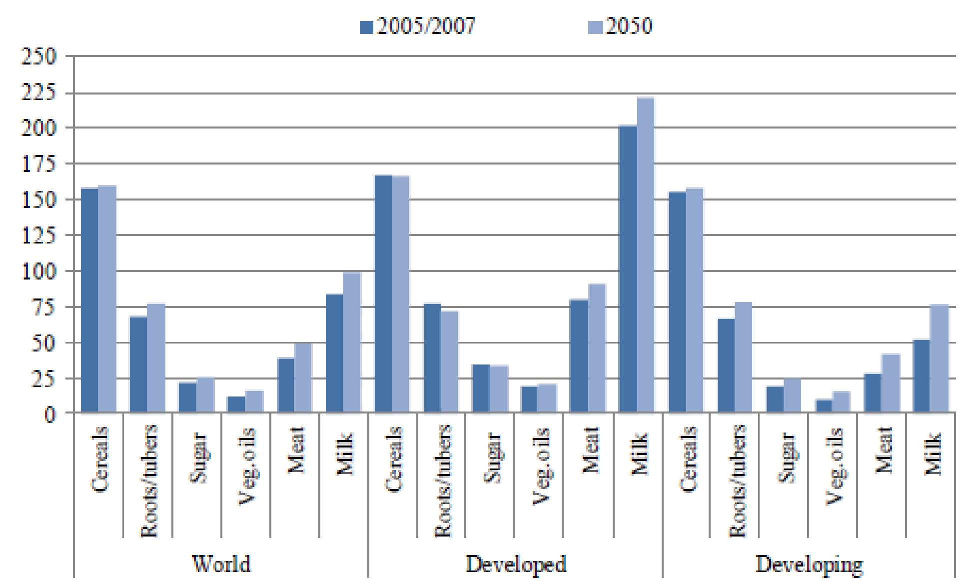
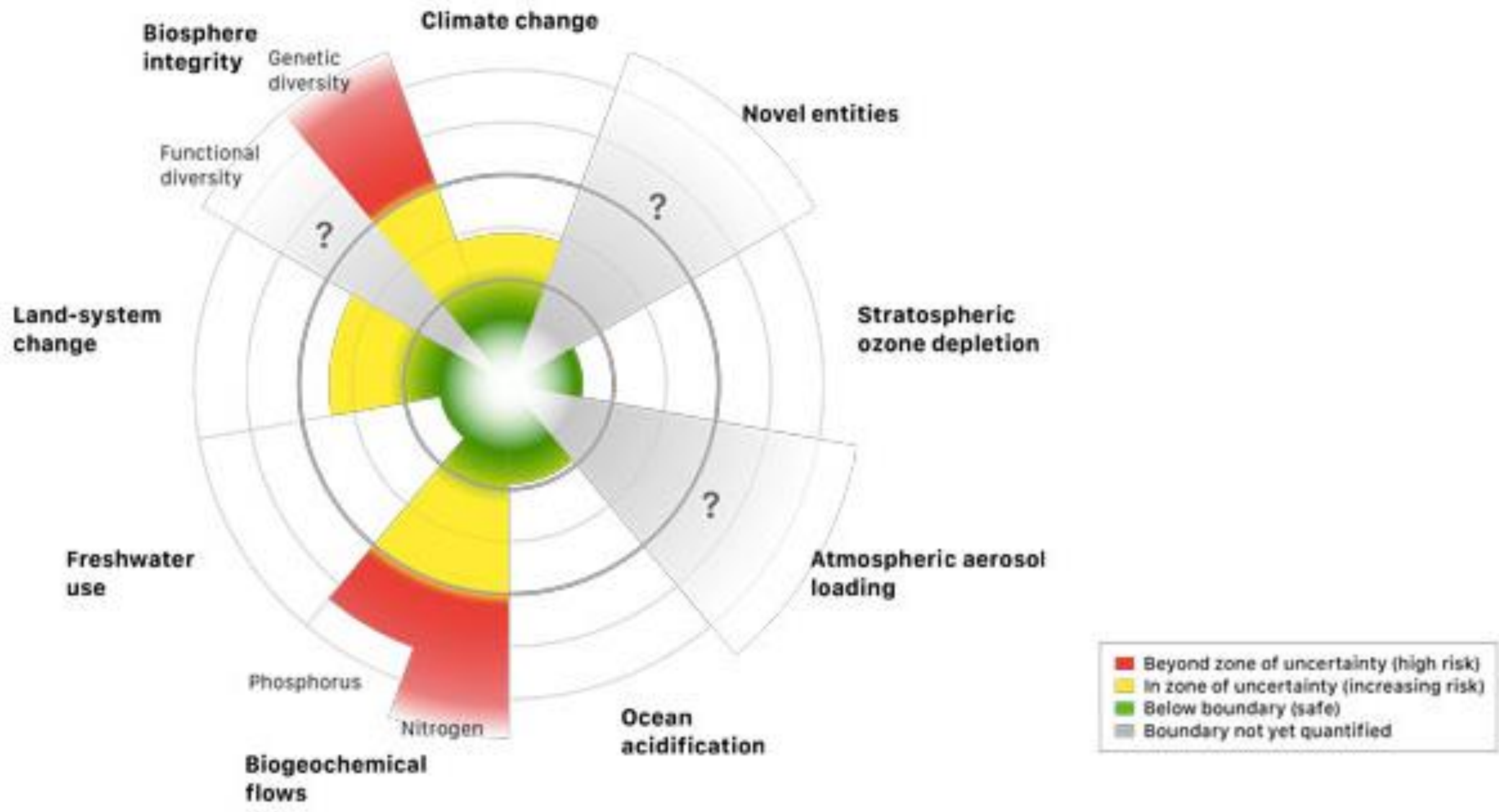


Figure 1.2 Food consumption per capita, major commodities (kg/person/year)



