Air Pollution Effects Research in a Changing World

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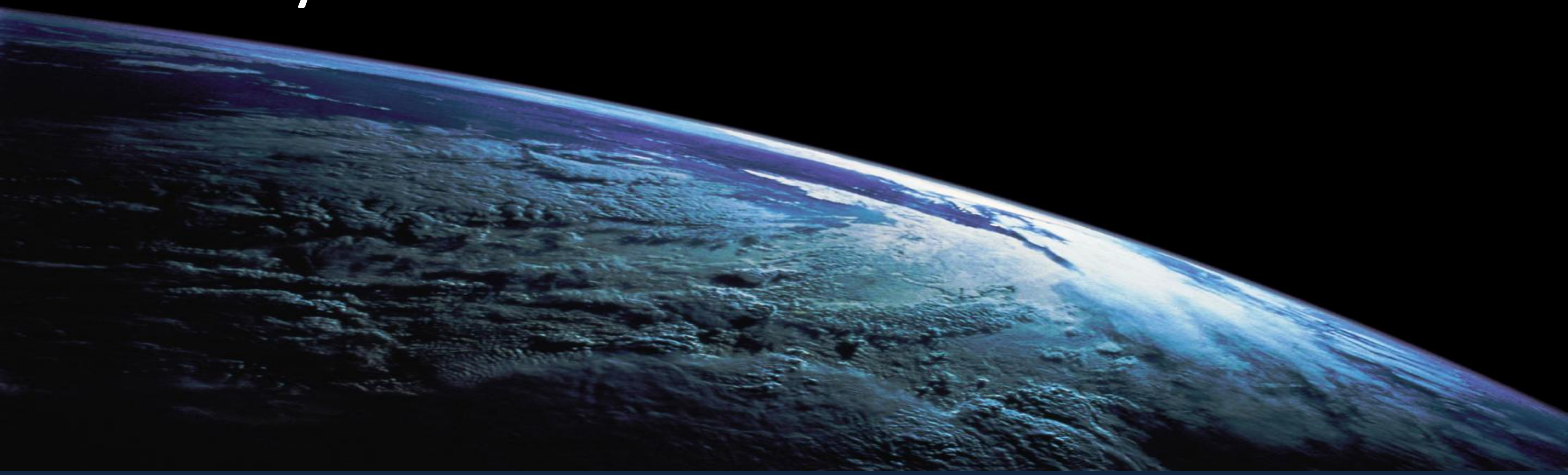

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Over the 40 years since CAPER started we have seen massive changes in the UK pollution climate

RoTAP reported that in rural areas of the UK between 1988/1990 and 2008/2010:-

- Mean [SO_2] declined by 96% and S deposition decreased by 77%
- Mean [NO_2] declined by 50% and oxidised N deposition declined by 24%
- Maximum daily mean [O_3] concentrations declined by 30%
- Lead emissions declined by 98% and mercury emissions declined by 83%
- NH_3 emissions declined by 21%

BUT

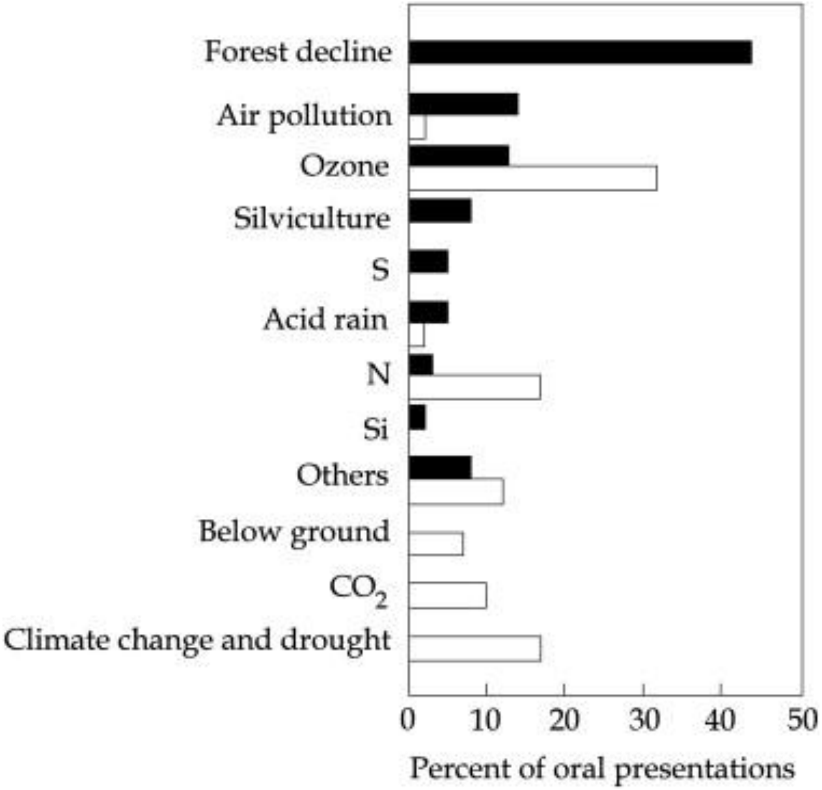
- There has been no signification change in reduced N deposition
- Background mean O_3 concentrations increased by 10%

AND

- Critical loads for N deposition and critical levels of O_3 are still exceeded over large areas

and the focus of CAPER research has also changed as well

- Less on sulphur dioxide, nitrogen oxides
- More on ozone, N deposition
- Forest decline dominant in the 80s, now ignored
- Research linked to policy in a two-way process
- Evidence of impacts from CAPER and other science groups has demonstrated the benefit of measures to reduce emissions



RoTAP pollution effects research priorities for the UK are broadly reflected in this week's CAPER programme

- Better understanding of the terrestrial N budget and fate of deposited N
- Better tools for active restoration management for effects of N
- Tools to assess ecological benefits of reducing N deposition
- Further research to assess N impacts on sensitive ecosystems
- Implications of changes in pH and DOC for metal release
- Impacts of reduced as opposed to oxidised N deposition
- Further development of flux based assessment for ozone
- Better ozone dose-response relationships for background concentrations

RoTAP also identified some more generic priorities

- Enhance existing soil and vegetation monitoring to better detect change
- Closer integration of policy evaluation for air pollution and biodiversity
- Integrated national assessment of implications of future scenarios for provision of ecosystem services
- Focus on hemispheric or global policies to reduce impacts of ozone
- N deposition and ozone interactive effects
- Experimental and modelling studies to better understand interactions with climate change

Which perhaps reflect other changes in our research focus over the last 40 years?

- From pots/chamber/ field studies to landscapes
- From individual impacts to integrated approaches
- From individual experiments to regional risk assessment
- From ecosystem impacts to ecosystem services
- From single disciplines towards multi- disciplinary
- From national to regional to global
- From short-term acute effects to long-term chronic effects

But what about the future?

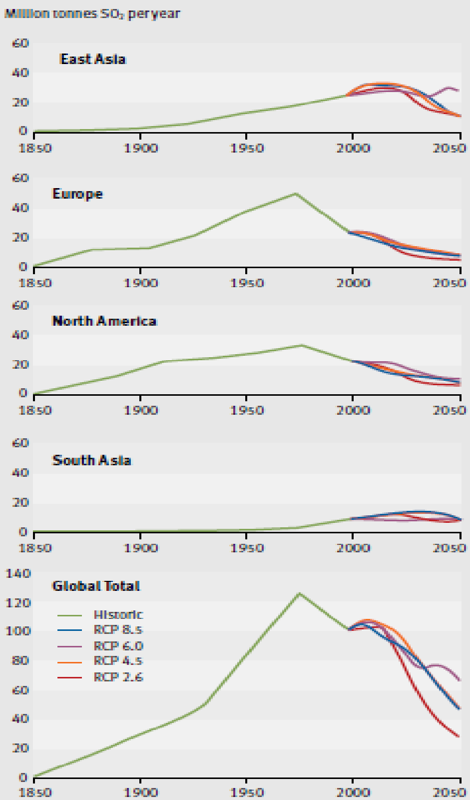
- How will the air pollution climate change?
- Are there new pollutants or sources to consider?
- What are the critical new questions and challenges?
- What are the key policy drivers?
- Do we have the process understanding needed for analysing multi-stress effects?
- Do we have the facilities and expertise we need?
- Are we communicating the continued importance of air pollution effectively
- Are there new sources of funding and support?

