Role of nutrient management in agriculture for addressing climate change & related co-benefits

Mark Sutton
CEH Edinburgh

UNFCCC COP25 Koronivia Workshop:
Improved nutrient use and manure management
towards sustainable and resilient agricultural systems
3 Dec 2019, Madrid

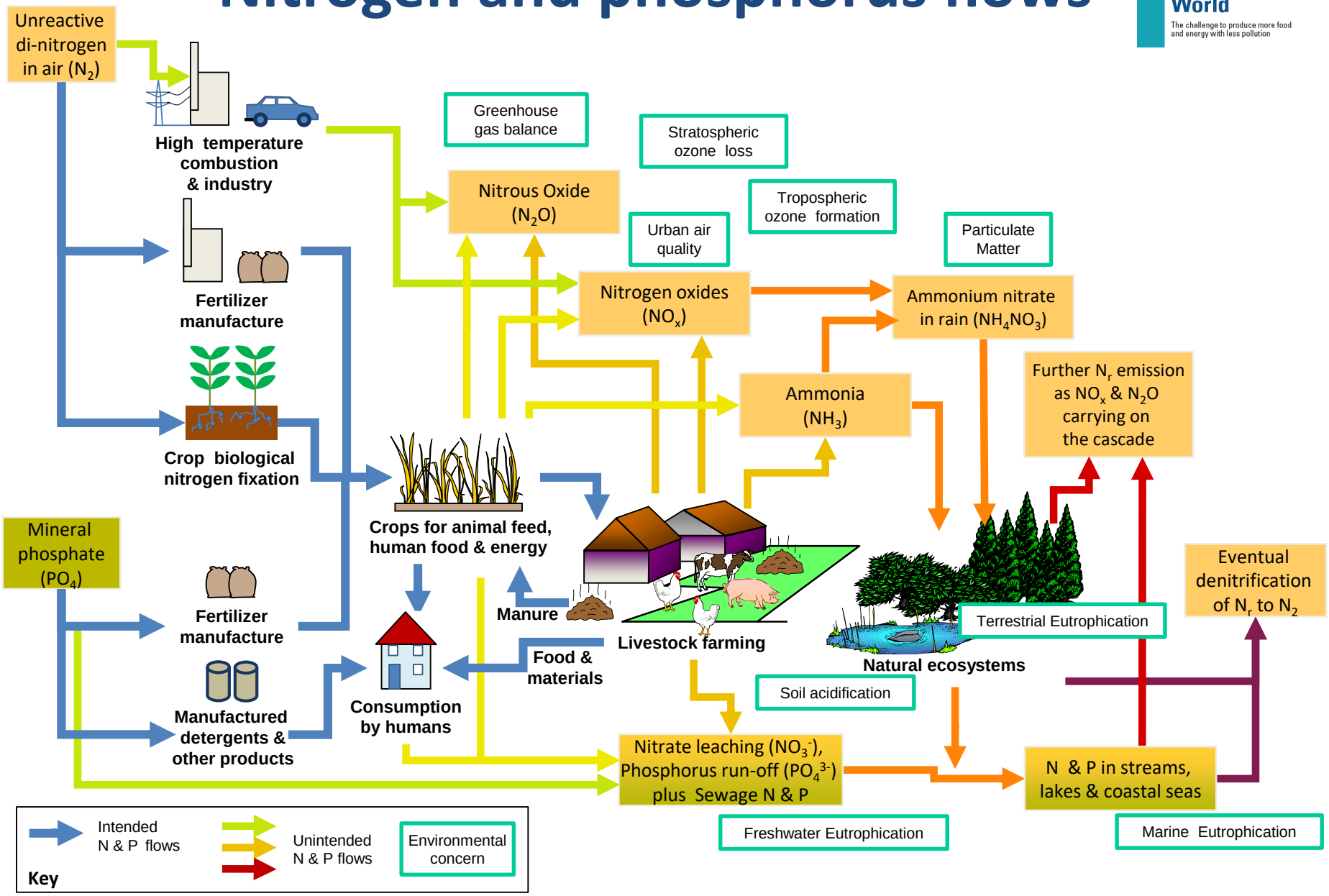
www.inms.international
@MarkNitrogen

Why Nutrients & Climate?

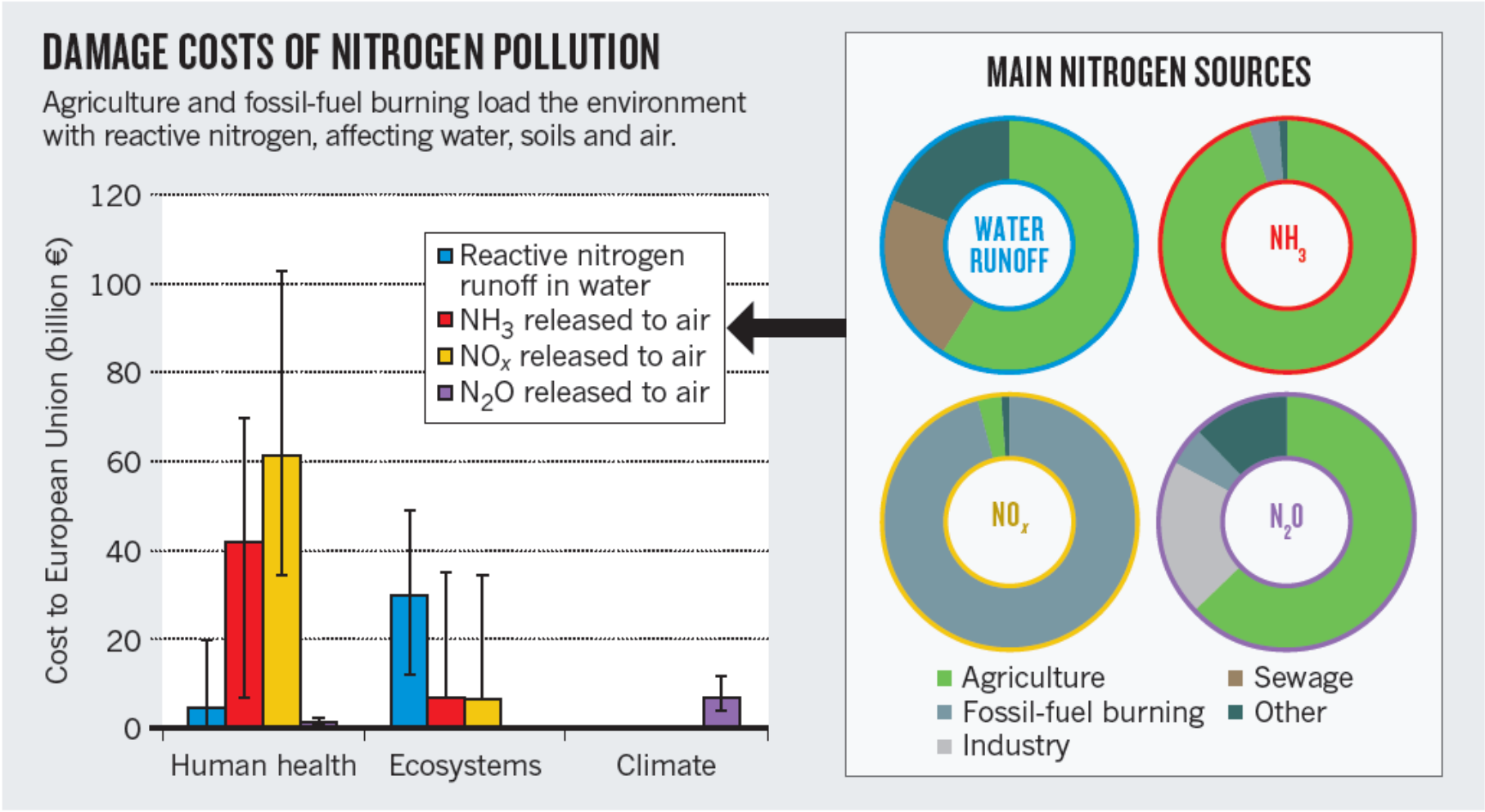
- Action on N_2O essential to meet a 1.5°C goal
- N_2O emission control requires system-wide improvement in Nitrogen Use Efficiency
- A circular economy strategy for nitrogen means avoiding denitrification to save on new N inputs
- Avoiding eutrophication from N & P can also help reduce CH_4 emissions
- Nutrient management offers co-benefits for climate, air, water, biodiversity, soils & the ozone layer