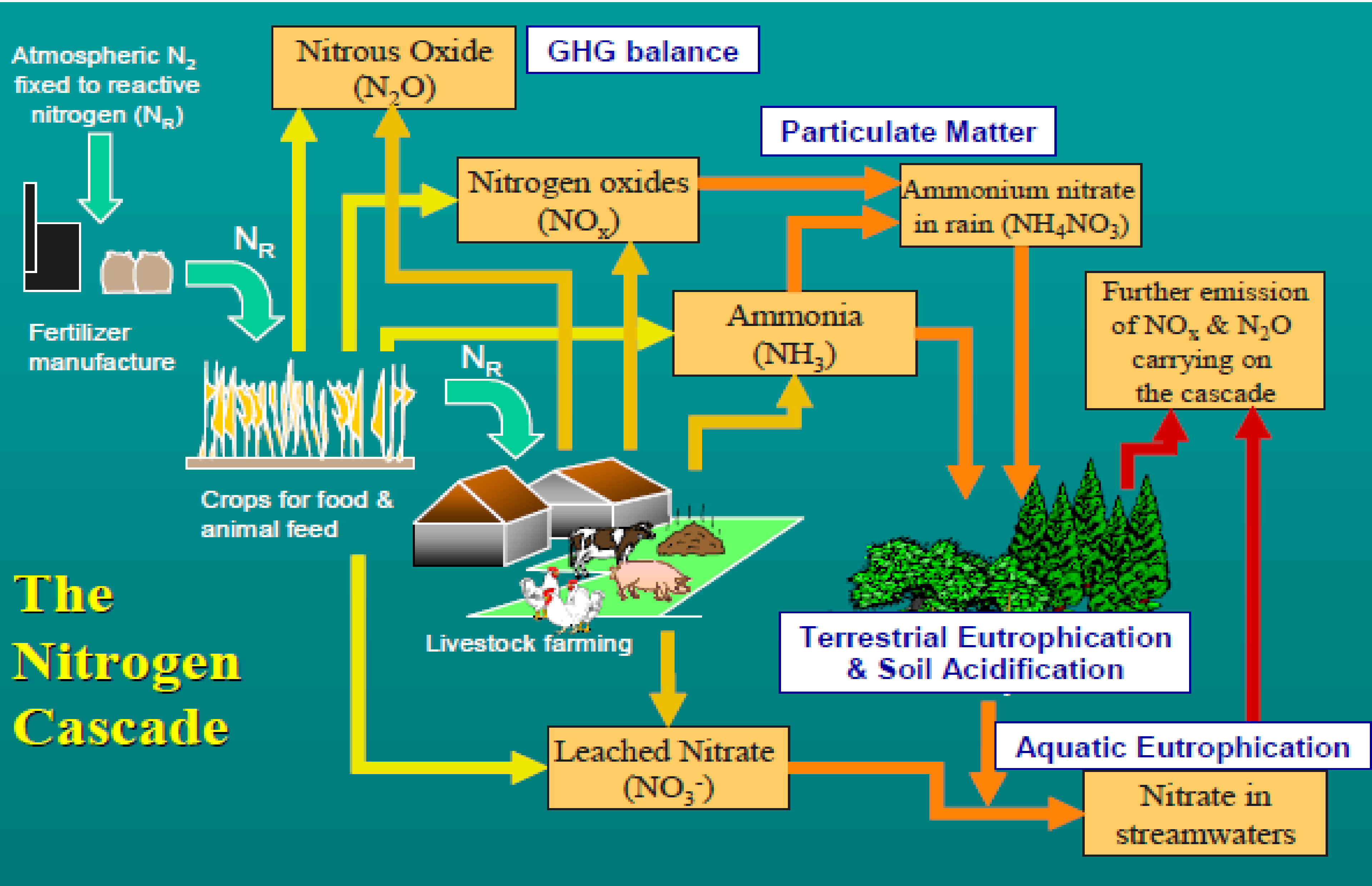
Source: FAO World Towards Agriculture, 2012

Planetary boundaries



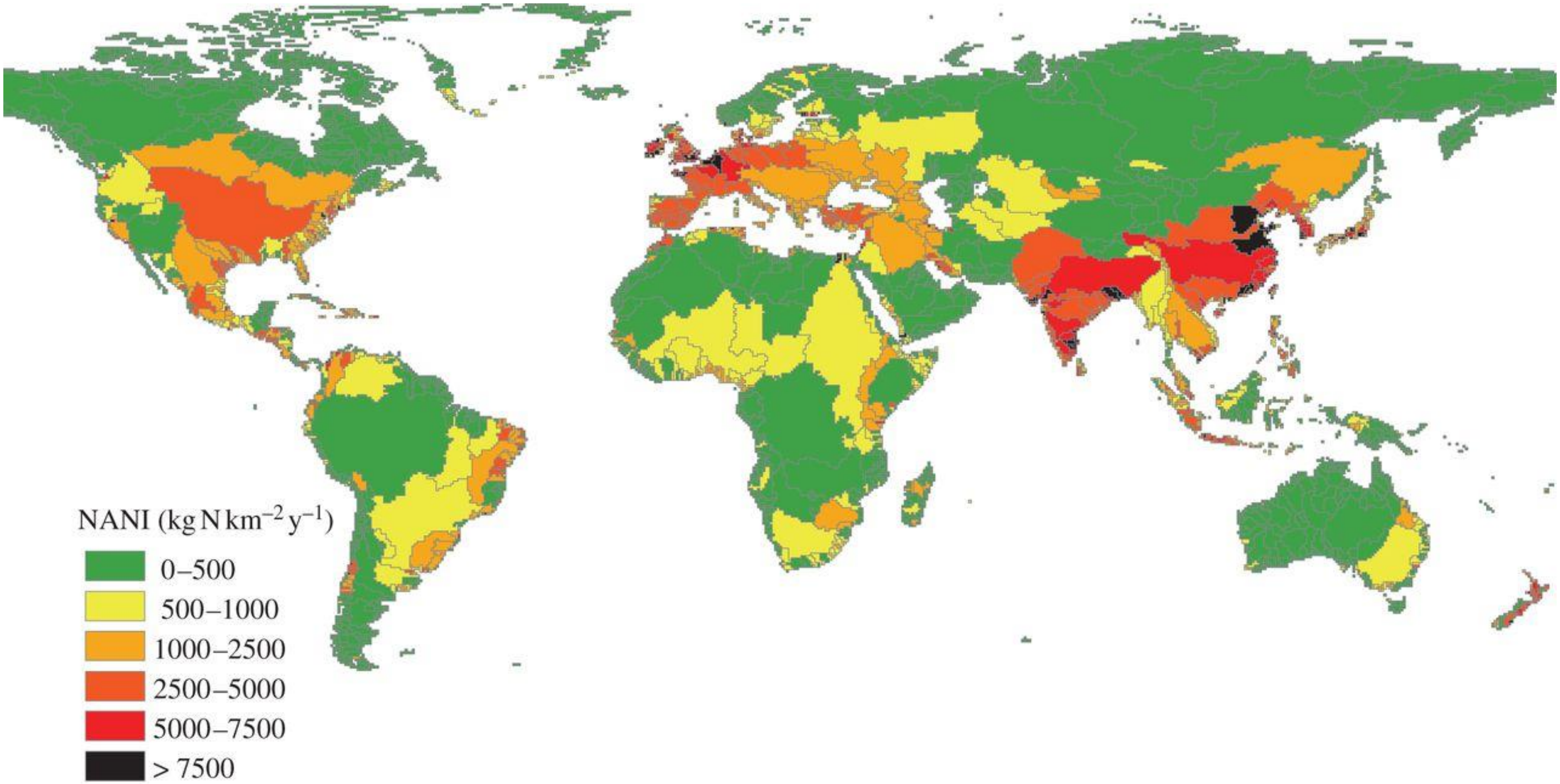
Source: Steffen et al. 2015
Stockholm Resilience Centre