We want to argue today that increasingly the main policy issues and scientific questions for future air pollution effects research reflect a changing world rather than a changing country

- This is very much a personal view
- Not a comprehensive analysis
- Many issues will be neglected or ignored
- More a basis for discussion than a detailed critique
- Consider the period from now to 2030
- Use the recent GEO5 report of UNEP as a starting point

Sulphur emissions fall globally but not in Asia, and acidification is a potential concern

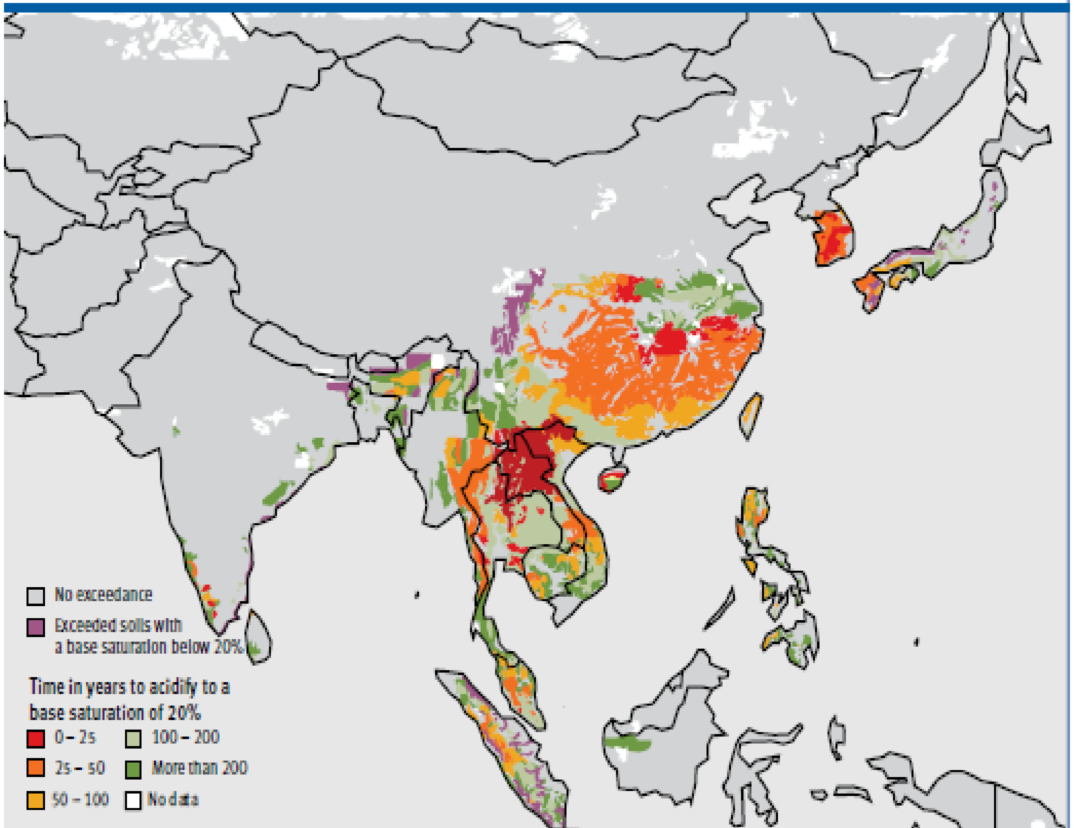
Figure 2.8 Regional trends in sulphur dioxide emissions, 1850–2050



Emission trends from 1850–2000 and four Representative Concentration Pathway (RCP) scenarios from 2000–2050, developed to contribute to the Fifth Assessment of the IPCC, are shown for the four source regions and for the global total from the hemispheric transport of air pollution (HTAP) multi-model experiments.

Source: HTAP 2010

Figure 2.9 Areas at risk and timeframe for acidification damage in Asia

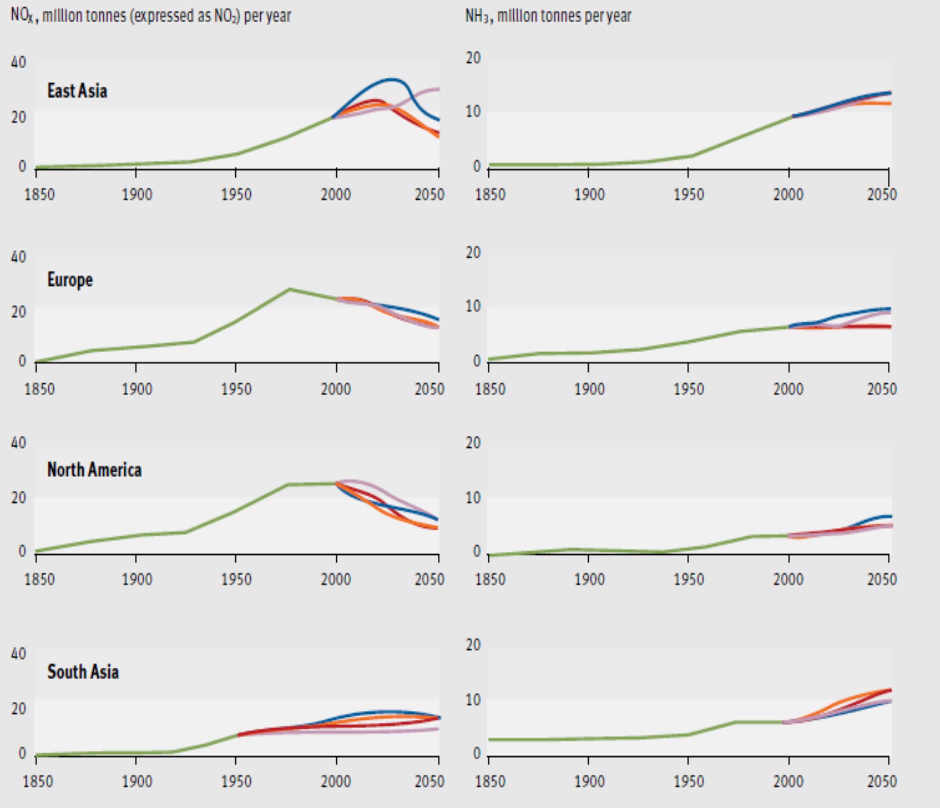


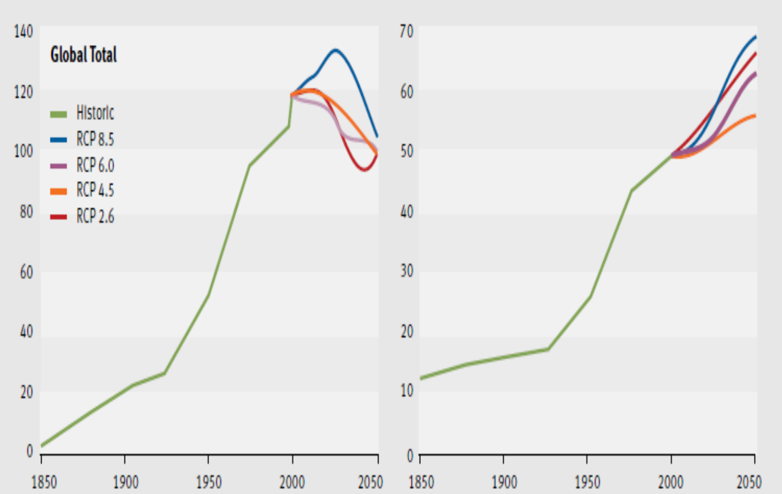
This shows the time taken to acidify soils down to a base saturation of 20%, which would be associated with a reduction in soil pH. Below a base saturation of 20%, more serious impacts of acidification can occur (such as increases in soil water aluminium which is toxic to plant roots). The projections are based on emissions according to the IPCC SRES A2 scenario for 2050.

Source: Hicks et al. 2008.

Oxidised and reduced nitrogen show different trends
Global NHx emissions continue to rise
NOy emissions fall globally but increase in Asia

Figure 2.10 Regional trends in emissions of nitrogen oxides and ammonia, 1850–2050





Emission trends from 1850–2000 and four RCP scenarios from 2000–2050, developed to contribute to the Fifth Assessment of the IPCC, are shown for the four regions and for the global total from the HTAP multi-model experiments. Total nitrogen oxide emissions (left) remain more or less constant at global scale while global ammonia emissions (right) are projected to increase in most scenarios.

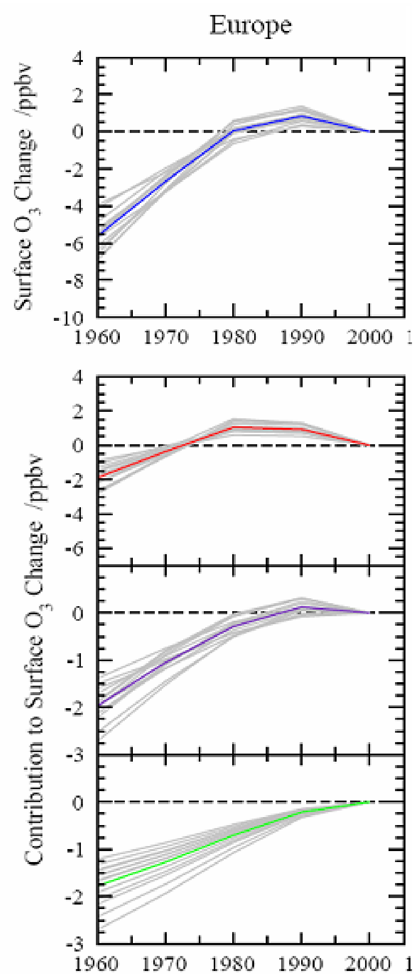
Recent changes in annual mean O_3 in the EU primarily due to global drivers

