

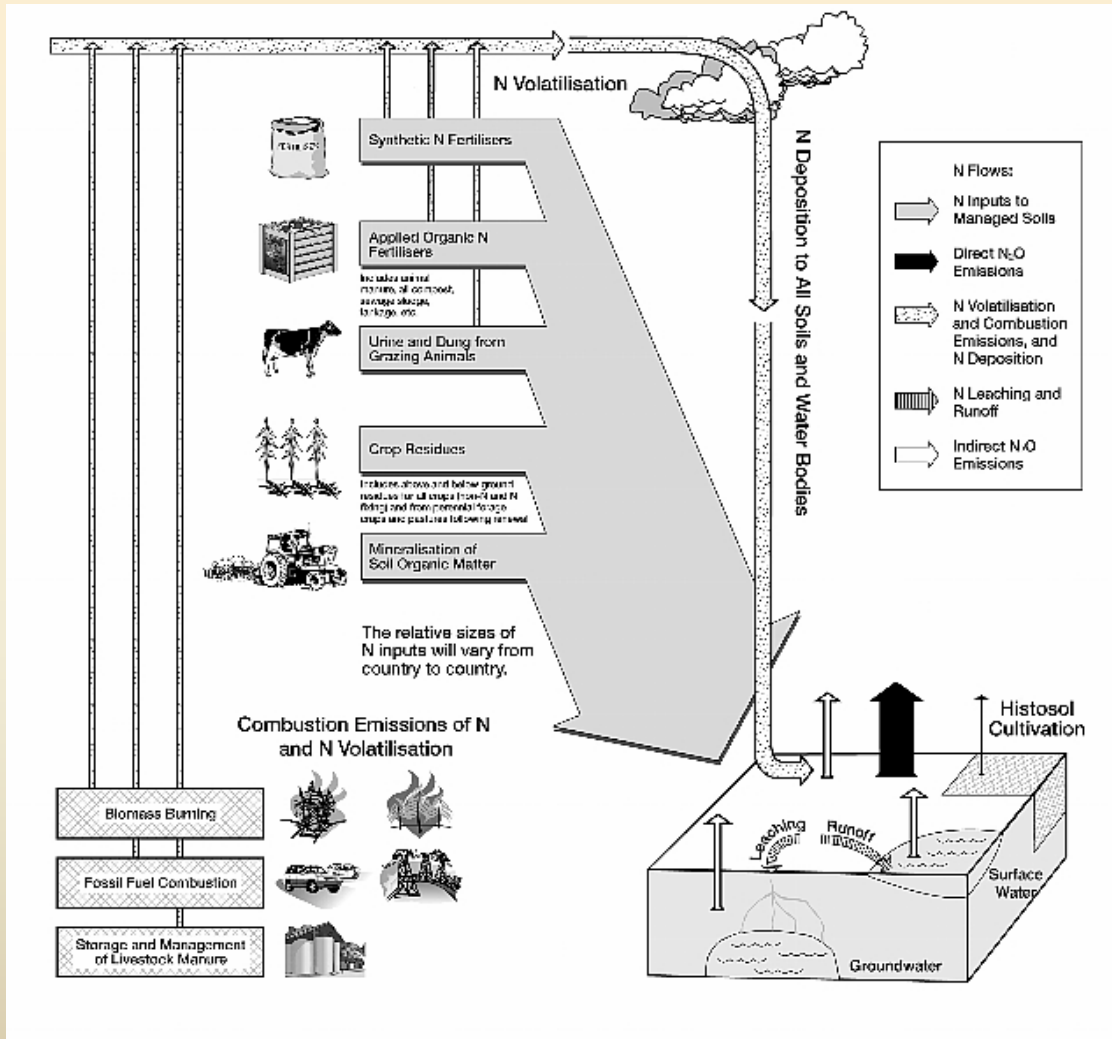


IPCC Methodology for Agriculture: Relevance to N₂O mitigation

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Figure 11.1. Sources and pathways of N that result in direct and indirect N₂O emissions from soils and waters.



