Atmospheric N_2O Releases from Biofuel Production Systems: A Major Factor Against "CO_2 Emission Savings": A Global View

Paul J. Crutzen, Arvin Mosier, Keith Smith, and Wilfried Winiwarter

Abstract In this study we propose a global average quantitative criterion for the Nitrogen to dry matter ratio, r(N/dm), in the harvested plant material, which shows the degree to which the reduced global warming, reduced by using plant biomass instead of fossil fuels as an energy source ("saved CO_2"), is counteracted by the release of N_2O. The results indicate that the specific use of agricultural crops for energy production in several cases can be counterproductive from a climate point of view due to accompanying N_2O emissions. This effect has been much underrated in studies of the climatic impact of biofuel production.

Keywords Agriculture · biofuels · nitrogen cycle · N_2O emissions · impact on climate

Introduction and Main Conclusion

Nitrogen oxide (N_2O), a product of fixed nitrogen application in agriculture, is a "greenhouse gas" with a 100-year average global warming potential (GWP) 296 times larger than that of CO_2.

P.J. Crutzen (✉)
Max Planck Institute for Chemistry, Department of Atmospheric Chemistry, Mainz, Germany
Scripps Institution of Oceanography, University of California, La Jolla, USA
E-mail: air@mpch-mainz.mpg.de

P.J. Crutzen and W. Winiwarter
International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

A. Mosier
Mount Pleasant, SC, USA

K. Smith
School of Geosciences, University of Edinburgh, UK

W. Winiwarter
Austrian Research Centers – ARC, Vienna, Austria

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As a source for NO_x, it also plays a major role in stratospheric ozone chemistry. Its atmospheric abundance has been increasing from about 270 to almost 320 nmol/mol during the Anthropocene.

The use of biofuels to achieve "CO_2 neutral" energy production may cause atmospheric N_2O concentrations to increase further because of emissions of N_2O associated with N-fertilization.

Here we propose a global average quantitative criterion for the Nitrogen to dry matter ratio, r(N/dm), in the harvested plant material, which shows to what degree the reduced global warming by using plant biomass instead of fossil fuels as an energy source ("saved CO_2"), is counteracted by the release of N_2O.

Our study strongly indicates that in many cases the specific use of agricultural crops for energy production and climate protection can have the opposite effect on climate due to accompanying N_2O emissions.

For a more thorough analysis see Crutzen et al. 2008.

N_2O and fixed nitrogen budget: (Galloway et al. 2004; Prather et al. 2001)

- Pre-industrial (anthropocene) $\mu_{N_2O} = 270\,\text{nmol/mol}$ (μ is volume mixing ratio)
  Sink/source of N_2O: 10.3 T_g N_2O-N/year, 2–6 T_g N_2O-N/year from oceans
  4.3–8.3 T_g N_2O-N/year from land
  Fresh N input: 141 T_g N/year (Galloway et al. 2004)
  Yield of N_2O-N/fresh fixed nitrogen = 3.0–5.9%
- A.D. 2000: $\mu_{N_2O} = 315\,\text{nmol/mol}$
  Photochemical loss of N_2O: 12.0 T_g N_2O-N/year
  Atmospheric growth rate: 3.9 T_g N_2O-N/year

$\rightarrow$ N_2O source = 15.9 T_g N_2O-N/year
  Pre-industrial natural source = 10.3 T_g N_2O-N/year
$\rightarrow$ Anthropogenic N_2O source = 5.6 T_g N_2O-N/year
  Industrial N_2O source = 0.7 T_g N_2O- N/year
$\rightarrow$ Agricultural N_2O source = 4.9 T_g N_2O-N/year
  New anthropogenic N input = 127 T_g N/year (Galloway et al. 2004)
  Ratio = 3.8% = y (yield of N_2O-N per unit of fresh fixed N input)

Global average range of yields of N_2O–N from fixed nitrogen application gives y = 3–5%.
Assumption: This yield will also apply in future for energy plant production.

A Global Farm

Assuming that the fixed N, which is harvested with the biomass products to produce biofuel, must be replenished in the fields over time by fixed N input, we derive the following expressions for "saved CO_2" (M), and M_{N_2O}, which accounts for the climate warming by the N_2O emissions