Nitrogen and phosphorus flows

Our Nutrient World
The challenge to produce more food and energy with less pollution



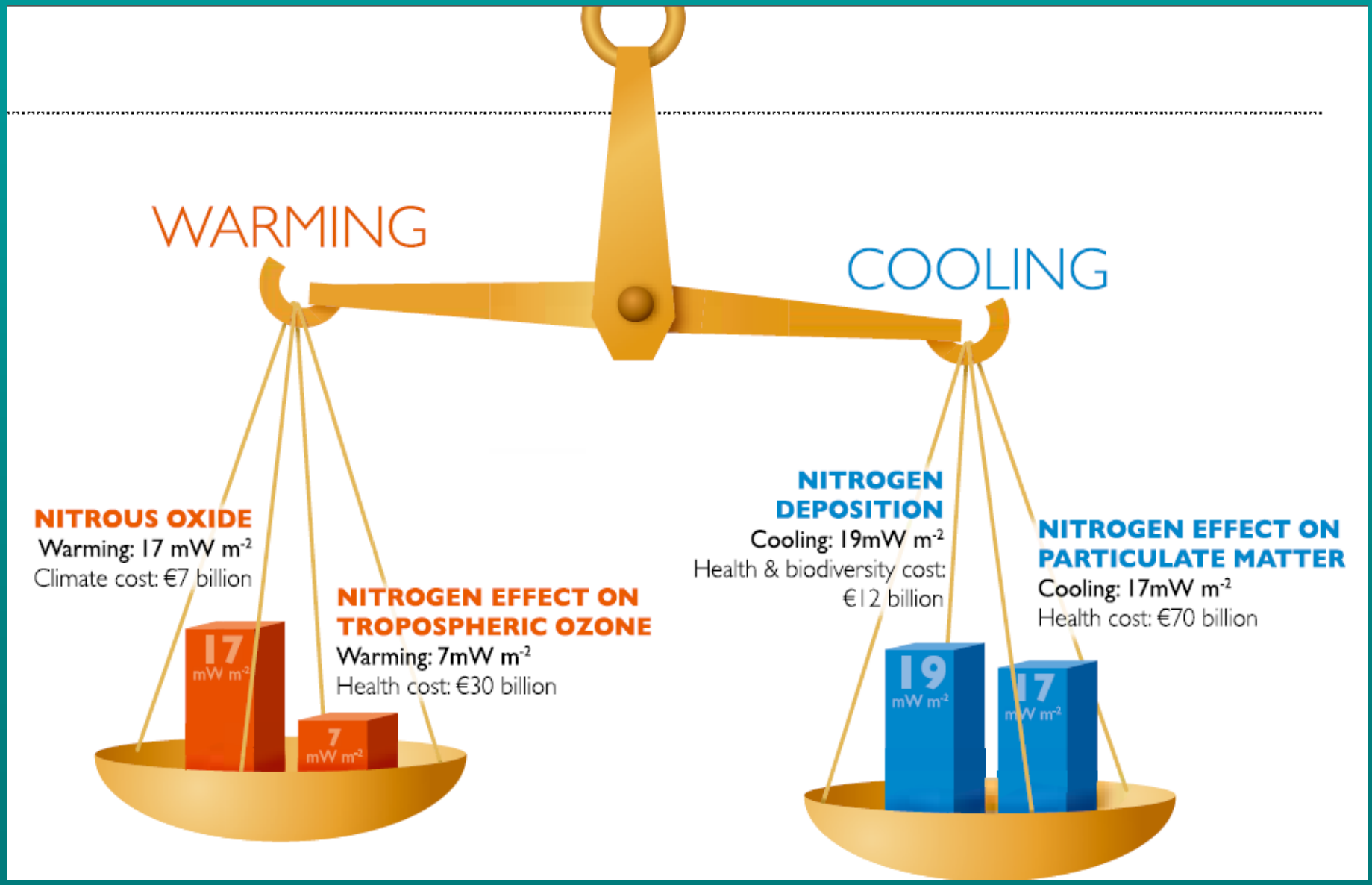
Nitrogen Damage Costs & Sources



EU Damage cost: 70 - 320 billion € / year

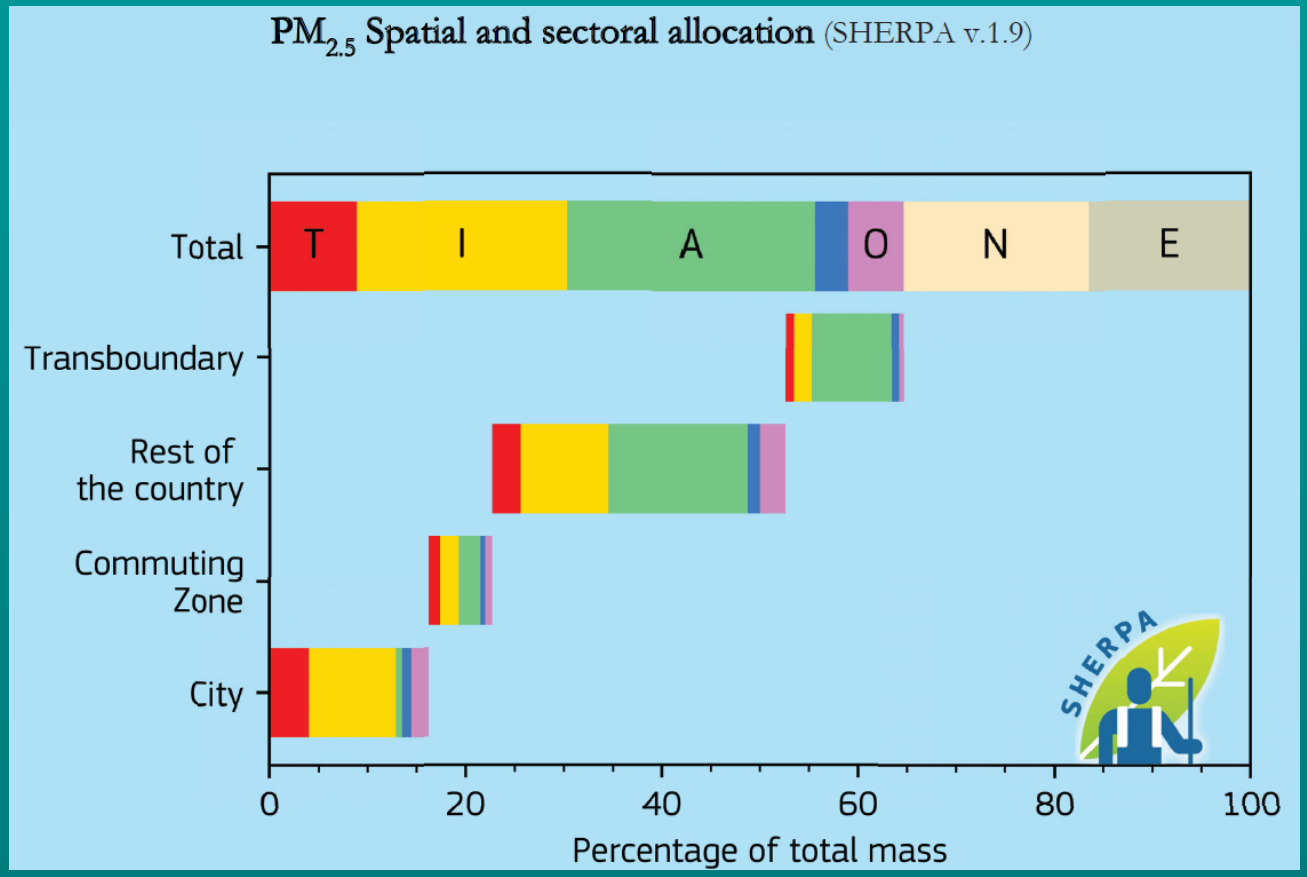
ENA and *Nature*

Balancing Nitrogen and Climate



Sutton & Howard, Planet Earth based on *the European Nitrogen Assessment*