Total change

Within EU

Outside of EU

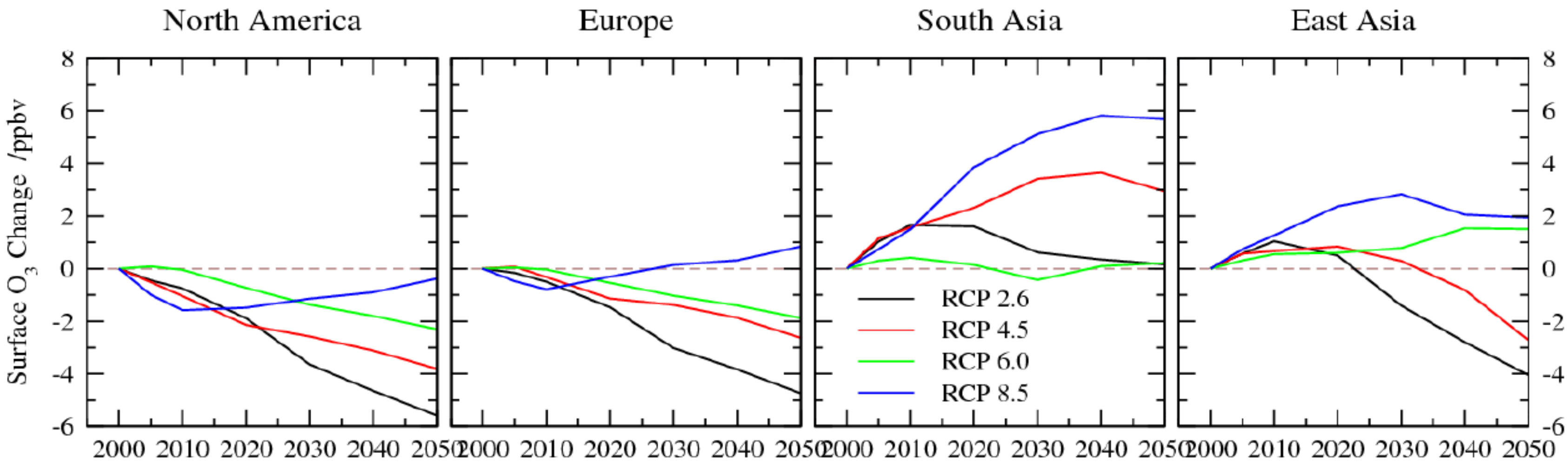
Methane



- Annual average - large region
- Small reductions in O_3 during 1980-2000, largest changes (6 ppb) happened before.
- O_3 reductions attributable to EU emissions partly compensated by increasing emissions elsewhere
- Important role for (global) CH_4 → 30-50 %
- Taken together changes in O_3 from outside EU and CH_4 are larger than within EU (60-70 % of total)
- External O_3 becomes more important when 'local' sources are more regulated
- More important at 'lower' concentrations

Wild et al., ACP, 2012

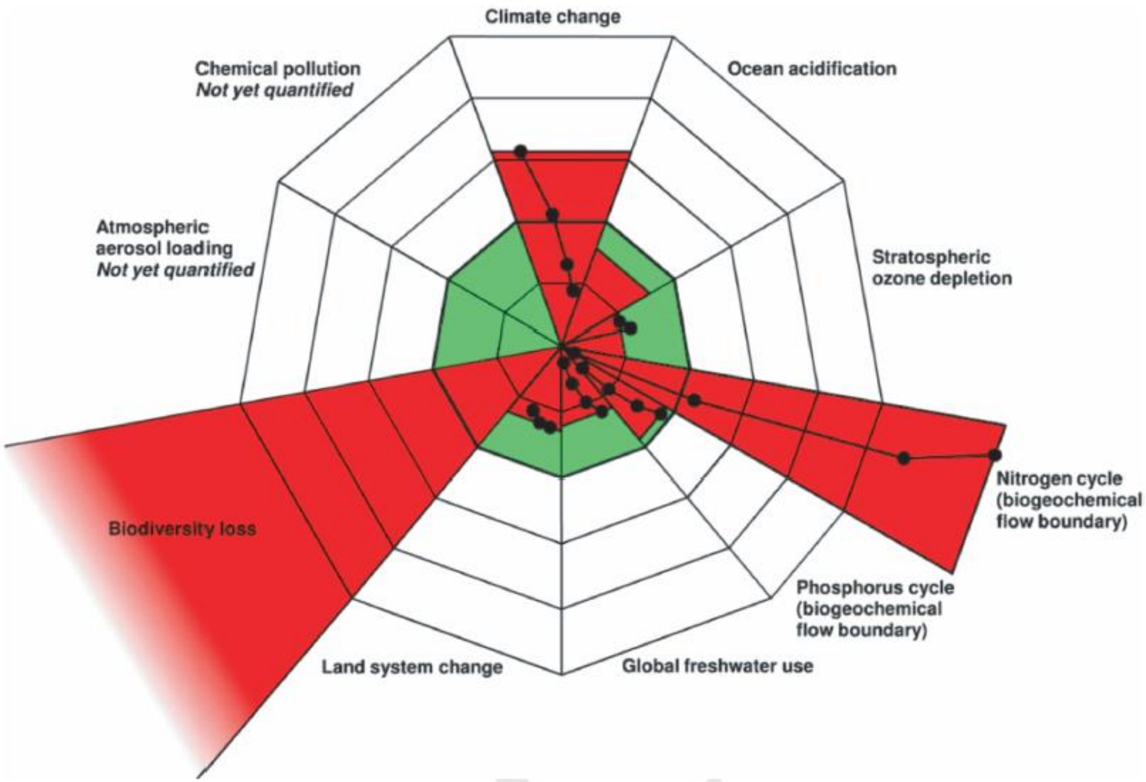
Future increases in ozone primarily in Asia rather than Europe and North America



HTAP, 2010

…but time course for concentrations of O_3 and other pollutants will largely depend on when and how specific control options are implemented

But we need to put these changes into the wider context of global environmental challenges



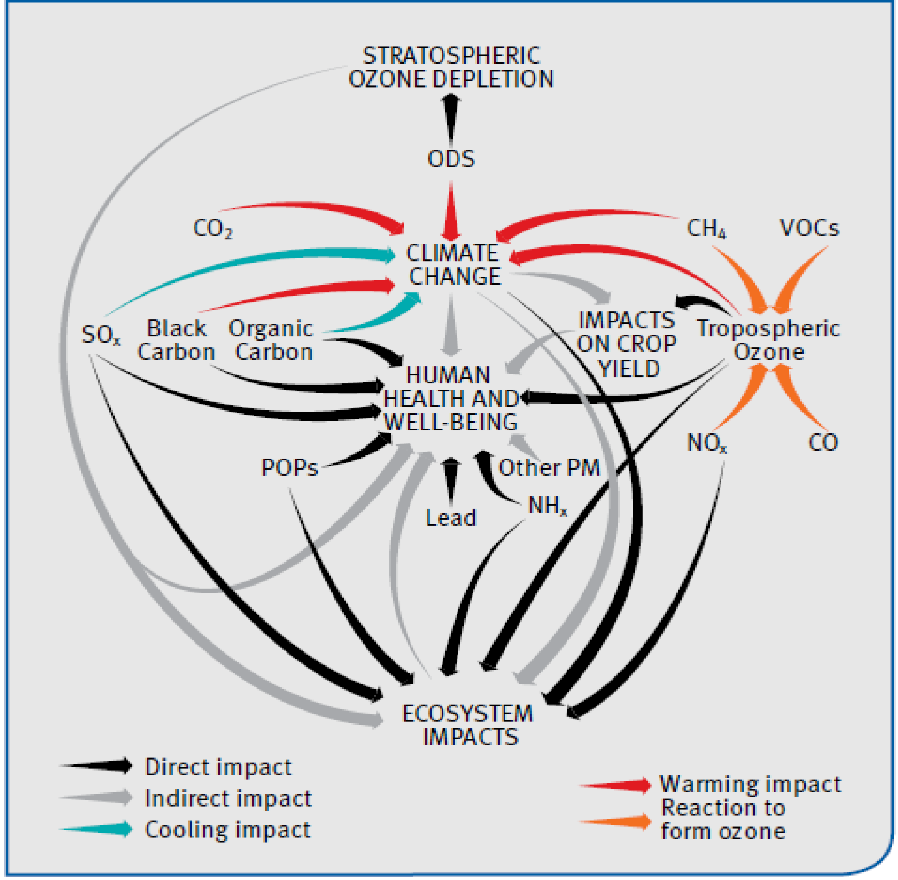
The green areas indicate 'safe' levels of human interference; red areas indicate the level of interference at present. The dots indicate evolution by decade from the 1950s

Or more broadly, air pollution is linked to a whole set of global drivers and policy challenges that include….

