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Interactive Comment

Interactive comment on "N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels" *by* P. J. Crutzen et al.

P. J. Crutzen et al.

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Before touching on the specific points raised by Anonymous Referee #2 (2007) there are a few general points that we wish to make. We agree that there is potential for over-interpretation of the result we present (Crutzen et al., 2007), and attempt, in the revised version, to be more precise in our language. Moreover we make the assumptions that lead to our results more explicit in the text, as we will also explain for the specific points. Finally, we emphasize, as reiterated in the manuscript, that the purpose of the paper is to encourage further research rather than to provide a final answer.

However we dismiss the notion that this approach is "simplistic" – this expression does not do justice to our study, nor would it do justice to those studies that currently fail to consider the continuing effects of fixed N beyond direct and explicitly defined indirect field emissions.

Specific issues:

1) Differences of numbers used to those presented in the IPCC Third Assessment report

In the revision we state more precisely that the figures used do not directly derive from Prather et al. (2001) only and thus numerical deviations occur. The range from 0.6 to 14.8 Tg N_2O-N in Table 4.4 of the Third Assessment Report is from publications from Mosier et al. 1998 and Kroeze et al., 1999; this range is based upon the range of field-based measurements and estimates of indirect emissions from reactive nitrogen once it has left an agricultural field. We do not use this bottom-up approach. Instead we derived a range of N_2O emissions (4.3-5.8 Tg N yr^{-1}) from the estimates of pre-industrial emissions of N_2O from oceans (2-6 Tg N_2O-N yr^{-1}) and the total global source/sink strength for N_2O (10.3 Tg N_2O-N yr^{-1}) to give a terrestrial N_2O emission of 3.0-5.9% of the global pre-industrial N input into terrestrial systems (141 Tg N yr^{-1}; Galloway et al. 2004). This ratio of new reactive N input to annual N_2O emissions to the atmosphere remained the same in the year 2000 and we make the assumption that it will remain the same in the future. For our subsequent calculations we have taken a conservative approach by reducing the upper end of the range, and use 3-5%.

2) Crops should be treated separately from animal husbandry

Total N_2O emissions include both emissions directly from agricultural fields and those derived from all of the N lost from agricultural fields (in gaseous and aqueous forms). The global N_2O balance we have derived (see preceding paragraph) is well within the range obtained from the direct and indirect field measurements (see budgets calculated by Mosier et al. 1998 and Kroeze et al., 1999) The issue here is one of proper accounting of the emissions actually occurring within agricultural systems and beyond. The question is tightly related to the one on by-products (see (3)). Separating animal husbandry and field crops requires additional assumptions to be made, and we con-

ACPD

7, S6591–S6595, 2007

sider that it is unjustified to do this on the basis of existing knowledge. Smeets et al. (2007) attempt to perform a specific budget for crops, ending up in a N_2O emission estimate of about 30% lower than our central estimate, but this is close to the lower limit of our emissions range. Galloway et al. (2003) note that approximately 16% of the annual reactive N input is processed through livestock, and this proportion is small enough not to have any great impact on our range.

3) Co-products cannot be ignored

Certainly the N content of biofuels is low; however, this is not relevant. What **is** relevant is the fact that a large amount of reactive nitrogen is used in the production of the biofuel crop. If biofuels are grown we should not assume, without any other knowledge, that N-rich byproducts such as oilseed cake will substitute for similar materials currently produced elsewhere. Only such a replacement would allow accounting for the N_2O emissions elsewhere than in the biofuel production. The revised text attempts to accommodate that issue.

4) Errors in Equation 1 and Appendix A

There were errors in the original manuscript that were only visible to the referees. These errors were corrected before it went online to ACPD. This was spotted by the very careful perusal of the referee.

5) Equation 1 is incomplete

The referee correctly states that a comparison needs to be done on the basis of energy content per carbon content of fuels. In the revised version we acknowledge that and state that this ratio is virtually identical for the fuels under consideration.

6) Potential double counting using factors e *and* y

The e factor serves as a mechanism to relate nitrogen use efficiency to crop production. It does not relate to the N_2O yield (y) from the nitrogen used to produce the biofuel crop. Thus the two factors are independent.

7) The result that low-input species are more favourable for climate than intensive crops

ACPD

7, S6591–S6595, 2007

is not new (e.g., Tilman et al. 2006)
We will acknowledge the Tilman reference in the revised manuscript.

8) Discrepancy between global analysis and field studies
In the revised version we specifically explain that the emissions estimated by our global analysis are much larger than the default value of 1% of applied N used by IPCC (2006) for direct emissions from agricultural fields. But we point out that the default value has a wide uncertainty range, and furthermore, that in addition to the direct emissions there are background emissions from diverse environments impacted by N fertiliser use; in total these background emissions appear to exceed the amount indicated by their default values.

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ACPD

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Interactive Comment

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