What is the main source of Particulate Matter ($PM_{2.5}$) in Edinburgh?

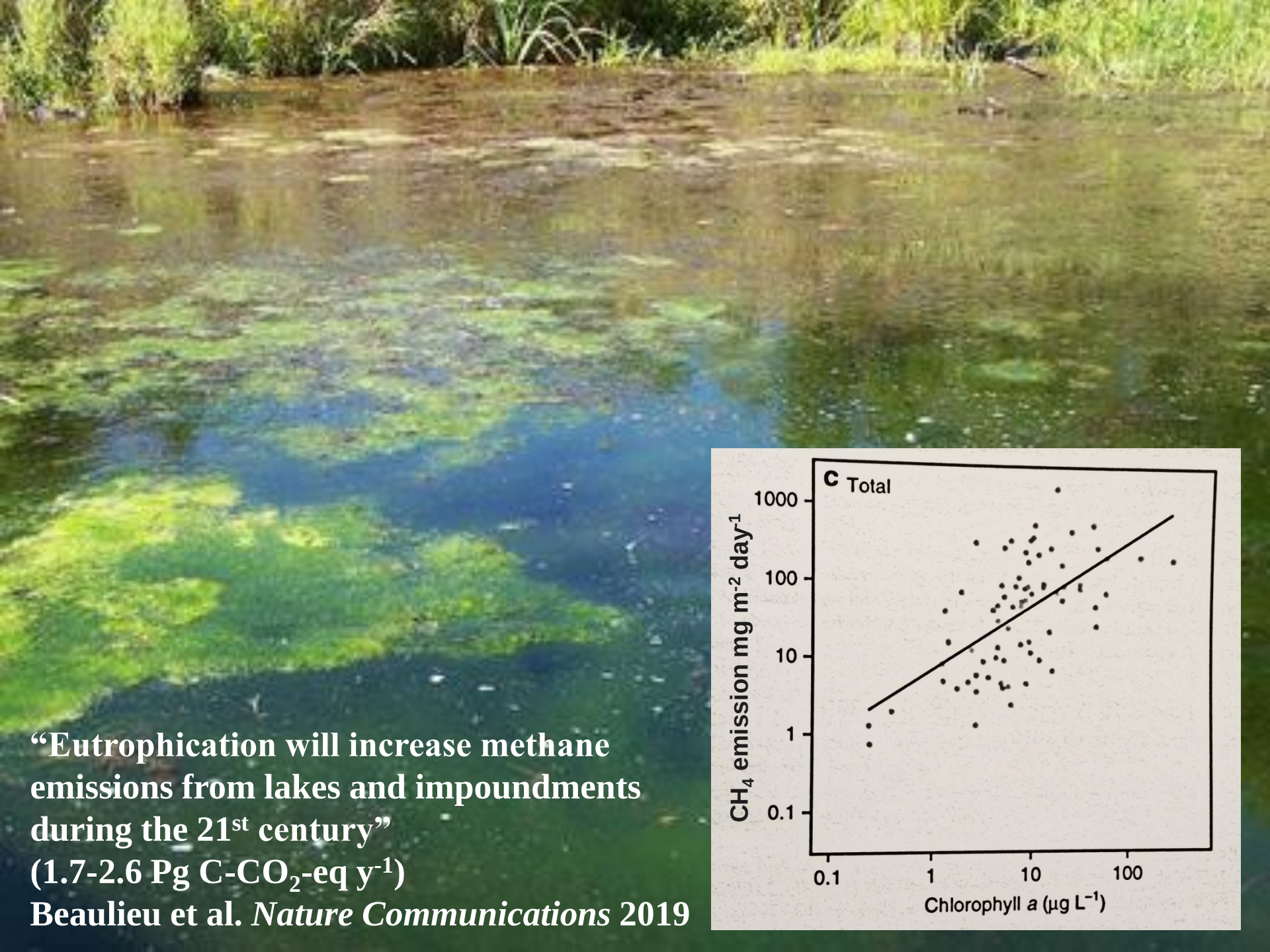


T - Transport
I - Industry
A - Agriculture
R - Residential
O - Other
N - Natural
E - External

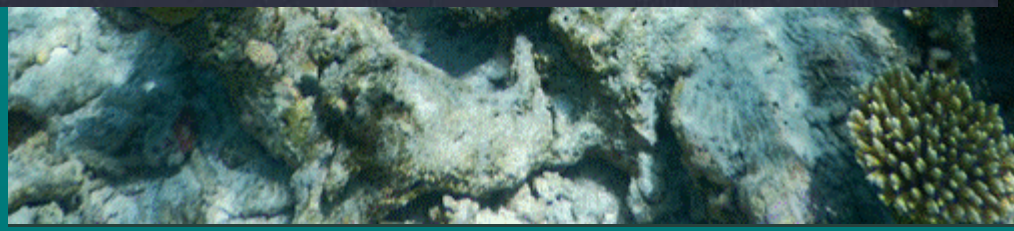
Urban PM2.5 Atlas: Air Quality in European cities
(Thunis et al. European Commission November 2017), Example Edinburgh