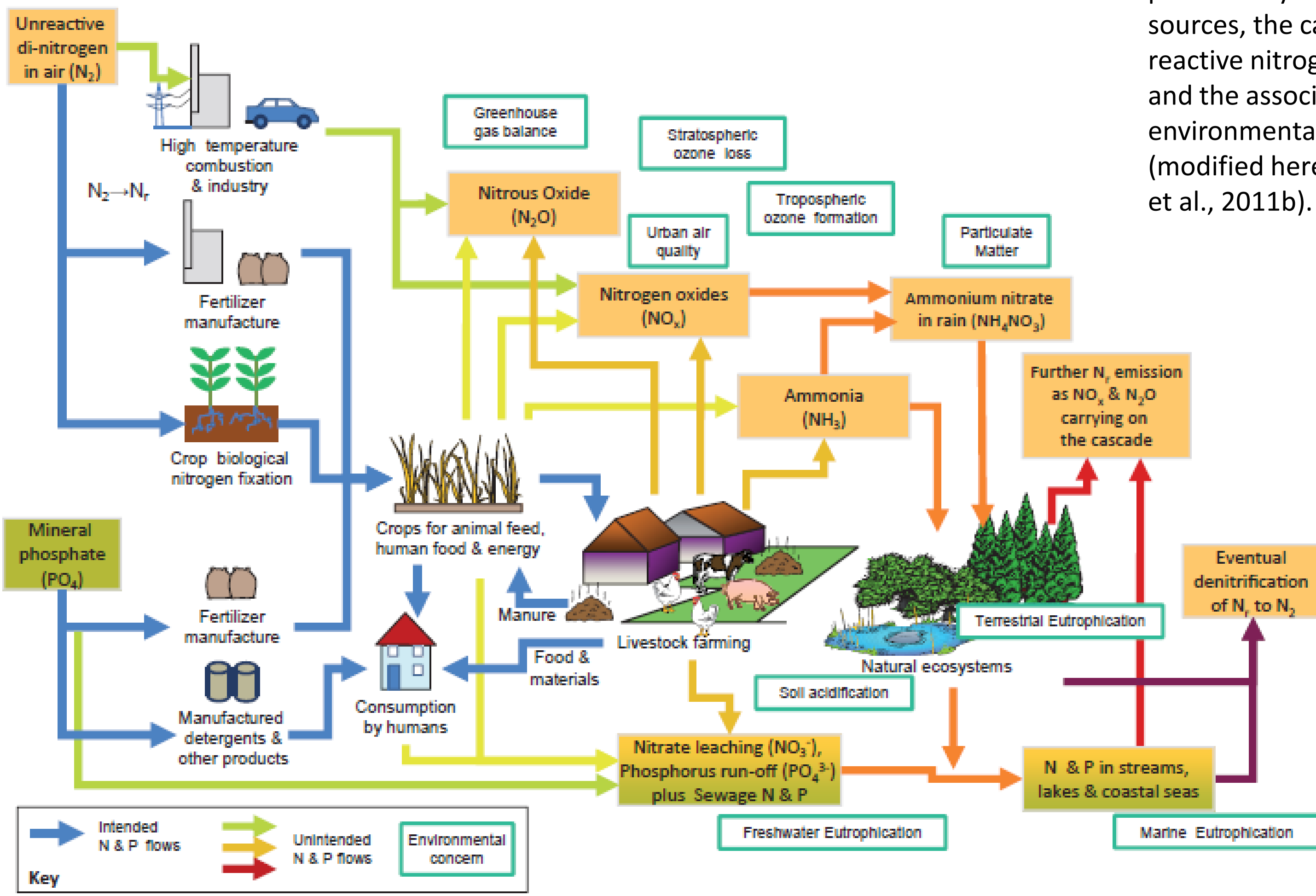
- Climate change
- Growth of population and consumption
- Urbanisation
- Food security
- Public health
- Loss of biodiversity and degrading ecosystem services
- Major political and social change
- Environmental justice

… and all of the challenges related to the global atmosphere are closely inter-linked; policy is moving towards more integrated approaches

Figure 2.1 Impacts of and links between selected substances emitted to the atmosphere

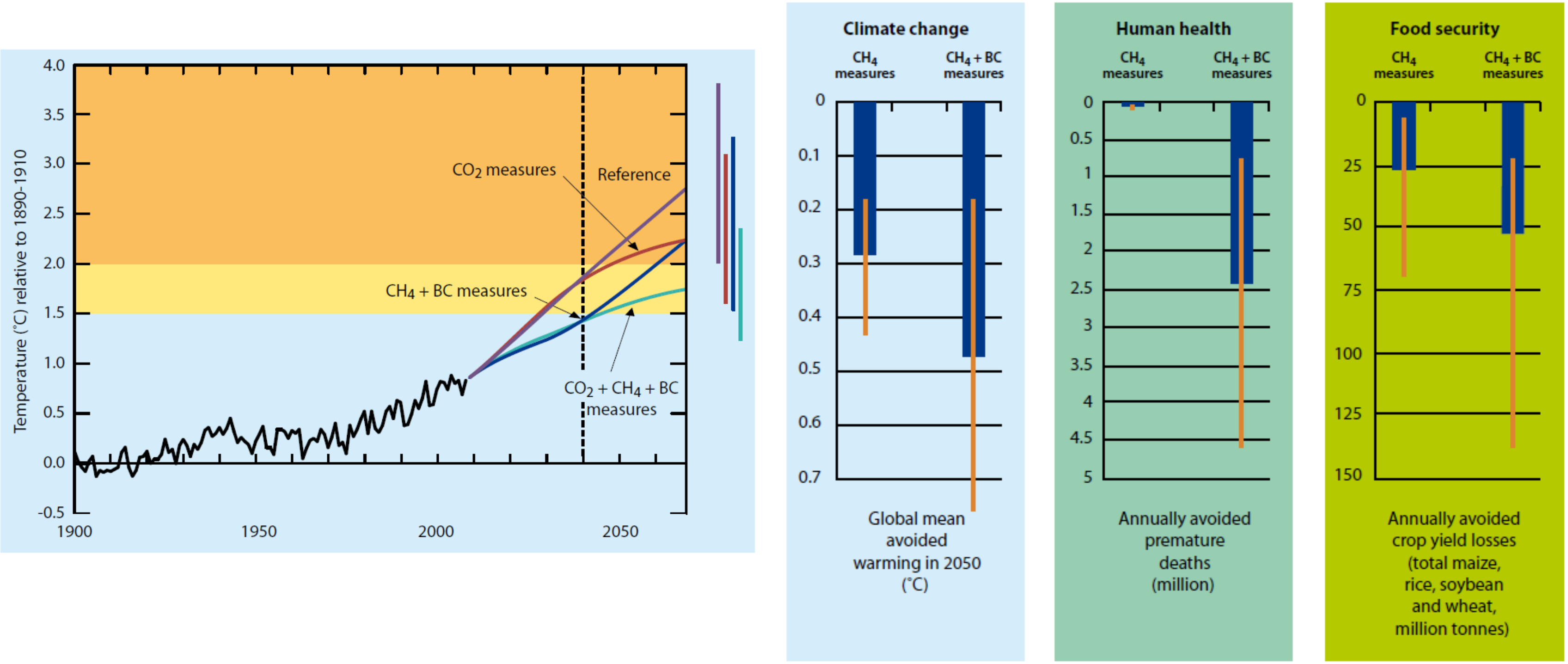


With the 'nitrogen cascade' as a nice example



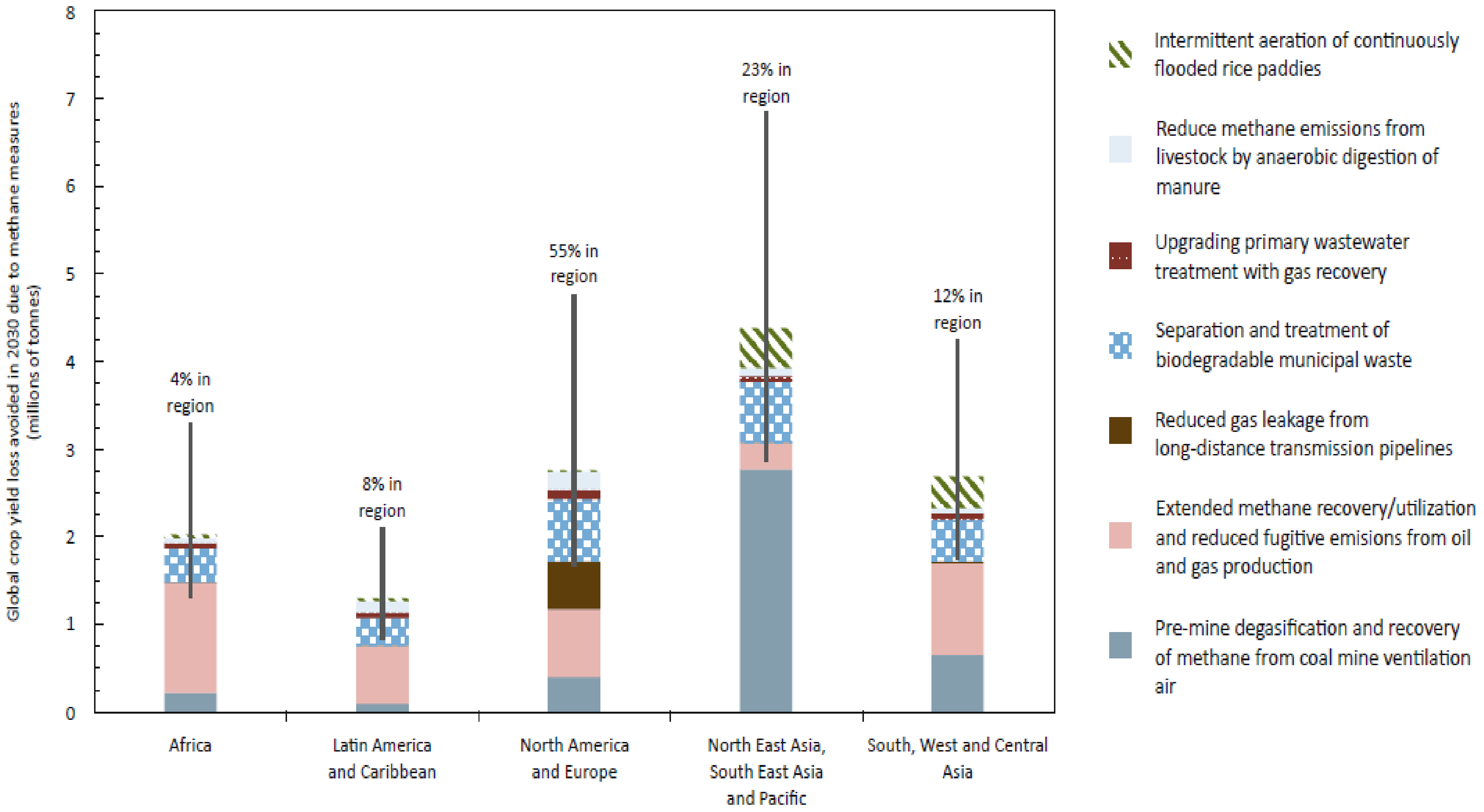
Simplified overview of nitrogen (N) and phosphorus (P) flows highlighting major present-day anthropogenic sources, the cascade of reactive nitrogen (Nr) forms and the associated environmental concerns (modified here from Sutton et al., 2011b).