Reactive N – the Nitrogen Cascade



Oenema et al. (2007b)

Net Anthropogenic Nitrogen Inputs to watersheds



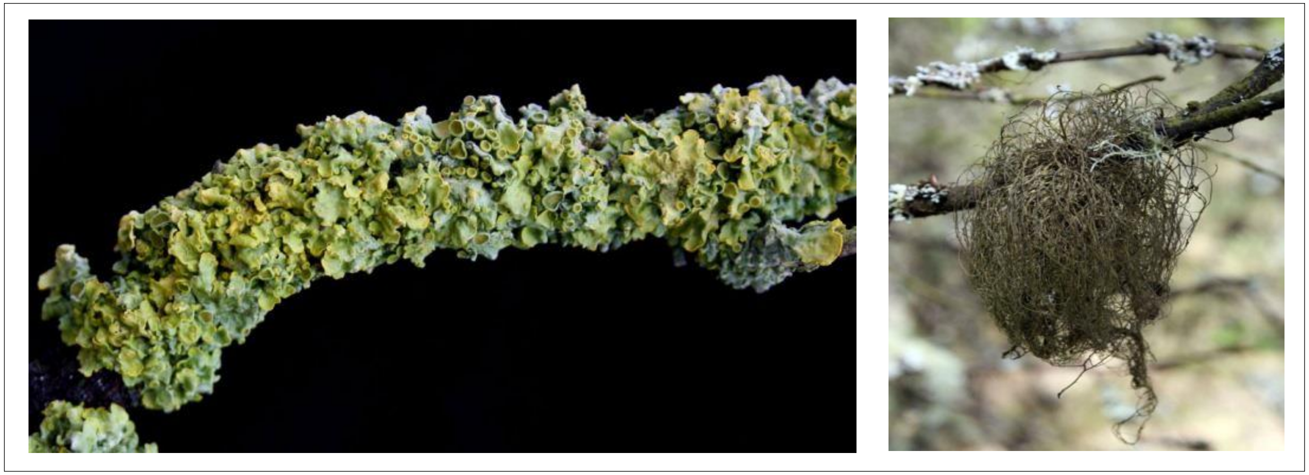
Billen et al. (2013) Phil Trans B http://rstb.royalsocietypublishing.org/content/368/1621/20130123

Ammonia

Environmental impacts:

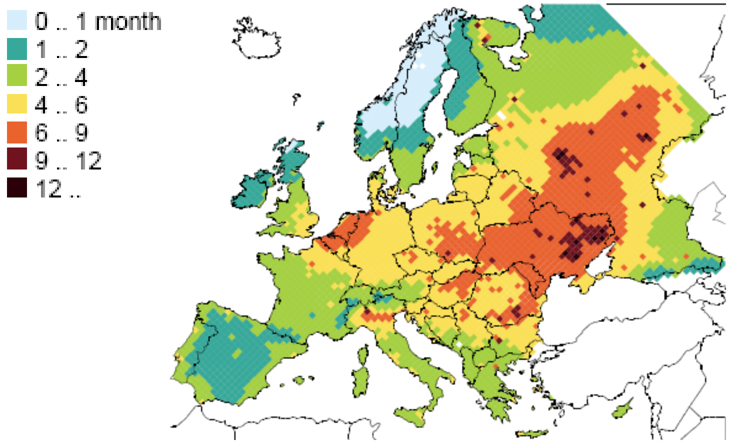
- **Eutrophication**
- **Soil acidification**
- **Local and long-range deposition**
- **Particulate formation**
- **Indirect GHG**

San Joaqin valley – particulate formation

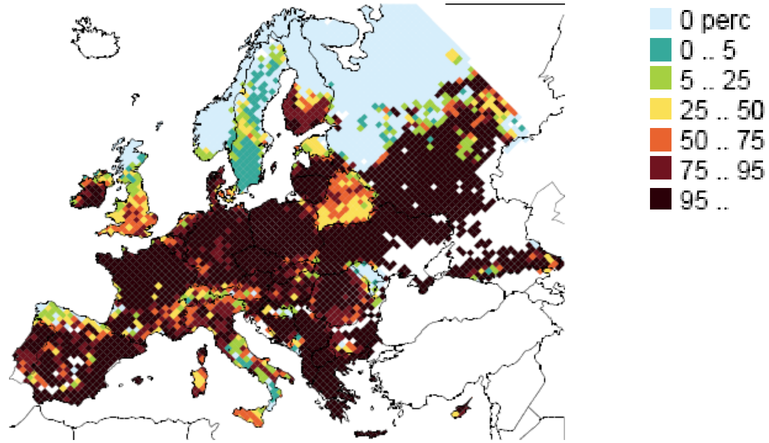


Nitrogen loving Xanthoria near a poultry farm (L); nitrogen intolerant Bryoria fuscens (R)

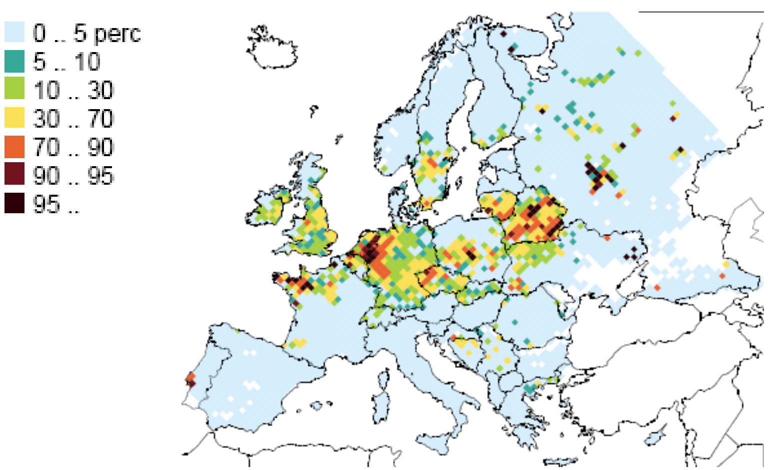
Baseline impacts calculated for 2020 - Europe