“The Trouble with Ammonia” to the #StikstofCrisis

A Tale of Two Tractors (*Nourish Scotland*)



"Eutrophication will increase methane emissions from lakes and impoundments during the 21st century"
(1.7-2.6 Pg C-CO_2-eq y^{-1})
Beaulieu et al. *Nature Communications* 2019



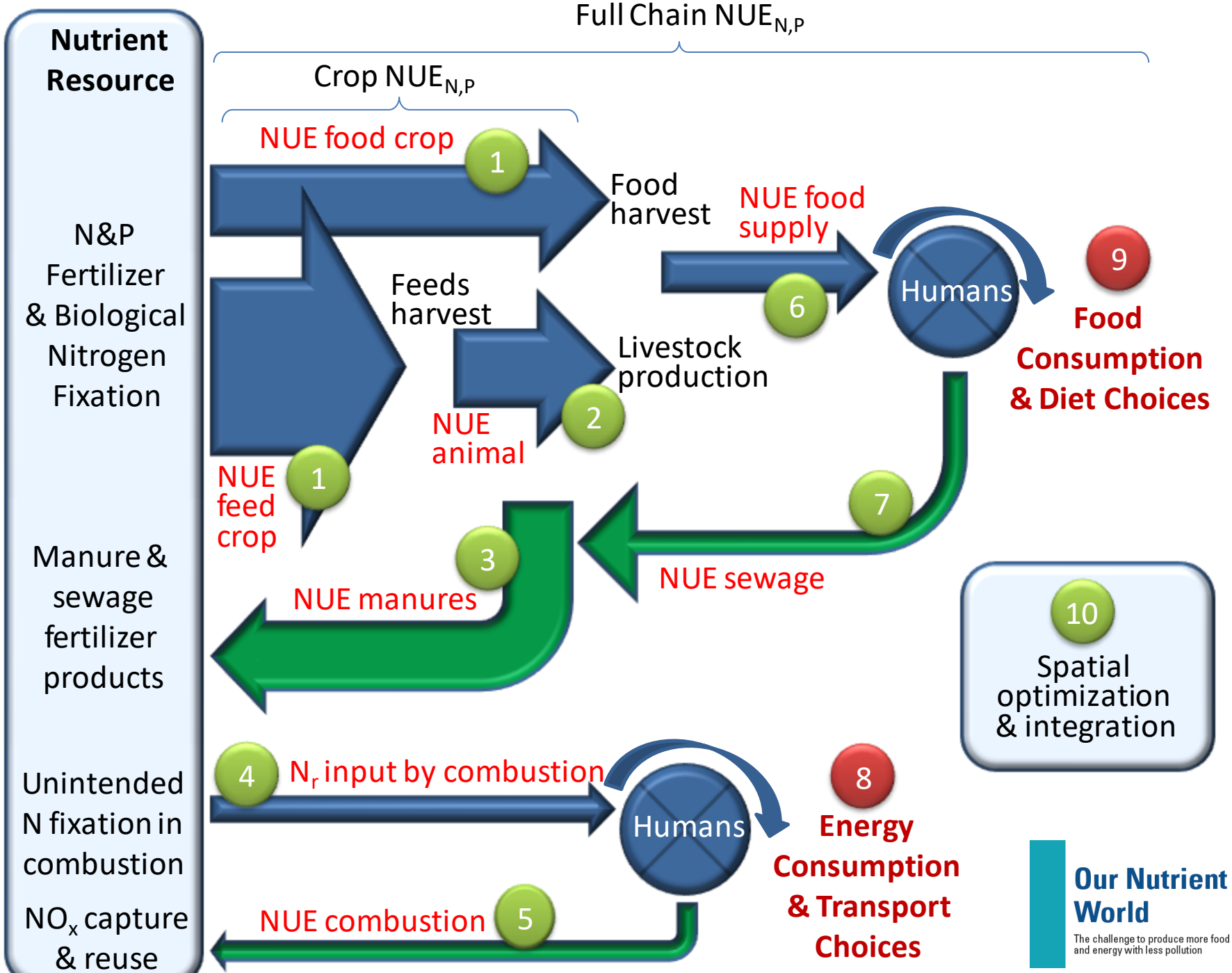
UKRI GCRF South Asian Nitrogen Hub

Maldives: Thoddoo

@MarkNitrogen

1 September 2019


Air Quality
Climate
Water Quality
Why Nitrogen?
$200 billion of N wasted annually
Soil Quality
Biodiversity


Nutrient Resource
N&P Fertilizer & Biological Nitrogen Fixation
Manure & sewage fertilizer products
Unintended N fixation in combustion
NO_x capture & reuse
Full Chain $NUE_{N,P}$
Crop $NUE_{N,P}$
NUE food crop
1
Food harvest
NUE food supply
6
Humans
9
Food Consumption & Diet Choices
Feeds harvest
Livestock production
2
NUE animal
NUE feed crop
1
7
3
NUE manures
NUE sewage
10
Spatial optimization & integration
4
N_r input by combustion
Humans
8
Energy Consumption & Transport Choices
NUE combustion
5
Our Nutrient World
The challenge to produce more food and energy with less pollution

Ten key actions for nitrogen management

Agriculture

1. Improving nitrogen use efficiency in crop production
2. Improving nitrogen use efficiency in animal production
3. Increasing the fertilizer N equivalence value of animal manure