This integrative approach has been applied, e.g. to assess the co-benefits of measures to reduce short-lived climate forcers ..but the methods used involved many empirical simplifications

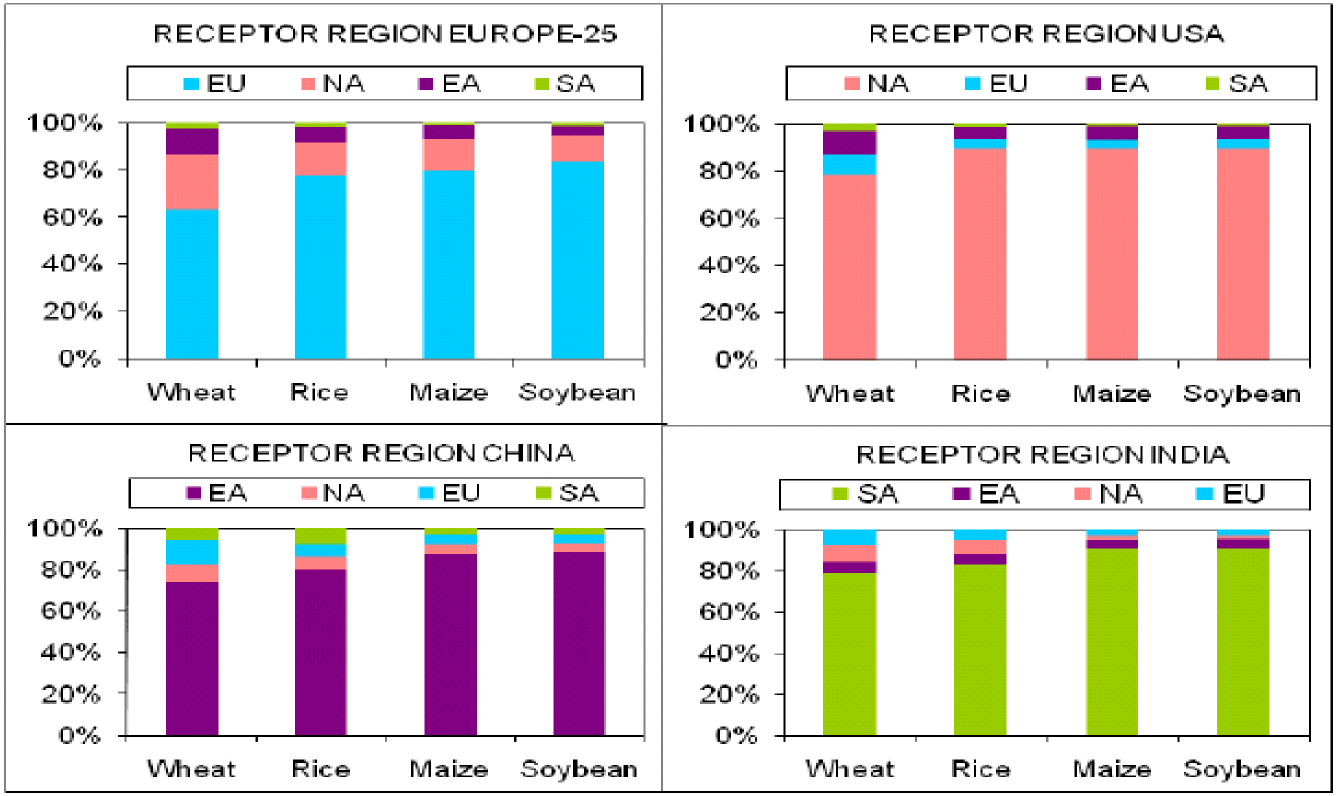


Allows benefits of measures to reduce methane and black carbon emissions to be assessed in terms of climate, human health and food security….but not a wider range of effects

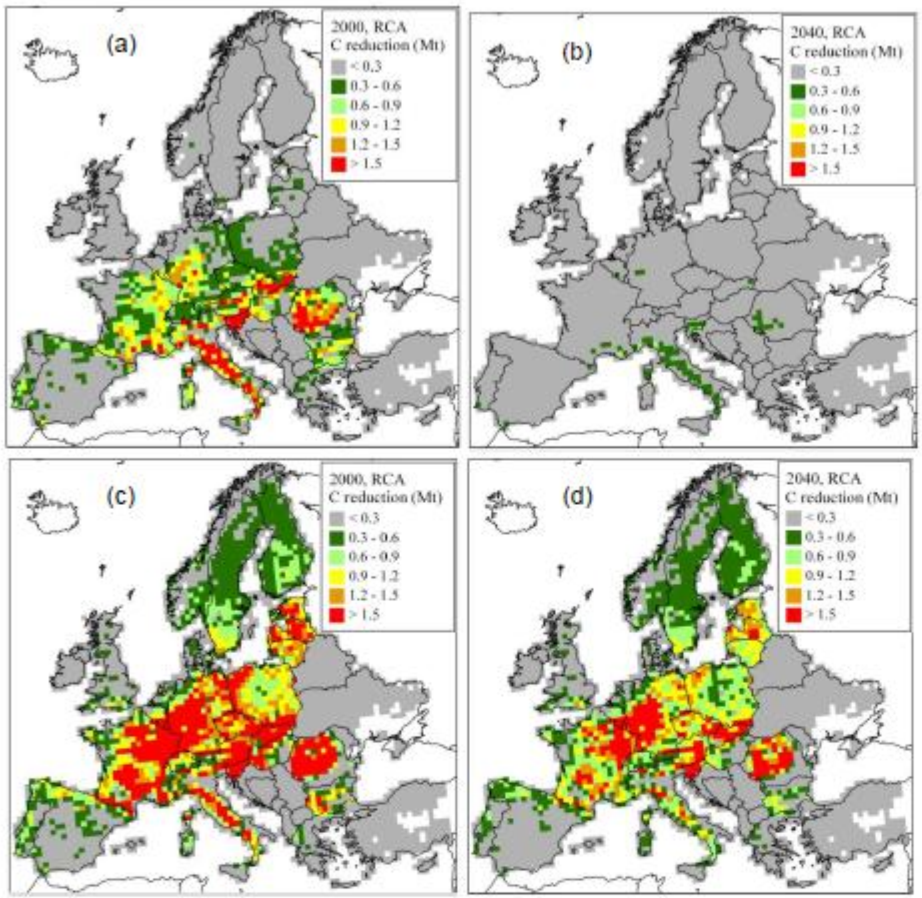
This analysis can be linked to specific policy measures in different regions



Detailed analysis possible of benefits of for different crops and regions but based on many assumptions, e.g. use of concentration not flux-based relationships

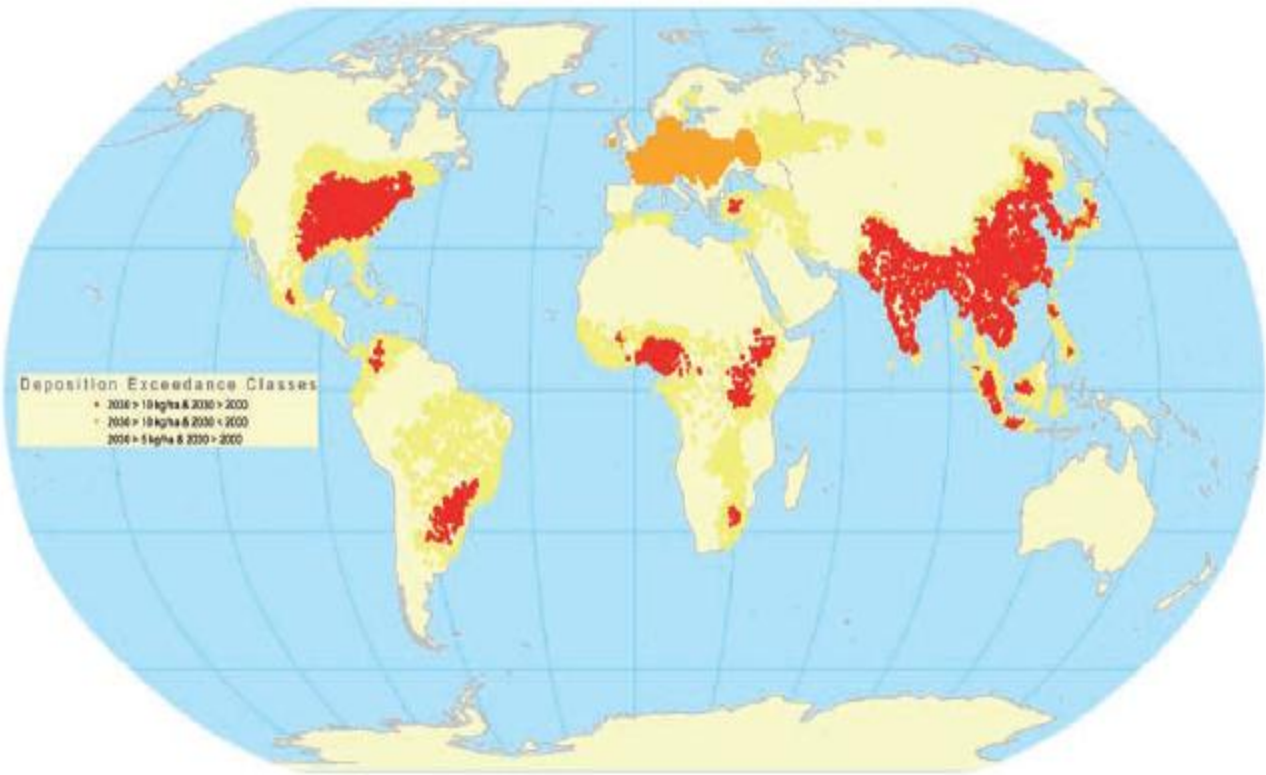


Ozone is also a threat to ecosystem services such as C sequestration
Same empirical approach applied across Europe
Very different results using concentration or dose