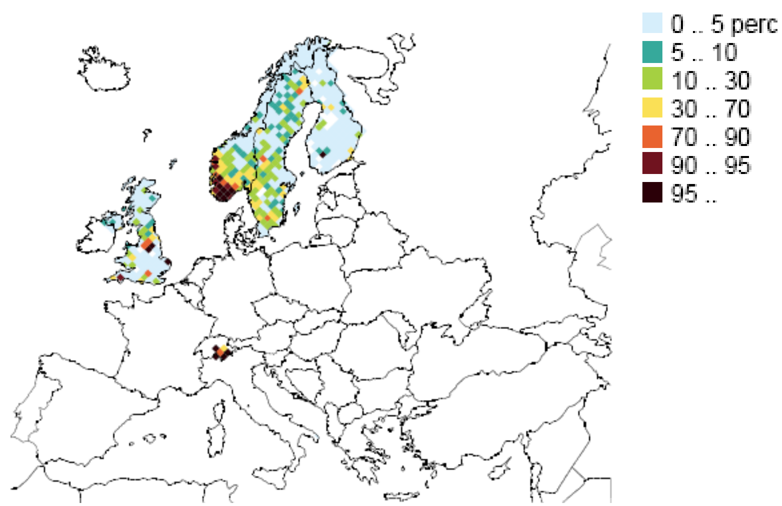
PM2.5: Loss in life expectancy



Eutrophication: Ecosystems area > CL



Acidification: Forest area > CL

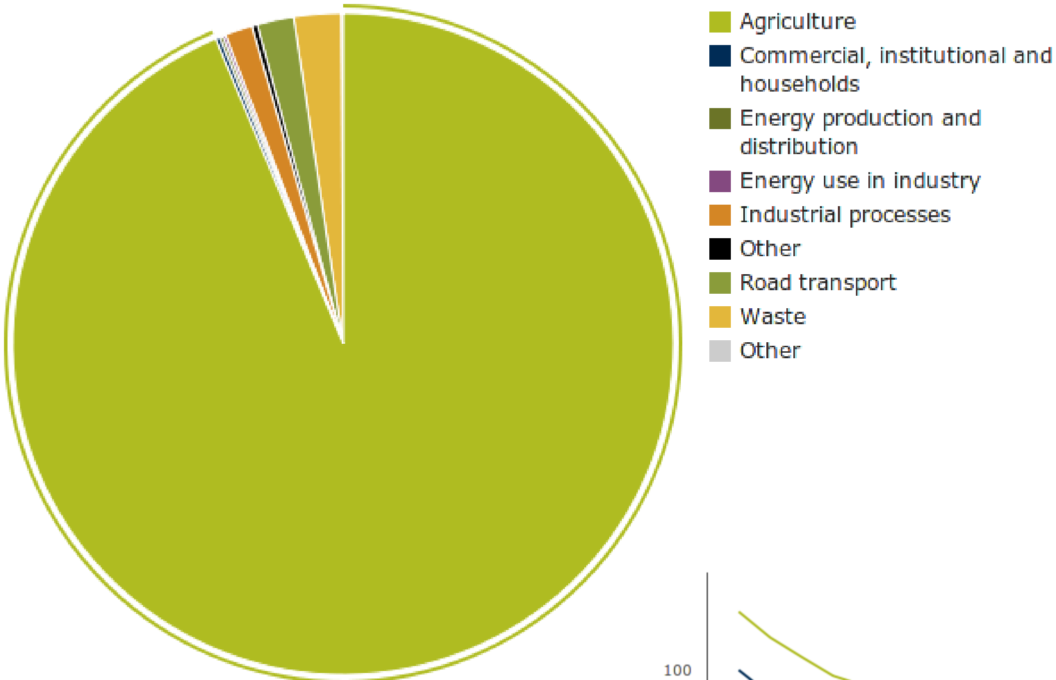


Acidification: Freshwater catchment > CL

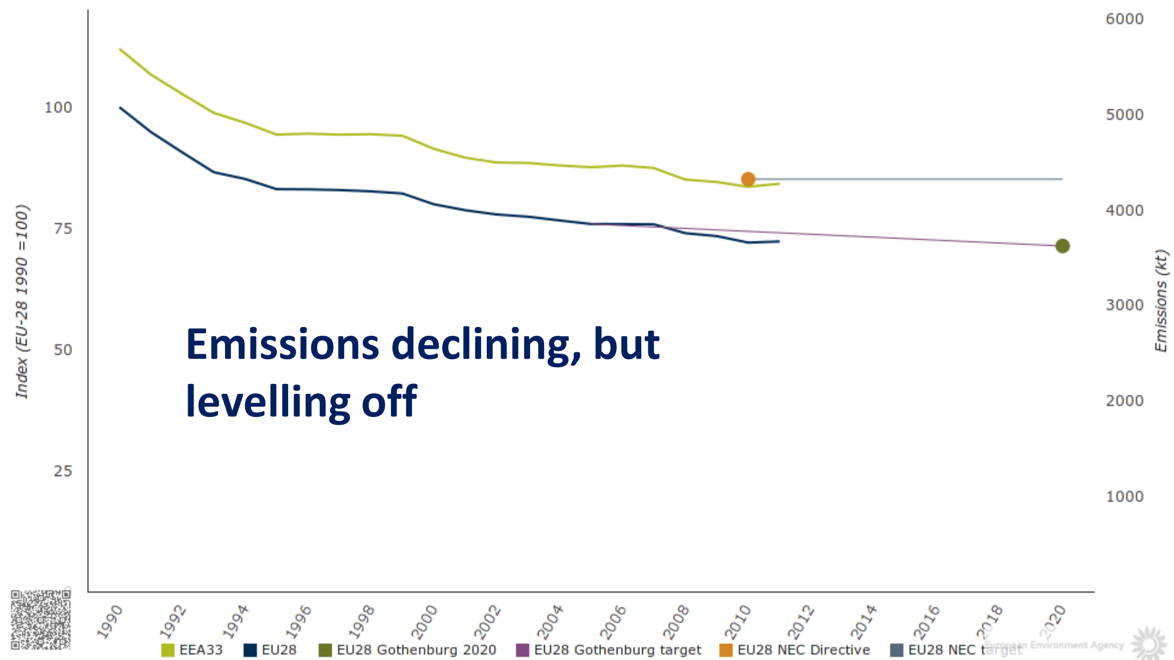
Source: IIASA, 2008

Emission sources

European ammonia emissions



- **Agriculture >90%**