Transport and Industry

4. Low-emission combustion and energy-efficient systems
5. NO_x capture and utilization technology

Waste water treatment

6. Improving food supply efficiency & reducing food waste
7. Recycling nitrogen (& phosphorus) from waste water systems

Societal consumption patterns

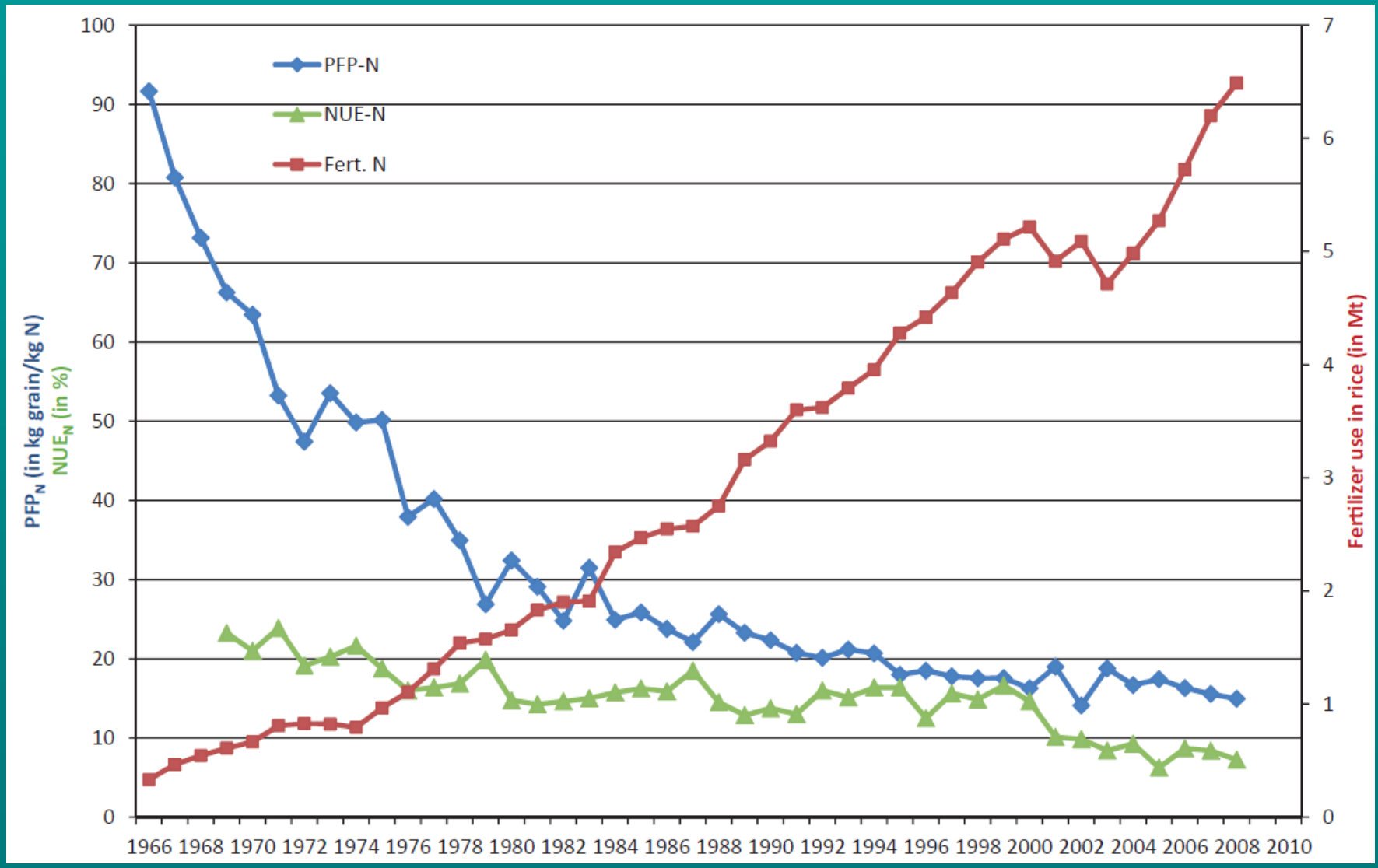
8. Energy and transport saving
9. Lowering the human consumption of animal protein