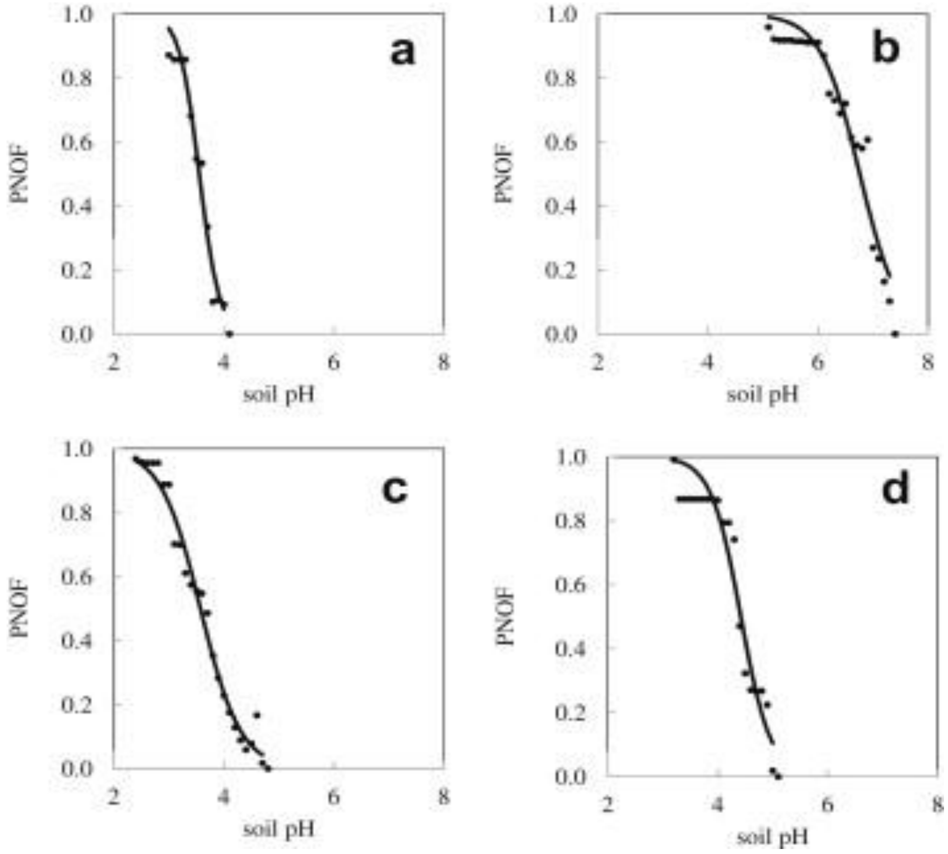
Absolute reduction (Mt C) in C storage in the living biomass of trees due to ozone applying AOT40 in (a) 2000 and (b) 2040, and PODY in (c) 2000 and (d) 2040, calculated from RCA input data and applying the generic parameterisation in DO3SE (Y = 1 nmol m-2 PLA s-1) (Büker et al., 2012).

N deposition is recognised as a threat to global biodiversity.. but only assessed in terms of critical threshold exceedance



Distribution of Nr deposition classes and exceedance of deposition levels in the period 2000-2030 on Protected Areas (PAs) under the Convention on Biological Diversity (Bleeker et al., 2011; UNEP, 2012).

Very few attempts to systematically assess potential risk.. and very few experiments on the ground



Fraction of species potentially lost as a function of pH for

a) tropical moist broadleaved forest

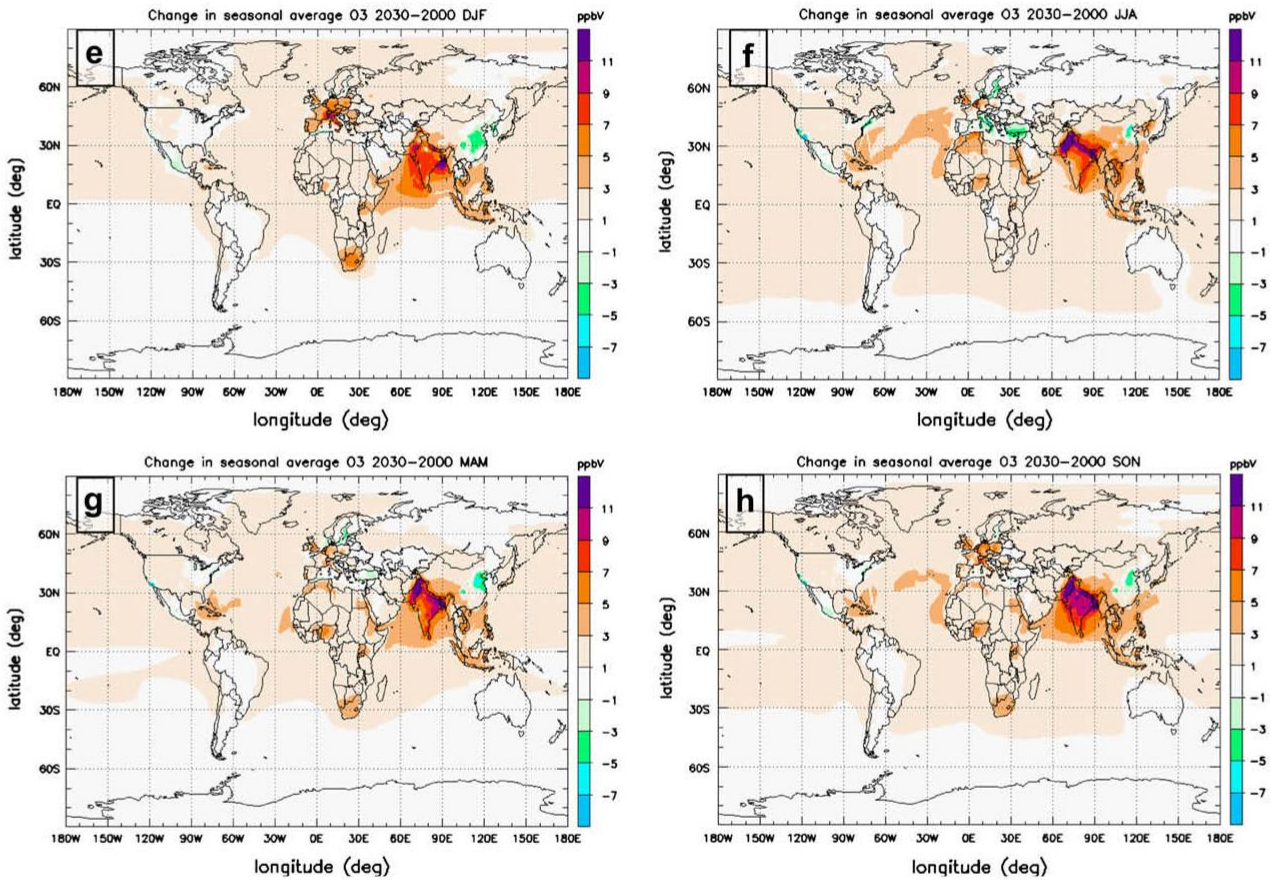
b) Desert and xeric shrubland,

c) temperate broadleaf mixed forest

d) temperature grassland, savannah and shrub

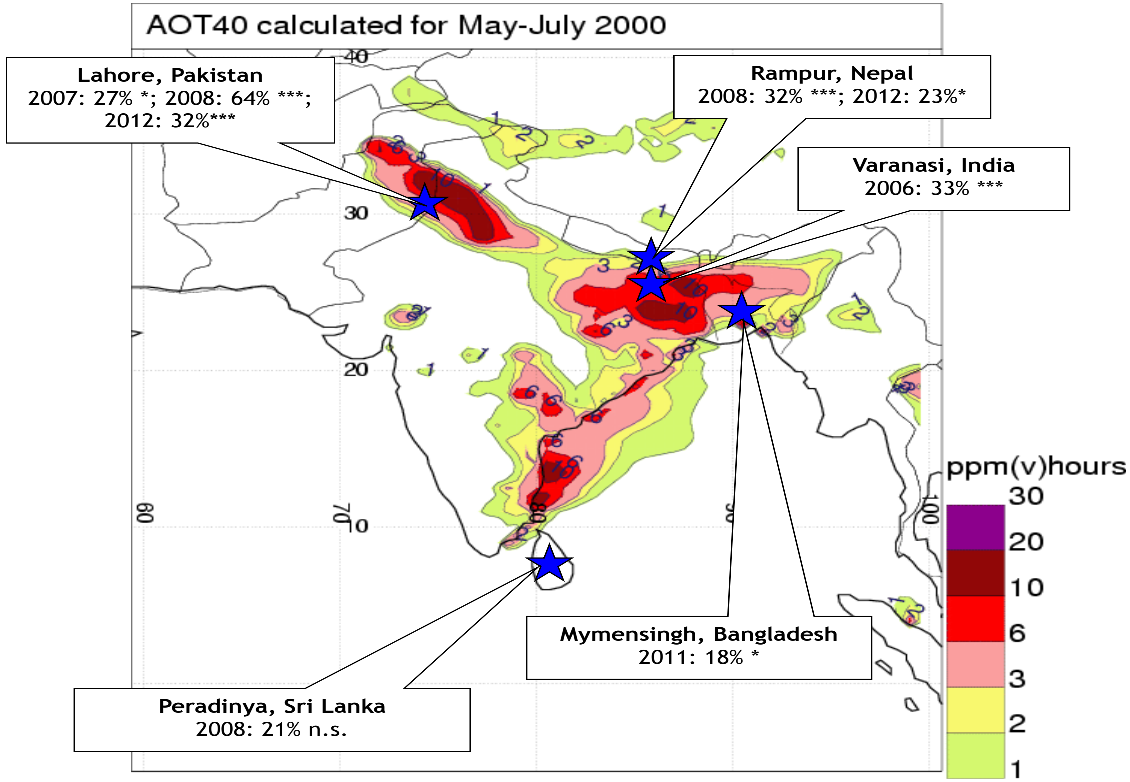
Azvedo et al, 2012

For ozone, global models highlight south Asia as a region with a major threat to food security