- **Mostly manure management**



Emissions declining, but levelling off

Source: European Environment Agency

Ammonia – emission sources

housing

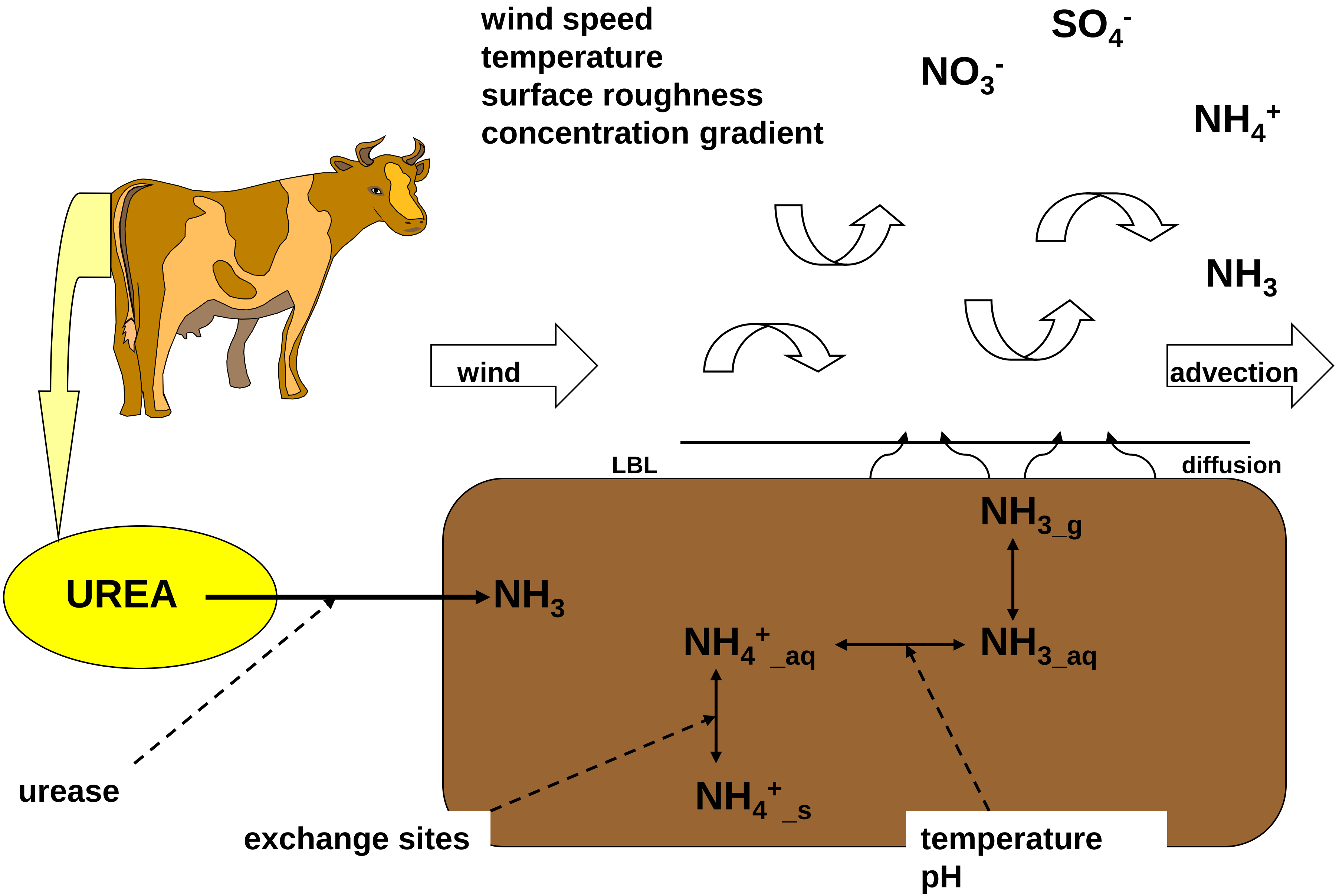
storage

spreading

grazing

fertilisers

Ammonia – emission process



Grazing

- **Rapid infiltration of urine – low emissions (c. 10% of urine N)**
- **Emissions from dung very low as mostly organic N**