(IPCC, 2006)

Figure 11.2 Decision tree for direct N₂O emissions from managed soils

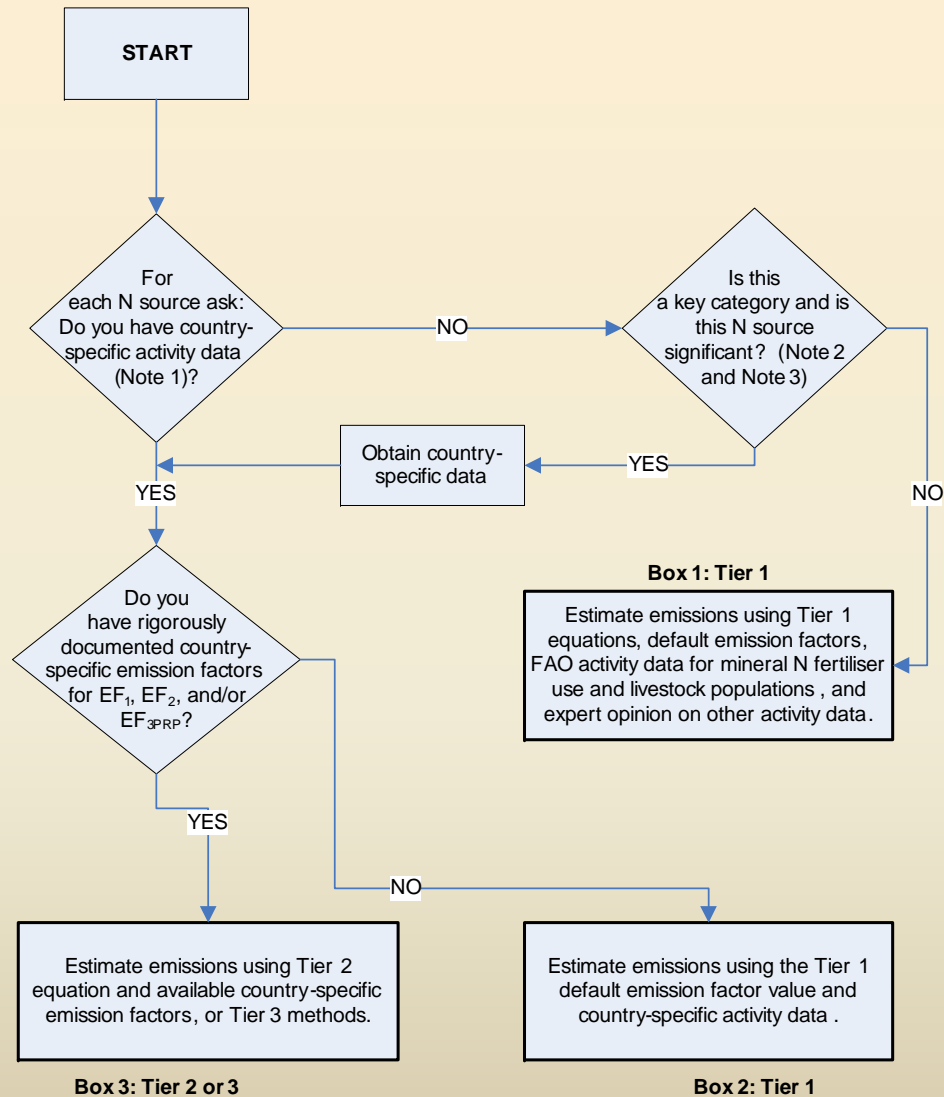
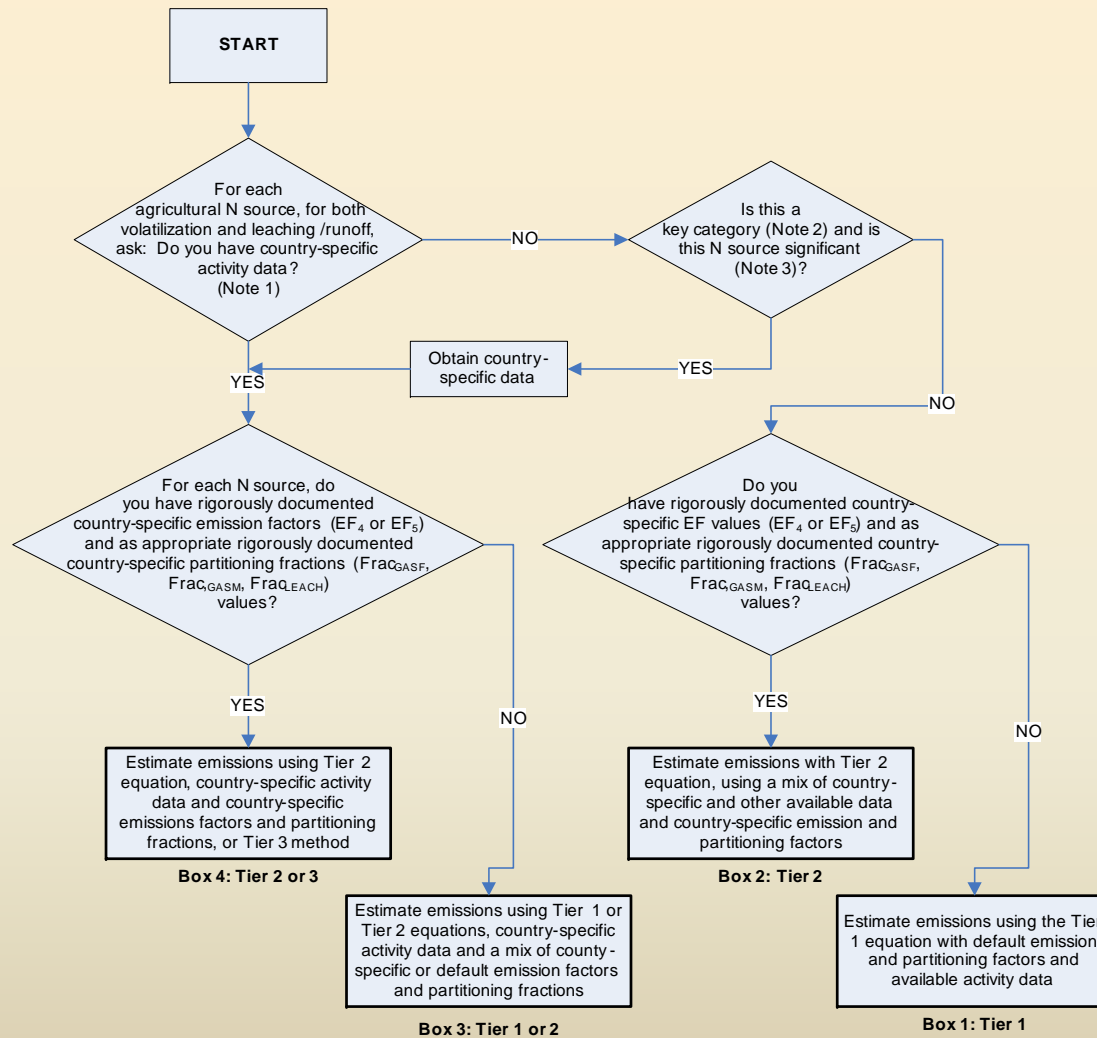