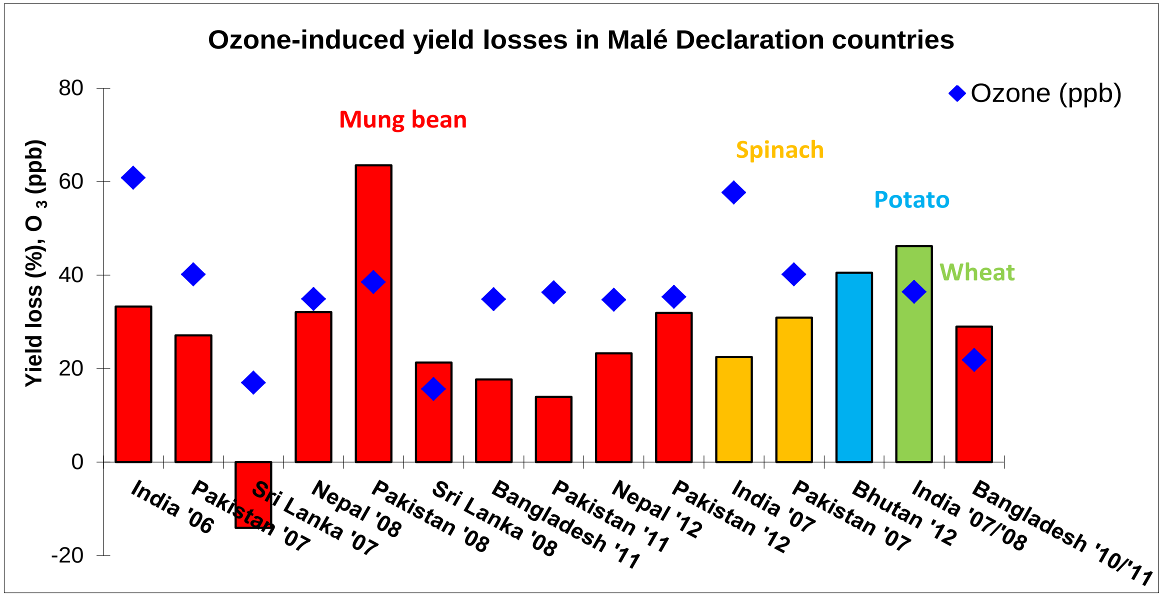
Change in seasonal surface ozone concentration by 2030 under a CLE scenario (van Dingenen et al., 2009)

Do the risks from global or regional models match the results of local experiments ?



MATCH modelled O_3 concentrations (year 2000) presented as 3-month AOT40 values for May to July. Blue stars represent South Asian experimental sites where EDU chemical protectant study for mung bean was conducted during equivalent months for assessment of ozone effect on yields (n.s. = not significant; * moderately significant and *** highly significant).

…..and support a conclusion that local crops already suffer significant yield losses due to ozone



Ozone-induced yield losses for Mung bean, spinach, potato and wheat in various South Asian countries as recorded during field experiments conducted between 2006 and 2012 as part of the RAPIDC project.

But we shouldn't just focus on the big global picture…local effects of point sources are also important in many parts of the world….

- HF impacts on sensitive crops around brickworks
- Source recognised but not effects on crops - most attention paid to reducing black carbon emissions
- Significant CAPER issue in 1970s/1980s
- Many such point sources around the world to meet consumption locally and in developed world
- Effects of SO_2, metals, and many other pollutants still important in parts of Asia, Latin America and Africa
- Potential for knowledge exchange and awareness raising

and urban pollution is a major issue in many rapidly developing cities

•Intense media interest in health effects or urban air pollution e.g. in China

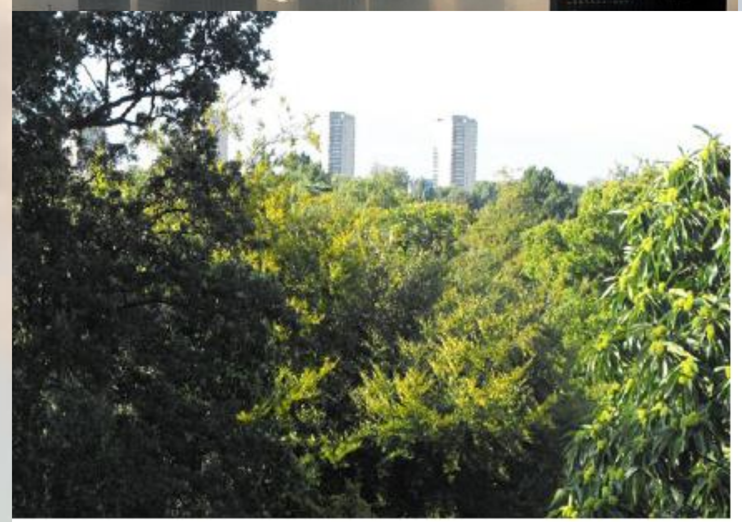
•Value of tree planting and green spaces in decreasing pollution levels and health effects

•Impacts on yields in urban subsistence agriculture

•Few studies but massive yield losses , probably due to SO_2 and NO_x , shown in China and India

•Greater problems with pests and diseases?

•Urban cropping as a contaminant pathway, e.g. for metals



What does this mean for air pollution effects science priorities?

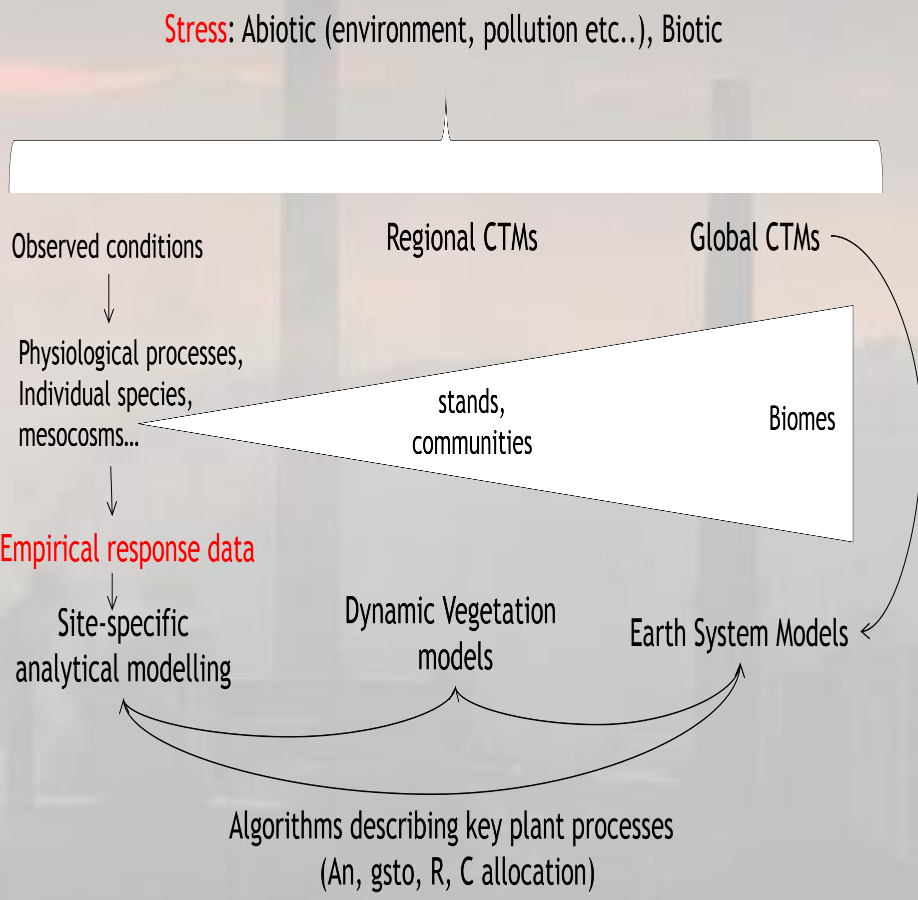
We suggest the following three 'big' themes:-

- building new integrative models with multiple factors based on stronger mechanistic understanding, linking targeted experimental studies through to earth system science models
- internationalisation of the science – global and regional assessments, building expertise and support for local scientists, understanding if and how our models can best be applied elsewhere, demonstrating the full benefits of pollution control
- integrating pollution effects science into the broader science effort to address key global challenges - e.g. solutions to increasing food production, measures to protect biodiversity and ecosystem services, better management of the nutrient cycle, consumption and life cycle based analysis

Our analysis assumes focuses on S, N, and ozone and assumes that there are no major new or neglected pollutants to consider (but HNO_3, HCl....)