Housing emissions

Temperature

Air flow

Management system – slurry *vs.* deep litter

Deep litter: bedding amount

bedding type

litter moisture content

Slurry: fouled floor area

floor design

cleaning method and frequency

Emission up to 20% of N excreted

Sources: Manure storage

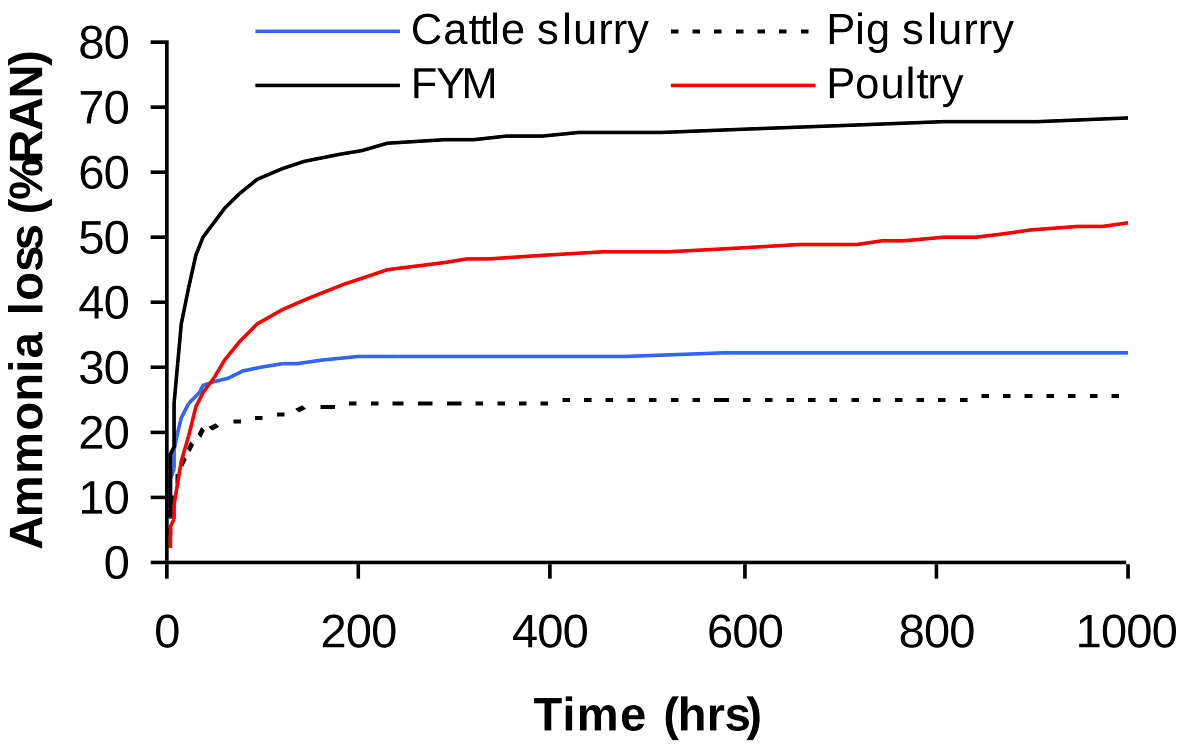
Typical emissions 5 – 25% of manure N

Sources: Manure spreading

Slurry – typically surface broadcast to grassland or arable

FYM – typically broadcast to arable land

Manure spreading – typical emission curves



- **Greater loss from solid manures (no infiltration)**
- **Slow hydrolysis of uric acid for poultry manure**
- **Pig slurry tends to be more dilute than cattle**

UK ammonia emission factors for livestock

Average annual emission, kg NH_3 per animal

	N excreted	Animal housing	Manure storage	Manure spreading	Grazing	TOTAL (% of N excreted)
Dairy cow	128	13.0	3.5	8.3	1.8	26.7 (21)
Other cattle	56	3.4	0.9	2.1	1.3	7.7 (14)
Fattening pig	13.3	2.3	0.9	1.0	0.1	4.3 (32)
Sow	18.1	2.4	0.7	0.4	1.1	4.4 (28)
Sheep/goat	9	0.1	0.1	0.0	0.3	0.5 (6)
Laying hen	0.6	0.13	0.02	0.08	0.01	0.24 (38)
Broiler	0.4	0.02	0.01	0.05		0.08 (21)

Source: Inventory of Ammonia Emissions from UK Agriculture, 2015

Emissions from N fertilisers

$$EF = EF_{max} \times RF_{soilpH} \times RF_{landuse} \times RF_{rate} \times RF_{rainfall} \times RF_{temperature}$$

Maximum potential emission factor, modified by a series of reduction factors according to:

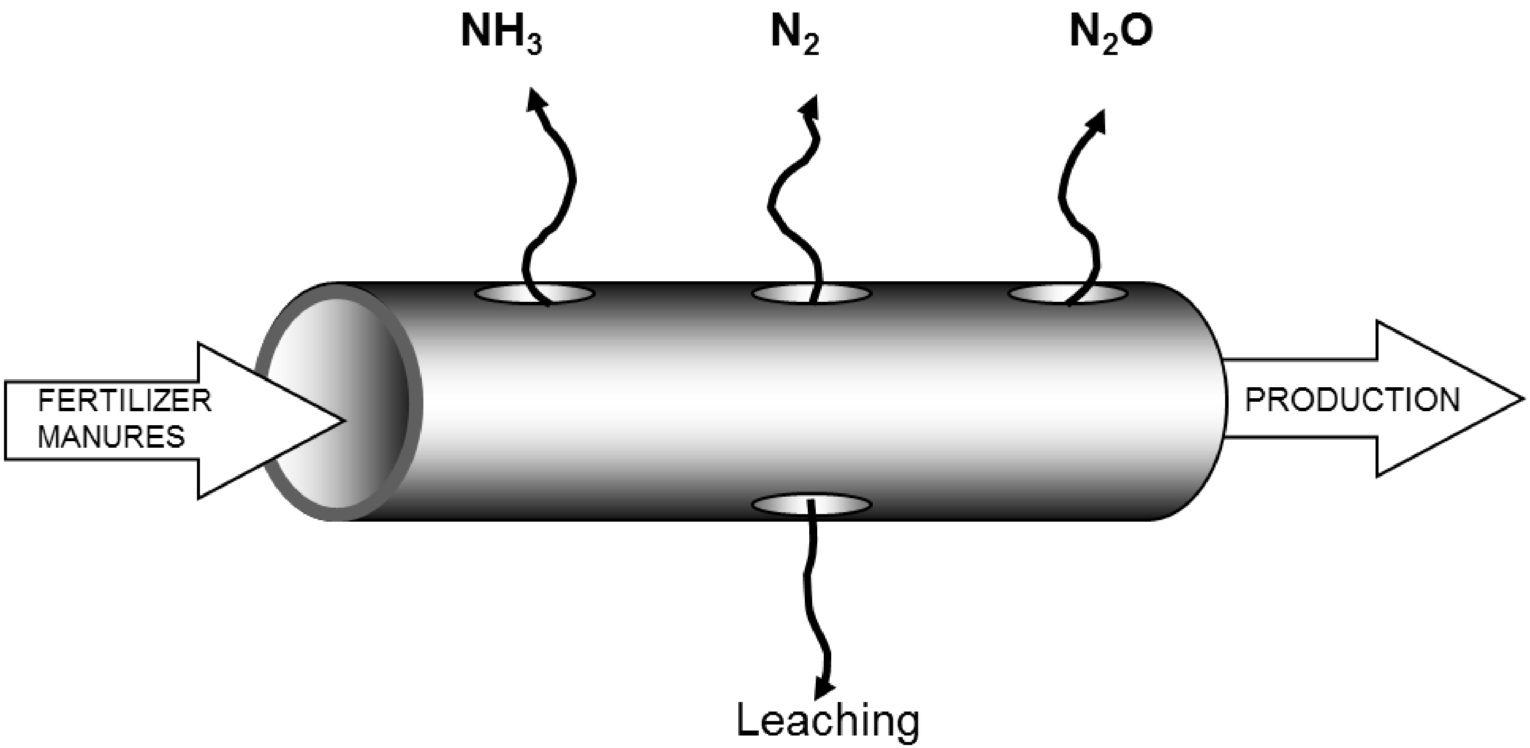
- **Fertiliser type**
- **Soil pH**
- **Land use**
- **Application rate**
- **Rainfall**
- **Temperature**

	EF (%N)
Ammonium nitrate (CAN)	1.7
Urea	9.7
UAN	4.9
AS/DAP	2.9

Mitigation

Mitigation – Reactive Nitrogen

- Reduce inputs (or increase outputs) – emission intensity
- Increase efficiency of utilisation
- Reduce losses



Low emission animal housing systems - cattle

Limited options:

Reduction in emissions

- Grooved-floor systems with toothed scrapers (new build) 35%
  £500 per animal place additional upfront cost
- Acidification/flushing – further assessment needed
- Washing down collecting yards £46 per animal place 70%
  Activity data