Figure 11.3 Decision tree for indirect N₂O emissions from managed soils



“Tiers” and “Defaults”

- The so-called Tier 1 methodology is to apply the default value to a particular emission, e.g. 0.01 (or 1%) for the direct emission from N fertiliser applied to the soil
 - the default value being the most representative average value that can be derived from the published data and expert judgement.
- IPCC encourages the use of Tier 2 methods, in which country-specific emission factors (EFs) are applied, based on representative measurements made in that country or region.
- Tier 3 methods are usually modelling methods, used to predict emissions from whole countries or regions for which experimental measurements are impracticable.
 - USA now uses Tier 3 methods for its inventory, based on the DAYCENT model originated by Parton et al.

Direct N₂O Emissions (IPCC, 2006)

The following N sources are included in the 2006 methodology for estimating direct N₂O emissions from managed soils:

- Synthetic N fertilisers (F_{SN});
- Organic N applied as fertiliser (e.g. animal manure, compost, sewage sludge, rendering waste) (F_{ON});
- Urine and dung N deposited on pasture, range and paddock by grazing animals (F_{PRP});
- N in crop residues (above and below ground), including from N-fixing crops and from forages during pasture renewal (F_{CR});
- N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM});
- Drainage/management of organic soils (i.e., histosols) (F_{OS}).

Changes from previous (1996) Guidelines

- Several “default” emission factors (direct and indirect) have been changed, based on new data:
 - Biological nitrogen fixation has been removed as a direct source of N_2O : lack of evidence of significant emissions from the fixation process itself (Rochette and Janzen, 2005).
 - The nitrogen residue from perennial forage crops is only accounted for during periodic pasture renewal.
 - Release of N by mineralisation of soil organic matter as a result of change of land use or management now included as an additional source.
 - N deposited as NH_3 and NO_x , but now also includes fossil fuel combustion, biomass burning, and processes in the chemical industry -- sources no longer confined to agricultural fertilisers and manures.