Societal consumption patterns

10. Spatial optimization and integration

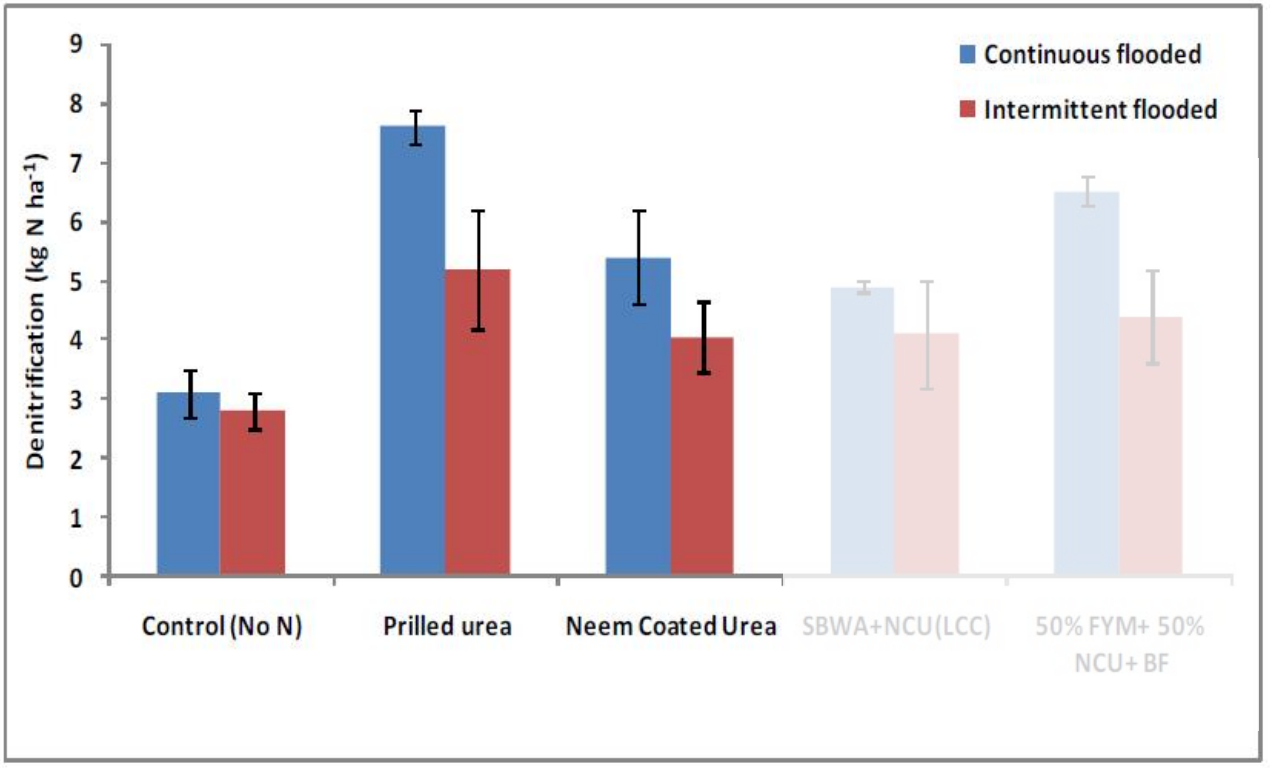
Nitrogen Fertilizer for Indian Rice

& the reduction in Nitrogen Use Efficiency



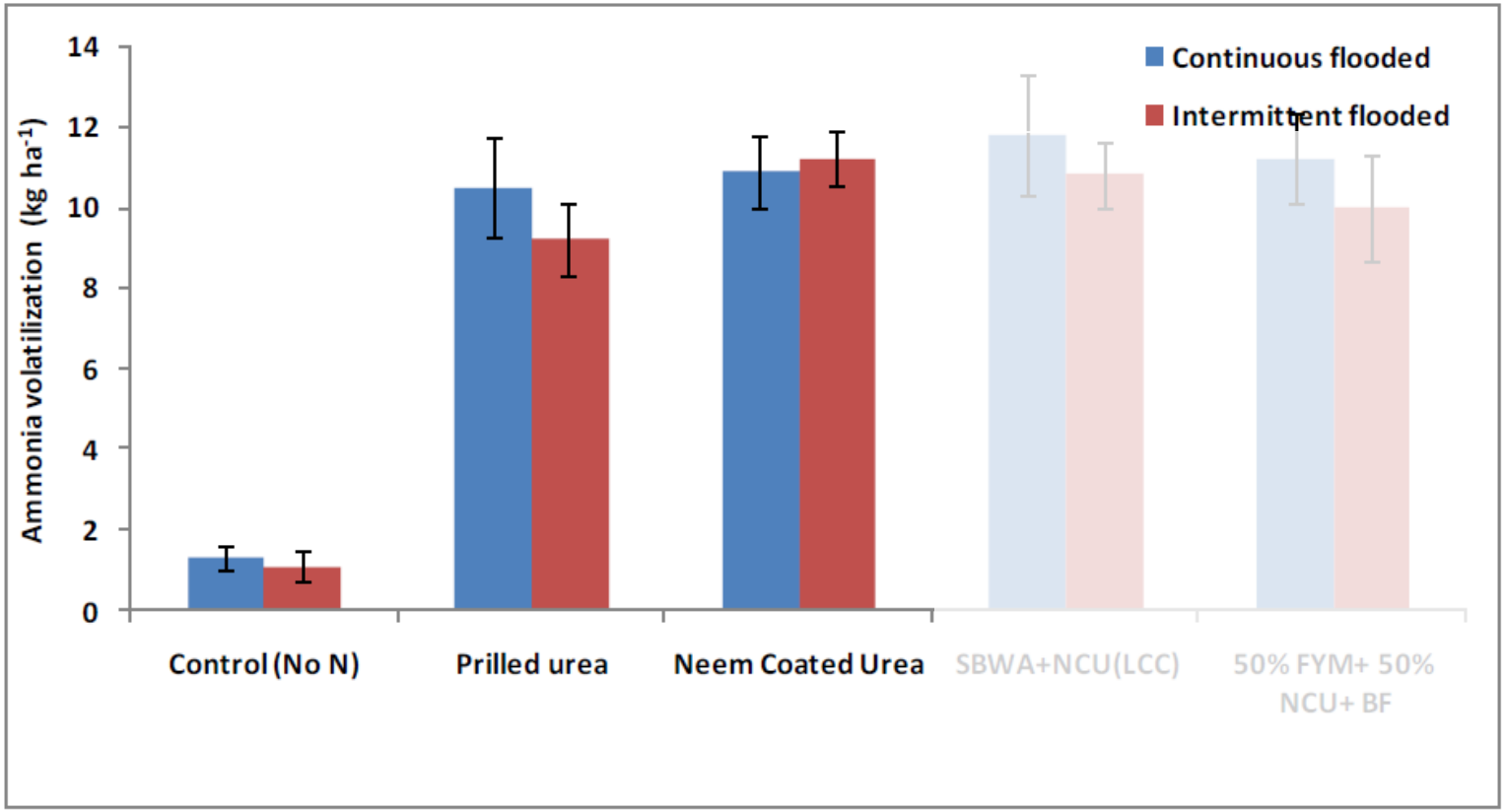
Our Nutrient World 2013

Denitrification (as N_2O)



Arti Bhatia, Niveta Jain, Renu Singh et al.

Ammonia volatilization (NH_3)



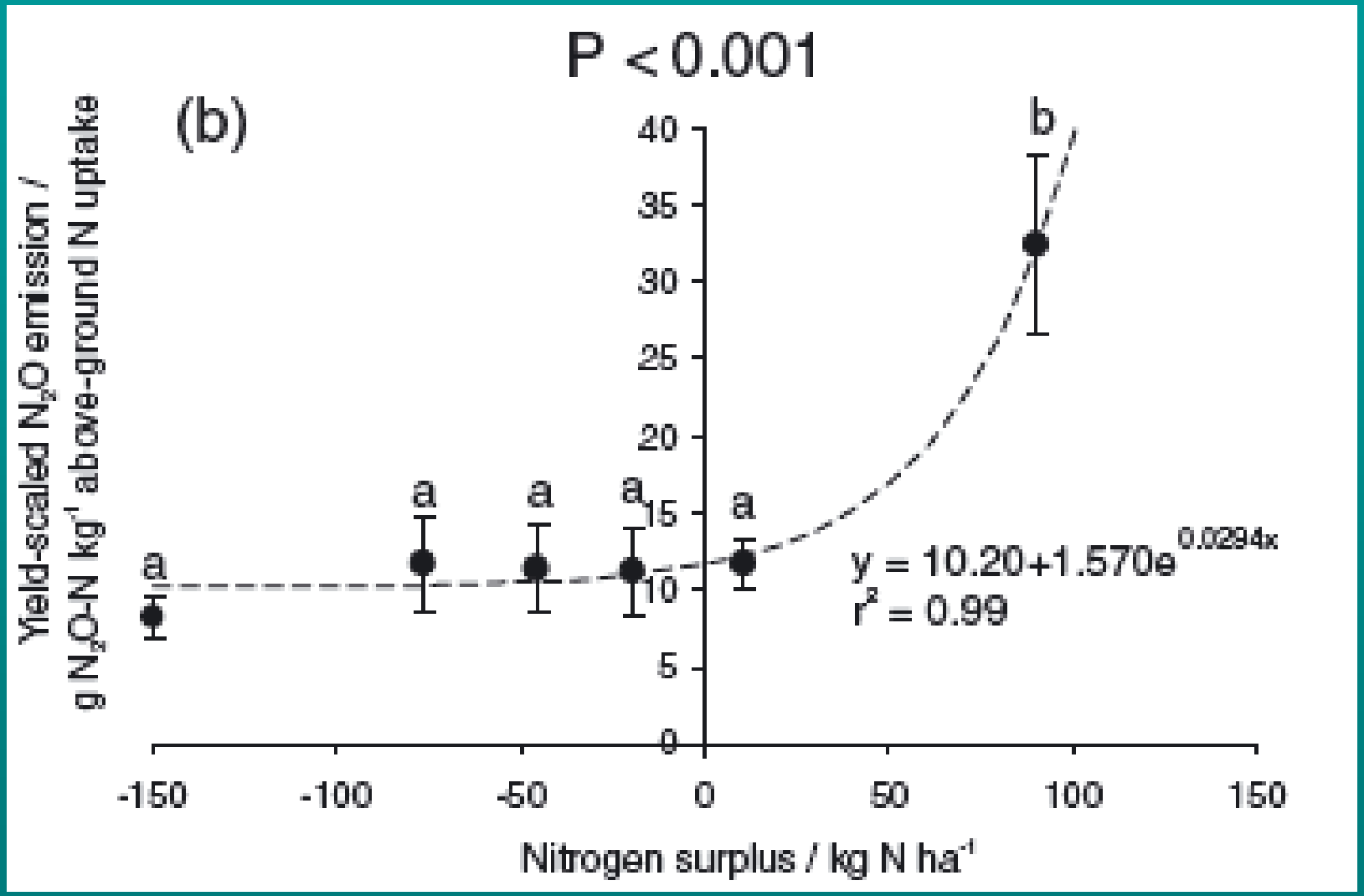
We need to develop capability for full nitrogen flux measurement

Arti Bhatia, Niveta Jain, Renu Singh et al.