Low emission animal housing systems - pigs

Slurry-based systems: **Reduction in emissions**

- Partially-slatted floors with reduced pit area **30%**
  £55 per animal place upfront cost
- Air scrubbers **80%**
  £54 per animal place upfront cost
- Flooring systems – definition/evidence
- In-house acidification (e.g. Denmark)

Straw-bedded/naturally ventilated:

Few options

Co-benefits of scrubbers – PM reduction

Low emission animal housing systems - poultry

Layers:

Reduction in emissions

- **Belt-drying of manure** — 30%
  £0.34 per animal place operating cost
- **Air scrubbers** — 80%
  £2.47 per animal place upfront cost

Broilers:

- **Litter drying – heat exchangers** — 30%
  £0.23 per animal place annual cost
- **Air scrubbers** — 80%
  £2.47 per animal place upfront cost

Co-benefits of scrubbers – PM reduction

Low emission manure storage systems

Rigid tank covers

Reduction efficiency 80%

£22.40 per m^3 slurry upfront cost

- **Applicability - not always possible to retro-fit**
- **Co-benefits - exclude rainfall, reduce other emissions**

Low emission manure storage systems

Floating covers

Reduction efficiency 60% **£3.25 - £6.91 per m^3 slurry upfront cost**

- **Applicability – can apply to existing stores**
- **Secondary impacts – may increase N_2O emissions**

Low emission manure storage systems

Slurry bags

- ‘Pillows’ for increasing current capacity
- Full systems to replace tanks/lagoons

Reduction efficiency – estimated at 95%

Assumed cost neutral for replacing existing slurry storage
Upfront cost £29 per m3 slurry (cf £34 for steel tank and £17 for lagoon)

- Applicability – is an alternative to current systems, therefore may take a long time to penetrate the sector
- Co-benefits – reduction of other emissions

Low emission manure storage systems

- Practicalities – difficult where heaps sequentially formed
- Waste sheeting
- Current requirement for poultry field heaps in NVZ

Reduction efficiency 60%

Annual cost £0.70 per tonne manure

Only makes sense if manure is rapidly incorporated after spreading

Low emission spreading approaches

Slurry

Trailing hose

Trailing shoe

Shallow injection

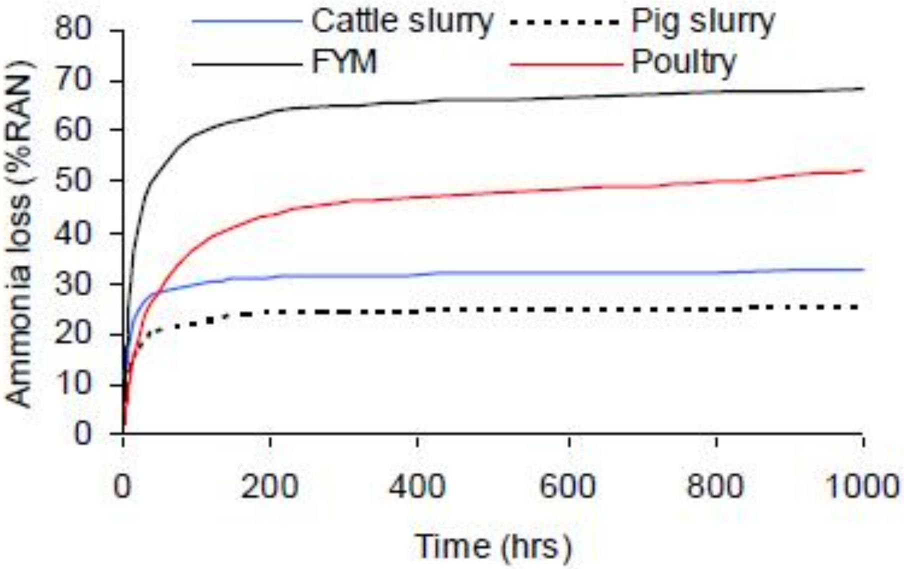
Emission reduction, % (range)

Trailing hose	Trailing shoe	Shallow injection
30 (0 – 50)	60 (20 – 80)	70 (30 – 90)

Operating costs (additional to splashplate) per m³ slurry, assuming contractor operation:

Trailing hose	Trailing shoe	Shallow injection
£0.73	£0.61	£0.50

Low emission spreading approaches



Rapid incorporation – within 4h, 12h, 24h

Reduction efficiency 17 – 82%

Timing, method and manure type influence efficacy

Cost

Per t manure spread £0.08 – 1.57

Slurry acidification

Reduce slurry pH to <5.5

Emission reduction up to 70%

Acidify during storage or using specially adapted tanker

Becoming common in Denmark

N fertiliser applications

Urea

- Switch from urea to AN
- Use urease inhibitor; combined inhibitors
- Soil incorporation