Uncertainty ranges

- The default value for direct emissions from non-flooded agricultural land is 0.01, or 1% of the N applied or released by mineralisation
- The associated uncertainty range of 0.003-0.03 (or 0.3% - 3%) is, essentially, logarithmic:
 - From one-third of the default value to three times the default value.
- Analogous ranges are applied to the default values for other direct emissions, e.g. for cultivated organic soils.

TABLE 11.1
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N₂O EMISSIONS FROM MANAGED SOILS

Emission Factor	Default Value	Uncertainty Range
EF ₁ for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N ₂ O-N (kg N) ⁻¹]	0.01	0.003-0.03
EF _{1PR} for flooded rice fields [kg N ₂ O-N (kg N) ⁻¹]	0.003	0.000-0.006
EF _{2 CO₂, Temp} for temperate organic crop and grassland soils (kg N ₂ O-N ha ⁻¹)	8	2-24
EF _{2 CO₂, Trop} for tropical organic crop and grassland soils (kg N ₂ O-N ha ⁻¹)	16	5- 48
EF _{2F, Temp, Org, R} for temperate and boreal organic nutrient rich forest soils (kg N ₂ O-N ha ⁻¹)	0.6	0.16-2.4
EF _{2F, Temp, Org, P} for temperate and boreal organic nutrient poor forest soils (kg N ₂ O-N ha ⁻¹)	0.1	0.02-0.3
EF _{2F, Trop} for tropical organic forest soils (kg N ₂ O-N ha ⁻¹)	8	0-24
EF _{3PRP, CPP} for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N ₂ O-N (kg N) ⁻¹]	0.02	0.007-0.06
EF _{3PRP, SO} for sheep and 'other animals' [kg N ₂ O-N (kg N) ⁻¹]	0.01	0.003-0.03

Sources:

EF₁: Bouwman et al. 2002a,b; Stehfest & Bouwman, in press; Novoa & Tejeda in press; EF_{1PR}: Akiyama et al., 2005; EF_{2CO₂, Temp}, EF_{2CO₂, Trop}, EF_{2F, Temp}: Klemmedtsson et al., 1999; IPCC Good Practice Guidance, 2000; EF_{2F, Temp}: Alm et al., 1999; Laine et al., 1996; Martikainen et al., 1995; Minkkinen et al., 2002; Regina et al., 1996; Klemmedtsson et al., 2002; EF_{3, CPP}, EF_{3, SO}: de Klein, 2004.

Indirect emissions from N deposition

- The uncertainty range here, too, has been widened
 - emissions from some environments, particularly deciduous forests receiving high rates of N deposition from the atmosphere, are substantially higher than those previously reported (e.g. Butterbach-Bahl et al., 1997; Brumme et al., 1999; Denier van der Gon and Bleeker, 2005),
 - there is also clear evidence that EFs can be very low ($\ll 0.01$) in low-deposition environments (e.g. Corre et al., 1999).
- The mean value of 0.01 (or 1%) has been retained
 - Data don't merit a change, and it conveniently coincides with the revised EF for direct emission from managed land.

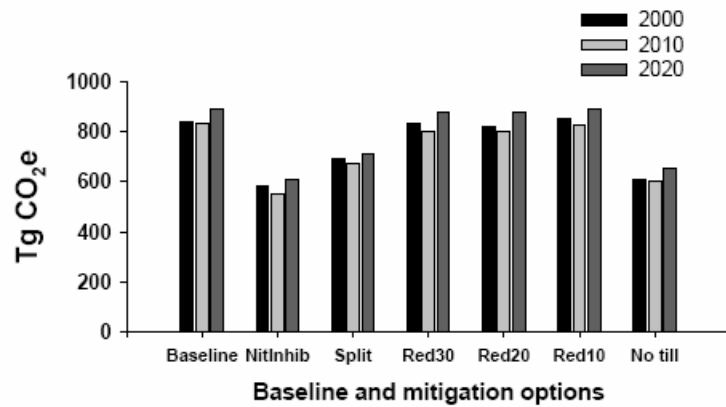
TABLE 11.3
DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N₂O EMISSIONS

