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

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Crutzen, Mosier, Smith and Winiwarter claim that the nitrous oxide (N_2O) emissions from energy crop production have been underestimated in existing studies of the greenhouse gas (GHG) balances of biofuels. We agree that N_2O emissions are an important and often neglected issue in the debate on biofuels. However, there are several aspects of the calculations presented by Crutzen *et al*. that may cause a substantial overestimation of their N_2O emissions from energy crops, particularly the N_2O emission factor.

The N_2O emission factor

The N_2O emission factor of 3.3-4.6% proposed by Crutzen *et al*. is the total worldwide emission of N_2O from agriculture divided by the total global anthropogenic input of "new" fixed N in the agricultural production system. Thus, Crutzen *et al*. include the N input in livestock production systems and the associated N_2O emissions. Energy crop production and livestock production may be related, for example through the use of distiller's grain and oil cakes as animal feed. We argue that the emissions associated with the use of these by-products from production of ethanol from starch crops and biodiesel produced from oil crops should not be allocated to energy crop production, but to the production of animal products where they substitute conventional animal feed.

We argue that the inclusion of the animal production system is not correct and propose the use of a 2.7% crop specific emission factor that is defined as the total worldwide emission of N_2O from crop production divided by the total worldwide N input into the crop production system. The 2.7% crop specific emission factor is calculated as follows. The global N_2O emission from agriculture is 6.7 Tg N_2O-N/y according to Stehfest and Bouwman (2006) and MNP (2006). Crop production contributes 3.4 Tg N_2O-N/y and emissions from grassland used for livestock production add 2.7 Tg N_2O-N/y. This leaves 0.5 Tg N_2O-N/y from N leached from fertilized fields, which we allocate completely to crop production. We recognize that this causes an overestimation, since part of the leaching occurs in grassland. The total N_2O emission from crop production is thus 4.0 Tg N_2O-N/y.

We use data on N inputs in agriculture (81 Tg N in the year 2000) from FAO (2007) of which 97% (78 Tg N/y) is applied to cropland (FAO/IFA/IFDC, 2003). In contrast, Crutzen *et al*. use an estimate of 100 Tg N from Galloway *et al* (2004). However, this 100 Tg N is the total N_2-fixation by the Haber-Bosch process, of which 86 Tg N is used for the production of fertilizers and 14 Tg N is '*dispersed to the environment during processing or used in the manufacture of synthetic fibres, refrigerants, explosives,*

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plastics, rocket fuels, nitroparaffins, etc.' (Galloway *et al*, 2004). In our opinion, the 14 Tg N/y should be excluded from the calculations of the emission factor, because it is not an N input in the agricultural system.

The global N input from biological N_2-fixation (BNF) on agricultural areas is 38 Tg N/y of which 22 Tg N/y is fixed by leguminous crops such as pulses. We recognize that estimates for global N_2-fixation by leguminous food crops are fraught with potential errors. Atmospheric deposition adds another 35 Tg N/y, of which 16 Tg N/y is deposited on cropland. Furthermore, the application of manure in cropland amounts to 33 Tg N/y. The cropland-specific N_2O emission factor is thus 2.7% (4.0/[78+22+16+33]). Hence, by considering the global crop production system exclusively and using figures that are roughly the same as used by Crutzen *et al*., the emission factor for N_2O that is attributed to energy crop production is reduced by 0.6-1.9% compared to Crutzen *et al*.

N_2O release versus CO_2 saved in biofuels

We also re-calculated the values for the equilibrium mass ratio of N to dry matter in gN/kg (r_Ne) and compared these values with the actual mass ratio of N to dry matter in gN/kg (r_Na) to determine the N_2O release versus CO_2 saved in biofuels (following the same approach as used by Crutzen and his team). For cases where r_Ne < r_Na, the actual N input required to compensate for the N removed from the field via the harvested matter leads to N_2O emissions that exceed the CO_2 saved in the biofuels. We calculate the following r_Ne values: r_Ne = 42 g N/kg dry matter for diesel produced from rapeseed, r_Ne = 19 g N/kg dry matter for ethanol from corn and r_Ne = 15 g N/kg dry matter for ethanol from sugar cane.

We see that r_Ne > r_Na for biofuels produced from rapeseed, corn and sugar cane (r_Na = 39 g N/kg dry matter for rapeseed, r_Na = 15 g N/kg dry matter for maize, r_Na = 7.3 g N/kg dry matter for sugar cane). The same is true for ethanol produced from barley or oat (r_Na = 19 g N/kg dry matter), assuming the conversion efficiency of corn to ethanol. Only for wheat the r_Ne is lower than r_Na (r_Na = 22 g N/kg dry matter). Hence,

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we conclude that the CO_2 savings from biofuel use are larger than the N_2O emissions from energy crop production, except for ethanol made from wheat, and that the values assumed by Crutzen *et al* lead to a significant underestimation of the CO_2 savings.

Discussion

The above simple global estimates ignore the variability of emissions caused by differences in crop type and the associated management system, and soil and climate conditions and the impact of the choice of the type of reference land use (i.e., the land use replaced by energy crops). Furthermore, we (and Crutzen *et al*.) ignored other (non-N_2O) emissions during the production of the energy crop and the conversion to fuel (as also proposed by Crutzen *et al*.), as well as changes in soil organic matter in areas converted to energy crop production. These issues need to be analysed in a full life cycle analysis with spatially explicit calculations of N_2O emissions to account for differences in environmental conditions, to provide a firm basis for drawing conclusions about the GHG emission reductions from the substitution of fossil fuels by biofuels. In addition, no attention has been paid to the (substantial) uncertainties related to the data used to calculate the N_2O emission factor and which are particularly large for the N input from biological nitrogen fixation and for the emissions of N_2O.

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