Illustrative Nitrogen Flows in Fertilized Rice

• Inputs			
– Fertilizer	100		
– Manure	(50)		
– Atmosphere	20	TOTAL IN	170
• Losses			
– Nitrous oxide (N_2O)	3		
– Dinitrogen (N_2)	**30**		
– Ammonia (NH_3)	**30**		
– Nitric oxide (NO)	2		
– Leaching/Run off	**30**		
• Yield			
– Grain	25	TOTAL OUT	120
–		Missing	50

Avoiding excess nitrogen in agricultural likely soils critical to reduce N_2O, NO & NO_3 losses



Van Groeningen et al. 2010, Eur J Soil Sci

Is biological nitrogen fixation the answer?

- BNF – a natural form of slow release fertilizer = expect smaller % N loss than with fertilizer
- Can BNF deliver enough N?
- Hot-moments of N_2O and other N losses from ploughed-in legumes?
- Brave new world: Nitrogen fixing GM wheat & rice?
- Most harvest goes to feed livestock, so still need better urine & dung management


Azolla

Slurry spreading:
a wide range of low-emission techniques are available


Splash Plate Spreader
- 1950s technology


Trailing Hose


Trailing Shoe


Slot Injector

The car and the exhaust pipe…

Nitrogen & Food Choice

Nitrogen on the Table

The influence of food choices on nitrogen emissions and the European environment.

Special Report of the European Nitrogen Assessment

TFRN LRTAP

THE TIMES

Scotland Edition

Friday April 25 2014 | thetimes.co.uk | No 71180

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Britain's livestock farm
suffer a "severe" loss of i
such a change in diet but th
environmental benefits, in
pollution of the air, water a
lower greenhouse gas emis
A team of scientists a
United Nations Economic
for Europe (Unece) studi
reducing nitrogen pollu
chemical fertiliser and ma
The task force on reacti
concluded that if everyon
became "demitarian" —
amount of meat and other a

28 January 2015

TIMES PAST — THE TIMES — FUTURE

Eat Less Meat

A vital message is buried in a new report on climate change

It is not alarmist to predict food shortages and price inflation within the next half century if we fail to change what we eat. The world's population, now roughly seven billion, is expected to rise to ten billion by 2050. More than 200 million hectares of forest have been cleared for farming in the past ten years and forest clearance in the Amazon alone continues at a rate equivalent to 93 football pitches an hour. In the meantime, by far the most costly use of farmland is for grazing cows and sheep.

Rising crop yields and better science will undoubtedly help with food supply, but rising prosperity will also give more humans a taste for beef and lamb. One option is to herd the bulk of the world's livestock indoors. The animals producing most of our red meat would never see the light of day or breathe fresh air. That might be economical but it would be neither compassionate nor healthy — for humans or the animals themselves. The right course is to raise livestock with due regard for animal welfare and retain meat as part of a balanced diet. That means eating less of it.

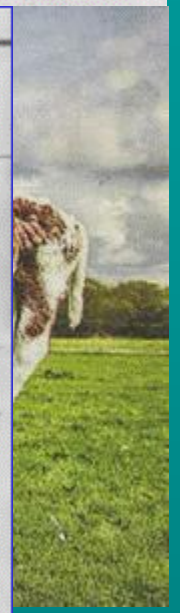
How much less? For Britons, 40 per cent less, according to the Department of Energy and Climate Change. The figure comes from a report on changes that the department says will have to be made to our lives to do our "fair share" towards limiting global carbon emissions.

Meat production is a carbon-intensive business, and the political urgency behind the report is the need to appear serious about carbon emissions in the build-up to a UN climate conference in Paris in November. The environmental urgency is another matter. It will be hotly debated long after the conference, whether or not the heads of state attending reach any sort of accord and whether or not world temperatures actually rise in line with scientists' projections.

What is not in doubt is the compelling case for cutting back on meat, regardless of its impact on global warming. A 30 per cent reduction in meat consumption would, a former chief medical officer has said, prevent 18,000 premature deaths a year in Britain. Globally, meat farming is a big cause of acid rain because of the high ammonia content in animal waste. It is a principal cause of deforestation but also of desertification as a result of over-grazing. The former drives down biodiversity. The latter hurts farm yields, and both trends will only worsen as demand for a more western diet grows among China's rapidly expanding middle class.

That demand will be used as an argument for more intensive factory farming of cattle and sheep. The technology exists and is being used to house huge new Chinese herds that live almost entirely indoors. This is neither an ethical nor a sustainable food future. The lesson of battery-farmed poultry and pork is that it depends on the over-use of antibiotics and produces meat that is too high in fat and low in protein to be worth the cost in animal welfare.

There is no doubt that freely grazing cattle are inefficient converters of farmland to food. A field the size of a football pitch produces, by weight, 60 times more fruit and vegetables than beef. This is not an argument for more industrialised farming, but for changing our habits. The US Department of Agriculture will shortly urge Americans to eat less meat. It is good advice. If we all did, we would be healthier and might even enjoy it more.