Factor	Default Value	Uncertainty Range
EF ₄ [N volatilisation and re-deposition], kg N ₂ O-N (kg NH ₃ -N + NO _x -N volatilised) ⁻¹ ²²	0.010	0.002-0.05
EF ₅ [leaching/runoff], kg N ₂ O-N (kg N leaching/runoff) ⁻¹ ²³	0.0075	0.0005-0.025
Frac _{CLASF} [Volatilisation from synthetic fertiliser], (kg NH ₃ -N + NO _x -N) (kg N applied) ⁻¹	0.10	0.03-0.3
Frac _{CLASM} [Volatilisation from all organic N fertilisers applied, and dung and urine deposited by grazing animals], (kg NH ₃ -N + NO _x -N) (kg N applied or deposited) ⁻¹	0.20	0.05-0.5
Frac _{LEACH(OB)} [N losses by leaching/runoff for regions where Σ(rain in rainy season) - Σ (PE in same period) > soil water holding capacity, OR where irrigation (except drip irrigation) is employed], kg N (kg N additions or deposition by grazing animals) ⁻¹	0.30	0.1 – 0.8

Note: The term Frac_{LEACH} previously used has been modified so that it now only applies to regions where soil water-holding capacity is exceeded, as a result of rainfall and/or irrigation (excluding drip irrigation), and leaching/runoff occurs, and redesignated as Frac_{LEACH(OB)}. In the definition of Frac_{LEACH(OB)} above, PE is potential evaporation, and the rainy season(s) can be taken as the period(s) when rainfall > 0.5 * pan evaporation. (Explanations of potential and pan evaporation are available in standard meteorological and agricultural texts). For other regions the default Frac_{LEACH} is taken as 2500.

Relevance to mitigation?

- The IPCC methodology is concerned primarily with inventories,
- But it is desirable to identify the main sources, and estimate their magnitude, before trying to mitigate the emissions.
- However, as long as countries use the default value, i.e. if they calculate emissions solely on the amount of N applied, then the only method of reducing reported emissions is by reducing the amount of N used
 - This faces much opposition from farmers.
 - There is considerable evidence that alternative manipulations can reduce emissions, e.g.
 - selection of crop type according to soil and/or environmental conditions,
 - splitting N applications,
 - use of a nitrification inhibitor, or
 - draining to lower the water table.



(from Verchot, 2007)

Figure 2: Global net GHG emissions from croplands (N₂O and soil carbon) estimated by DAYCENT under baseline and mitigation scenarios. Figure adapted from USEPA 2006b).