Building new integrative mechanistic models

- Many of our current tools (critical levels/loads, exposure-response relationships...) are empirical and focus on one pollutant
- Programmes starting to develop new models at different scales based on new experimental data
- Water stress and ozone – important new mechanistic understanding with potential to develop new catchment scale models
- Ozone, CO_2 and N – new experiments and models developing new insights on interactions both above- and below-ground

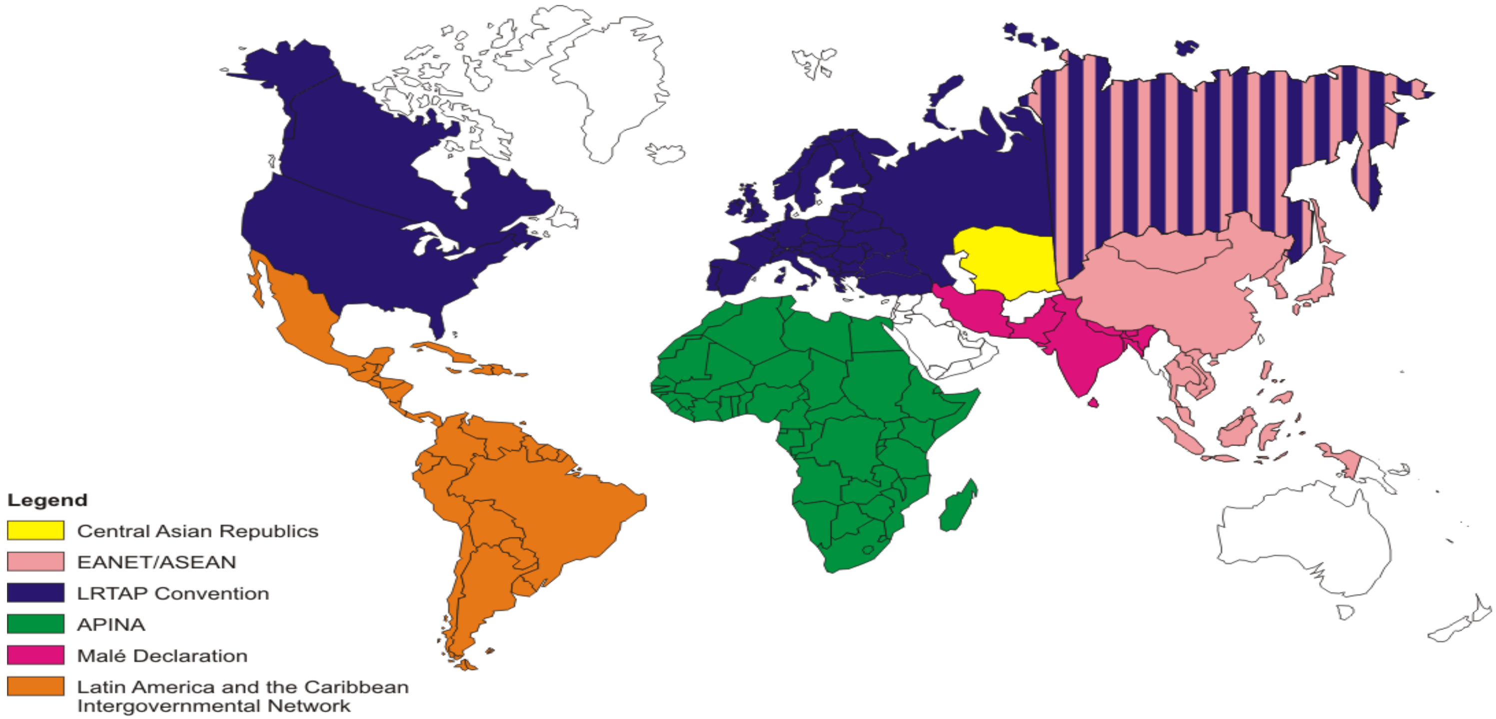


Supporting international air pollution effects science

How can we best support scientists on the ground in key priority areas for the future?

- Lots of programmes and engagement already in place
- Experimental studies in UK facilities to complement field studies overseas
- PhD training – but UK government policy now a major barrier
- Knowledge exchange and capacity building
- Providing risk assessment tools adapted for local conditions
- Improved rural monitoring of exposure and effects
- Engagement with new regional/global networks

Are there new regional policy forums with which we should engage more?



Types:

- Binding International Treaty Organisations
- Regional Inter-governmental Co-operation Agreements and Declarations
- International Research Initiatives and Programmes

Are there national and international agencies we need to engage with more strongly …and are there new funding sources we can approach??

- Global Environmental Facility (GEF) barely recognising air pollution issues
- How far have FAO and other global agriculture agencies considered air pollution?
- CBD identifies N deposition as a threat to what extent but it is supporting action and research?
- UK Research Council/DfiD programmes?
- Global charities addressing poverty equity and health?
- New UK interest – Plantlife, Woodland Trust, others….?

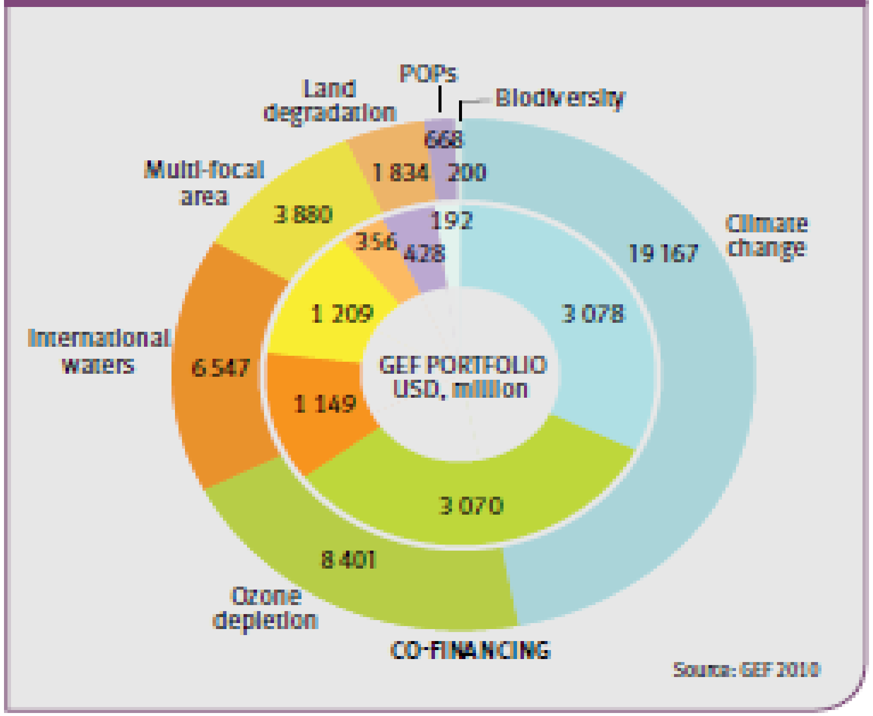


Figure 17.3: GEF portfolio and co-financing allocations by focal area, 1991–2010

Integrating into broader science programmes

- Examples already, mainly related to empirical risk assessment – e.g. reducing SLCFs as part of the response to climate change
- Integrating effects science into a wider policy framework, e.g. European Nitrogen Assessment, International Nitrogen Initiative
- Identifying specific solutions for food security and public health, e.g. cultivar selection for ozone tolerance is possible but rarely applied in practice, and needs to be integrated with selection for other traits
- Water shortages under climate change...e.g. links to ozone, and threats in critical areas (e.g. Northern India) where both are predicted to become more severe
- Fracking and shale gas exploitation – impacts of local NOx emissions, global implications of increased methane emissions
- Arctic warming, with shipping and exploitation of energy reserves – effects of sensitive local ecosystems, release of accumulated metals....

Do we have the necessary facilities and expertise?

UK science has led in many areas in the past and still makes major contributions to air pollution science and support of policy analysis…but…..

•Loss of key facilities e.g. for ozone exposure

•Future of long-term N experiments?

•A lot of us are getting old….generational change

•Limited funding to support major new programmes

•Less support for students than in past

…and other countries are investing significantly in building new facilities and expertise

Are we communicating these issues effectively?

As a science community, we have worked effectively with UK government and agencies and within CLRTAP but there are other challenges

e.g. problems of communicating key messages on pollution and agriculture in India

- Farmers are aware of changing yields but often not the causes
- Scientists and research institutes are aware of the issue but lack resources
- Government won't accept evidence or ask for more proof
- Participatory approaches (e.g. PGIS) to inform and empower local communities?
- Providing stronger evidence of socio-economic benefits of action

Use of citizen science e.g. OPAL

- Very effective at getting people engaged with nature but do they understand the significance of air pollution?

New media? Streaming CAPER? Video-link talks from abroad?

Engagement with a wider range of policy stakeholders

in summary....

•there remain many important air pollution issues within the UK that remain to be addressed......

•as well as a whole set of critical global environmental challenges to which air pollution is clearly linked, although this is not always fully recognised...

•UK science is already contributed relevant important new mechanistic understanding from experimental and modelling studies...

•But it is important to recognise the nature of the new challenges that we face globally and ensure our science remains relevant and useful

Any comments???