Atmos. Chem. Phys. Discuss., 7, S6596–S6601, 2007
www.atmos-chem-phys-discuss.net/7/S6596/2007/

Atmospheric Chemistry and Physics Discussions

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.

Received and published: 6 November 2007

We have, with great interest, taken note of the contributions to the interactive discussion. Due to time constraints, it was not possible to reply individually to all of the contributions, so here we will lay out the assumptions used in our original manuscript (Crutzen et al., 2007) and relate those to the critique/suggestions of the individual correspondents. Analyzing these suggestions allows us to identify clusters of ideas, which we are able to cover simultaneously. Further, similar comments have been received since the closure of the interactive discussion, which are also covered by the general concepts in our response.

In the revised version of the manuscript, we take account of the general concepts in most of the suggestions. Specifically, we emphasize that our perspective necessarily does not consider crop systems as they ideally could (and on test sites and in some regions actually can) be, but instead pinpoints current, average global agricultural conditions. We also take care to identify the individual assumptions made and indicate how improvements to current practice in biofuel crop production would be more beneficial, from the viewpoint of N_2O.

a) We assume that biofuel production requires fresh reactive nitrogen, i.e. mineral fertilizer only. Leip (2007) argues that, under current agricultural practice and probably also under a future extension of biofuels, sufficient manure will be available to provide approximately 20% of N needed for all crop production from livestock manure. This could potentially decrease mineral fertilizer requirement by 20%.
While it may be useful to account for manure for current systems and possibly also in the future, at the same time we observe a spatial and organizational separation of animal production and biofuel production in many places where industrial livestock production is practiced. Even if there is a flow of manure nitrogen back into fields to replace mineral fertilizer, mineral fertilizer will remain clearly the largest fertilizer source – as may also be seen by fertilizer industry's prospect of increased production due to biofuel production. For that reason we have – for the main line of argument – remained with our original figures.

b) We assume that CO_2 from combustion of biofuels is the same as "CO_2 saved", i.e. the emissions from fossil fuels that have been replaced. Both Leip (2007) and Anonymous (2007) note that this should be done in comparison to the fossil fuels replaced, in order to estimate the fossil CO_2 avoided. Using JRC (2007) – well-to-tank report – it is easy to show that the energy content of the fuels concerned per mass of C are almost identical (Ethanol 51.3, RME 48.6, Gasoline and Diesel 50 MJ/kg C). In the revised version of the manuscript we make this conversion explicit.

c) We assume that biofuel production is responsible for N_2O emissions from fixed N specifically converted from atmospheric N for its production, even if emissions hap-

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pen in subsequent stages far from the production site. Until proven otherwise we do not account for benefits and/or replacement of other crops due to biofuel production residues (as e.g. in cattle farms using ethanol distillation residues as feed). This is in stark contrast to the point made by referee #2, that biofuels should not be blamed for fertilizer N as the N is used elsewhere and is not contained in the biofuel.
The issue of appropriate accounting of N_2O emissions to the "polluter" has also been brought up by Smeets et al. (2007). These correspondents refer to the use of byproducts of biofuel production by animal husbandry, and claim that N_2O related to such by-products should not be attributed to biofuel, but to animal production. Eventually here we are moving into legal issues rather than scientific. Who is responsible for the release of a trace gas? Can we safely assume – without prior knowledge – that biofuel by-products will indeed replace agricultural crops previously produced for animal feeds? Ammann et al. (2007) argue on the same issue, just accounting N_2O emissions separately for the subsequent cycles reactive nitrogen takes in the environment. We have covered this in the specific response to these authors.
Additionally the discussion is reflected in the revised manuscript, where we note that we neglect the potential of byproducts to replace other animal feed crops (and the associated N_2O emissions), as they cannot be taken for granted on the global scale.

d) We assume that we need to add 2.5 times the amount of N to soil as is contained in the crops (e = 0.4). This has been challenged by Rauh and Berenz (2007) based on data from Europe. They suggest using the ratio between N-content of plants and fertilizer N-input to soils which they have demonstrated to be as high as 0.7. We recognise that test plots in some systems may give such N recoveries, and we are aware of other studies that provide nitrogen use efficiencies of 0.5-0.6 for rape seed (Nyikako, 2006), but the global average N efficiency in agricultural practice is lower (Balasubramanian et al. 2004), hence our factor of 0.4. Increase in nitrogen use efficiencies is needed in general (see Hirel et al., 2007). We now (in the revised manuscript) attempt to quantify what an improvement of 50% over the current global average could mean in terms of N_2O emissions.

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Our findings indicate that there are important cases where N_2O formation alone more than neutralizes CO_2 savings from biofuel use. This does not imply that any result that has savings larger than the corresponding nitrous oxide emissions is beneficial for climate. In addition to the emissions of N_2O, the general (often problematic) energy balance needs to be considered (see JRC, 2007, or Hill et al., 2006). We attempt to make this more clear in the current revisions. In the cases where an overall savings of CO_2-equivalents from a biofuel is found, it will remain important to quantify the impact of N_2O emissions on the greenhouse gas balance. This is evident, as for many biofuels net CO_2 savings are marginal, irrespective of the N_2O effect. The benefits accruing from such fuels could probably be more easily and more effectively achieved by energy savings of the same extent. This needs to be considered when it comes to choice of biofuels that are promoted by regulations and subsidy policy (as discussed by Conen, 2007).

An interesting estimation of the quantities, both financially and in terms of greenhouse gas emissions involved, – was presented by Reay (2007). These views support the need for more detailed studies on this issue.

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