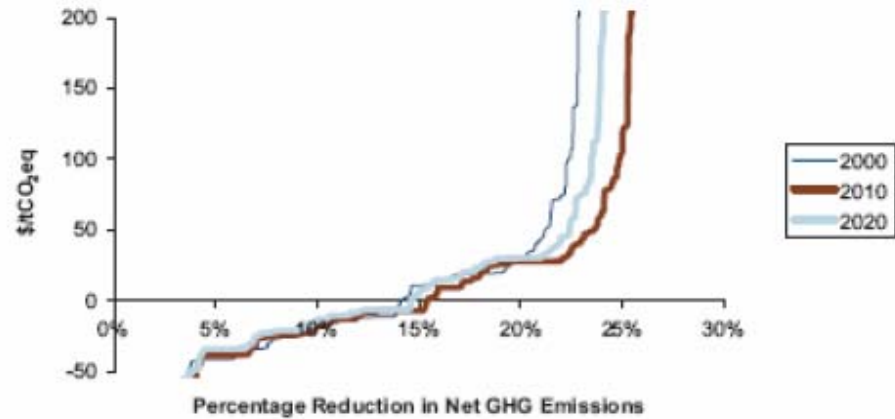


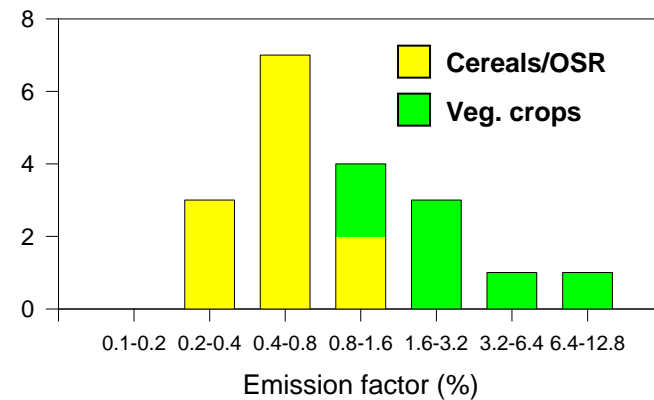
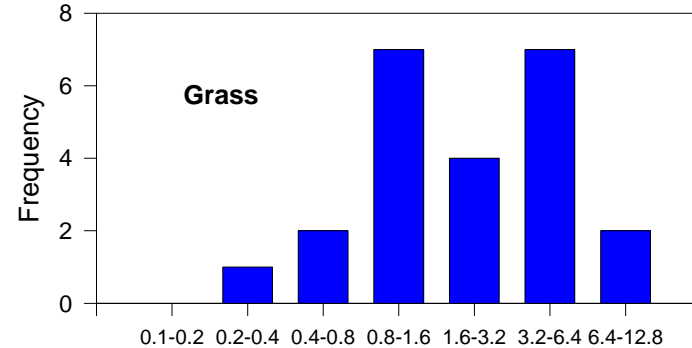
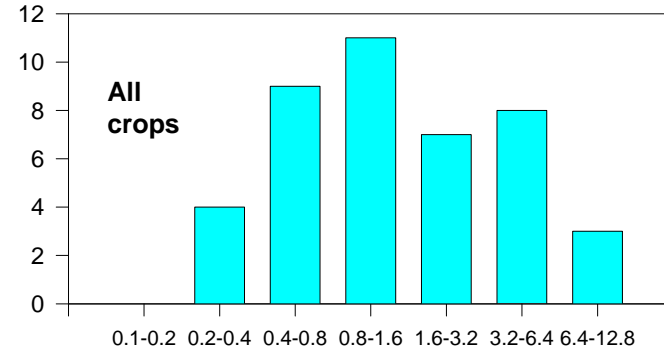
Figure 3: Global marginal abatement curve for net GHG emissions from croplands, holding area constant. Source: USEPA 2006b.

Emission Factors:

Contrasting approx. log-normal distributions of EFs:

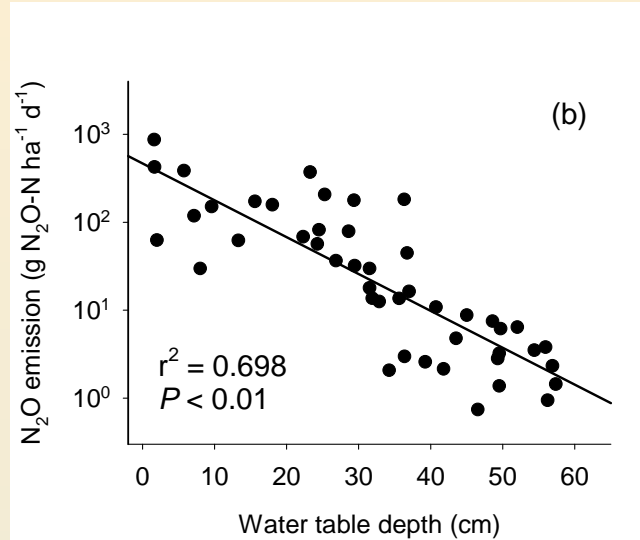
top: all crops;
centre: cut grassland;
bottom: arable crops

4-fold difference between peaks for grass and cereals.