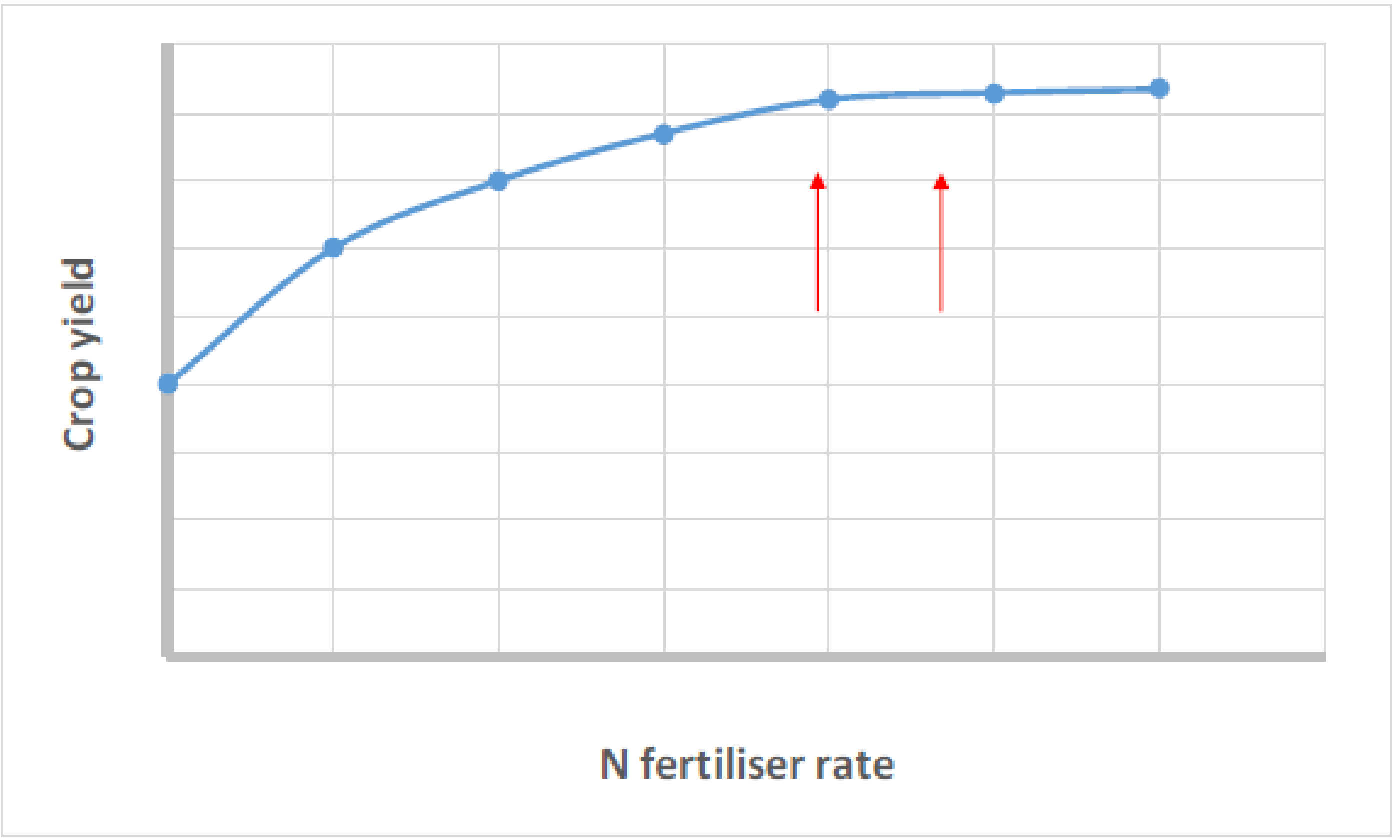
Reduction efficiency urease inhibitor 70%

Cost

Per kg N applied £0.15 - but variable

Crop yield benefits?

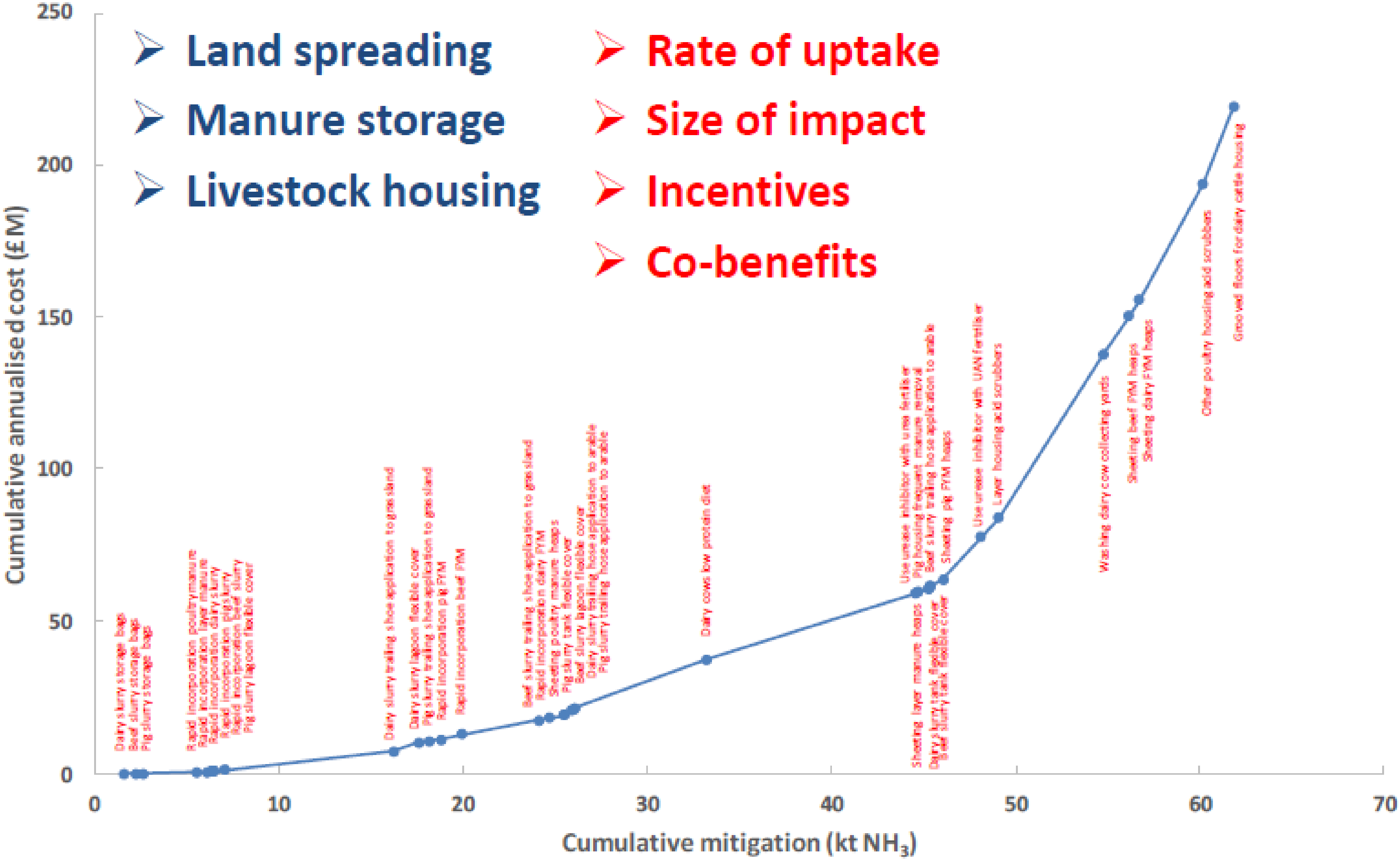
- Fertiliser value of saved NH_3-N
- Yield benefits often not significant



➢ Encourage use of DSS

➢ Use less fertiliser for same yield

MACC for ammonia mitigation measures for agriculture



MITIGATION METHODS – USER GUIDE

An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture

Newell Price, J.P., Harris, D., Taylor, M., Williams, J.R., Anthony, S.G., Duethmann, D., Gooday, R.D., Lord, E.I. and Chambers, B.J. (ADAS),
and
Chadwick, D.R. and Misselbrook, T.H. (Rothamsted Research, North Wyke)

December 2011

Prepared as part of Defra Project WQ0106

Options for Ammonia Mitigation

Guidance from the UNECE Task Force on Reactive Nitrogen

Any questions?

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