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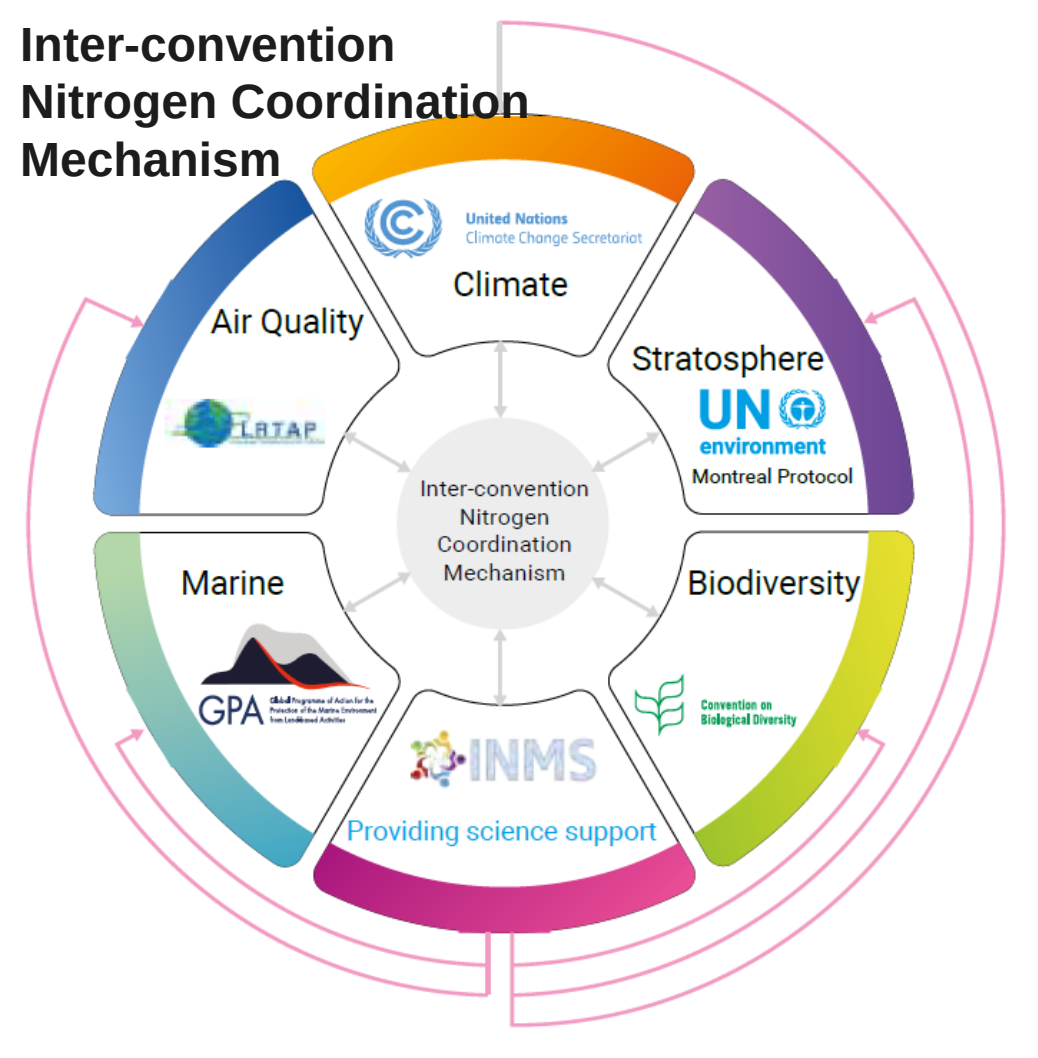
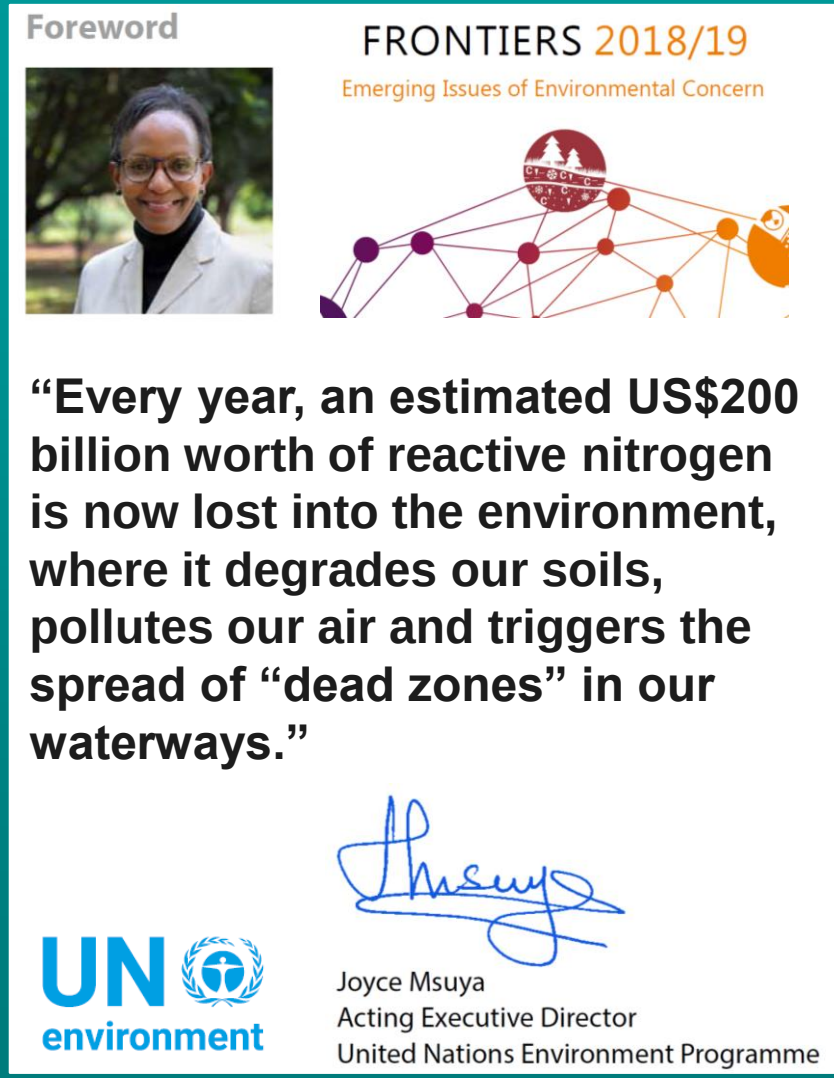
l., 2014

Towards improved nitrogen science and policy coordination





Sutton et al. The Nitrogen Fix *Frontiers 2019/2019*

Nitrogen Resolution UNEA 4/14

Should the UN agree a goal to "Halve Nitrogen Waste" by 2030?

- Challenge to more than double economy-wide NUE using all available options (crop, animal, food waste, food choice, sewage, combustion etc)
- Roughly halve the amount of N fertilizers produced from N_2 fixation (global saving ~€100 billion / year)
- Massive economic and environmental benefits for climate, air, water, health biodiversity etc.
- Huge business opportunities for circular economy innovation and business goals (*e.g. 20% of EU fertilizer made from recycled sources*)

UN environment

Towards the INMS
International Nitrogen Management System
www.inms.international

UN Campaign on Sustainable Nitrogen Management

23-24 October 2019

NITROGEN FOR LIFE

Colombo Declaration

on Sustainable Nitrogen Management

1. Endorse the proposed Roadmap for Action on Sustainable Nitrogen Management 2020-2022, including its activities as one of the instruments to establish an Inter-convention Nitrogen Coordination Mechanism and secretariat to better facilitate communication and coherence across nitrogen policies, consistent with mandates of existing conventions and MEAs,

2. Call upon UN agencies and other international organizations, development partners, philanthropic agencies, academic and civil society organizations, to support the implementation of this Declaration, through the establishment of mechanisms of cooperation to mobilize human, financial and technical resources, including capacity building and transfer of know-how and technology, for this purpose;

3. Agree that countries should consider, in line with their national circumstances and where relevant, to:

   3.1 Develop and implement comprehensive policies on Sustainable Nitrogen Management;

   3.2 Develop national roadmaps for sustainable nitrogen management, with an ambition to halve nitrogen waste by 2030;

   3.3 Conduct comprehensive assessments on quantitative and qualitative nitrogen cycling covering scientific aspects, policy, regulation and implementation;

   3.4 Promote innovation on anthropogenic nitrogen use and recycling, emphasizing the opportunities for the circular economy;

The Nitrogen & Phosphorus Bottom Line

- N & P affect climate, air quality, water pollution, biodiversity & ozone, relevant for multiple SDGs
- Past fragmentation has limited progress with N & P: A joined-up perspective offers multiple win-wins
- Measures require better use of fertilizers, urine, dung, with business opportunities from efficiency savings
  - Market scaling of improved fertilizer products (from 1% to 80%)
  - Commitment to Circular Economy (min "20% recycled N")
  - Economic tools to improve farmer confidence in measures
  - Avoiding excess meat and dairy multiplies the benefits
- Interconvention Nitrogen Co-Ordination Mechanism: INCOM to boost INCOME
- Colombo Declaration (Oct 2019): ambition to halve nitrogen waste by 2030 and save $100 billion annually.

The Nutrient Nexus
a master-key to many global challenges

Our Nutrient World
The challenge to produce more food and energy with less pollution