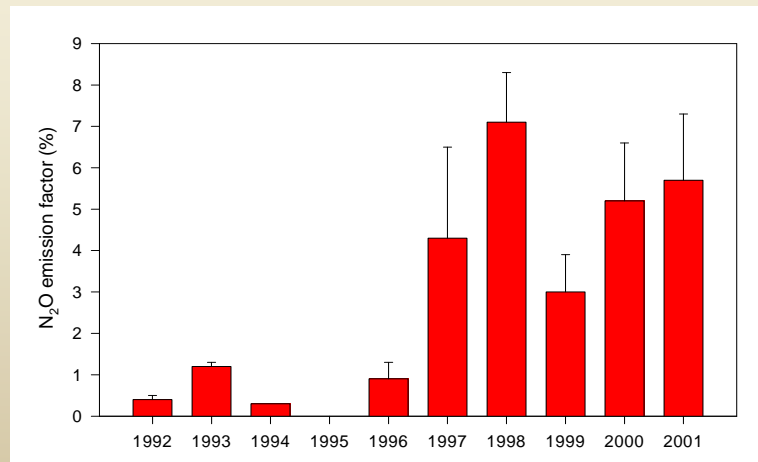


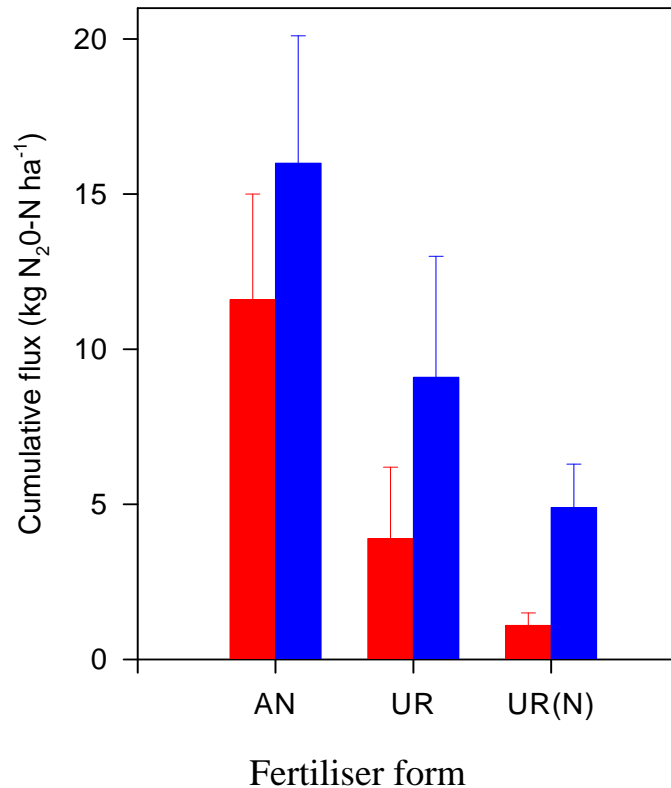
Silage grassland:

Relation
between N_2O
emission and
depth to water
table (Dobbie &
Smith, 2005)



Annual flux at
one site in
years with
drier summers
1992-96, and
wetter, 1997-
2001



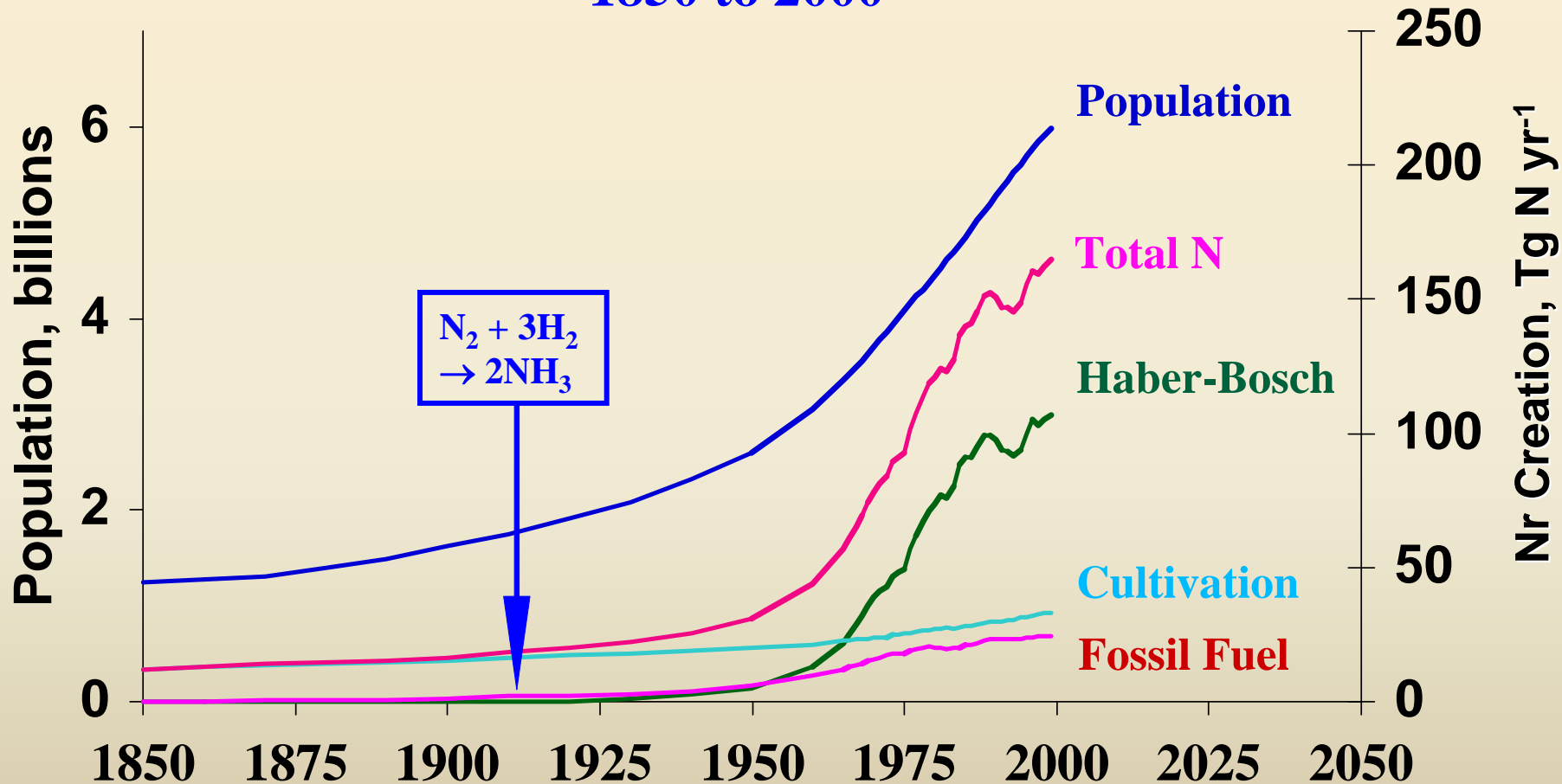


Effect of N
fertiliser form and
presence/absence
of nitrification
inhibitor DCD on
N₂O emissions
from grass sward:
red columns: June
1999 – June 2000;
blue columns: June
2000 – June 2001

(Dobbie & Smith,
2003)

Relationship between N₂O and New Reactive N (Crutzen et al., 2008)

Global Reactive N (Nr) Creation by Human Activity 1850 to 2000



P. J. Crutzen, A. R. Mosier, K. A. Smith and W. Winiwarter, N₂O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. Atmos. Chem. Phys. 8, 389-395, 2008:

1. **Pre-industrial period: [N₂O] = 270 nmol/mol (constant)**

- **Source of N₂O: 10.2 Tg N₂O-N/yr (of which 6.2 – 7.2 Tg came from land and coastal zones (Prather et al., 2001).**
- **N input: 141 Tg N/yr (Galloway et al., 2004).**

Therefore yield of N₂O-N = 4.4 – 5.1% of the N input.

- **A.D. 2000: [N₂O] = 315 nmol/mol and increasing.**

Photochemical loss of N₂O: 11.9 Tg N₂O-N /yr

Atmospheric growth rate: 3.9 Tg N₂O-N/yr.

Relationship between N₂O and New Reactive N (cont.)

- In 2000, therefore, total N₂O source = 15.8 Tg N₂O-N/yr;
- Pre-industrial natural source = 10.2 Tg N₂O-N/yr;
- Decrease in natural source = 0 – 0.9 Tg N₂O-N/yr;
- Therefore anthropogenic N₂O source = 5.6 – 6.5 Tg N₂O-N/yr.
- Industrial N₂O source = 0.7 – 1.3 Tg N₂O-N/yr
- Difference = terrestrial N₂O source = 4.3 – 5.8 Tg N₂O-N /yr

Therefore, as new anthropogenic N input to land = 114 Tg N/yr (Galloway et al, 2004; Smeets et al., 2007),

- the global average range of N₂O yields from application of fixed nitrogen = $[(4.3 - 5.8) \times (100)] / 114 = 3.8 - 5.1\%$.

Comparison of our top-down approach based on global budget with the IPCC bottom-up methodology

- We assume newly fixed N (fert. N and BNF) is the source of all related emissions:
 - direct soil emissions;
 - “secondary “ emissions, e.g.
 - ploughed-in crop residues;
 - dung and urine from livestock, (grazing and housed), fed on N-fertilised grain, & feeds containing BNF-N (clover, alfalfa, soya bean meal);
 - N mineralised from soil OM and root residues.
 - indirect emissions, in IPCC sense of the phrase, following N leaching and volatilisation.
- In IPCC approach,
 - emissions from crop residues and mineralisation are included in “direct” emissions; default value 1%, but uncertainty range = 0.3-3%.
 - separate EFs are used for emissions from grazing animals, and related to the N excreted; this N is treated as a “new” source, not as fert- or BNF-derived N; EF= 2% (range 0.7-6%).
 - indirect emissions amount to 0.35-0.45%, but again with wide uncertainty ranges.
- Given these uncertainties, the sum of the IPCC source terms is not inconsistent with the total derived by the top-down methodology

Implications for inventories

- The top-down global budget approach would provide a new simplified and all-embracing default EF of $4 \pm 1\%$ for all N introduced to terrestrial ecosystems, by N fertilisers and BNF.
- This would be a strong incentive for countries to develop Tier 2 and Tier 3 methods.
- However, it remains to be seen how well the total emissions calculated by this procedure match up to the global budget based on the annual growth in the atmospheric concentration.