Consequences of agro-biofuel production for greenhouse gas emissions

Mette S. Carter[1], Henrik Haugaard-Nielsen[1], Anders Johansen[2] and Per Ambus[1]
[1] Risø National Laboratory for Sustainable Energy, Technical University of Denmark, DK, phone: +45 4677 4238; fax: +45 4677 4160; mthy[a]risoe.dtu.dk
[2] National Environmental Research Institute, University of Aarhus, DK

Currently CO_2 from fossil fuel combustion accounts for 57% of the global greenhouse gas emissions, whereas the strong greenhouse gases nitrous oxide (N_2O) and methane (CH_4) contribute with 8% and 14%, respectively (IPCC, 2007). Agricultural activity is the dominant source of N_2O, which is mainly associated with the use of nitrogen based fertilizers in agricultural production. Replacing fossil fuel-derived energy by biomass-derived energy is commonly and with increasing emphasis proposed as a mean to mitigate the CO_2 emissions. However, a recent analysis of global emission data proposes that accelerated emissions of N_2O associated with the production of biomass for bio-fuel purposes will outweigh the avoided emissions of fossil fuel-derived CO_2 (Crutzen et al., 2008).

In the present study we examined the effects on N_2O and CH_4 emissions when residues from bio-energy production were recycled as fertilizer for a maize energy crop within an organic cropping system. Furthermore, we assessed sustainability in terms of greenhouse gasses for co-production of bio-ethanol and bio-gas from maize. This was compared to estimated greenhouse gas balances for rye and grass-clover as alternative raw materials.

The maize crop was sown on the 14th of May 2008 and on the same day two different bio-gas residues were applied as organic fertilizer via simulated injection. The residues were anaerobic digested cattle slurry+maize and anaerobic digested slurry+grass-clover. For comparison untreated cattle slurry was included in the experiment and all fertilizers were applied at a rate of 150 kg plant available N ha^{-1}. During the following two months emissions of N_2O and CH_4 were measured regularly using two-part static chambers. As observed in many other studies significant, but short-termed, emissions of CH_4 took place after the slurry-based fertilizers were applied. In contrast, elevated N_2O emission persisted for almost two months and quite often at very high rates. The cumulative N_2O emissions during the two months amounted to 895, 725, 583 and 46 mg N_2O-N m^{-2} in the digested slurry+maize, digested slurry+grass-clover, untreated slurry and control treatments, respectively.

Thus, in general more N_2O was emitted from anaerobic digested slurry as compared to untreated slurry and the N_2O emission factor varied between 3.6 and 5.7 % of the applied N. This is substantial higher than the 1%-loss proposed by IPCC for direct losses of N_2O from organic residues. The experiment is repeated in 2009 and the preliminary results support the results from 2008.

The maize biomass was used for co-production of bio-ethanol and bio-gas. A greenhouse gas balance was made in order to highlight how much the field emissions of N_2O accounted for in comparison to the fossil fuel-derived CO_2, which was avoided by producing the bio-fuels. Preliminary calculations show that the greenhouse gas benefit of growing maize for bio-energy production was reduced by up to 70% due to N_2O emissions after soil application of bio-gas residues. In some cases there were no greenhouse gas advantage of fertilizing the maize crop, because the extra crop yield, and thereby bio-fuel production, was offset by increased field emissions of N_2O. This greenhouse gas balance did not include fuels used by farm machinery and fuels used during the production of the bio-fuels, thus the net energy production was actually lower than assumed in the calculation. The N_2O emissions may therefore counteract an even larger proportion of the actual avoided fossil CO_2.

The reason for the high N_2O emission after simulated injection of slurry-based fertilizers is partly that the fertilizers were applied before the maize crop was present to take up the nitrogen. Furthermore, injection of the liquid materials produced anaerobic zones in the soil with high availability of nitrogen and labile carbon compounds, which is favourable conditions for denitrification and thereby N_2O production. Finally, the maize was sown late in spring to ensure high soil temperatures, which also stimulates the microbial turnover of nitrogen. In comparison, a similar experiment was carried out in a winter rye crop in March to May 2009, where three factors were changed: 1) The crop was present when the materials were applied, 2) materials were applied on the soil surface simulating application by trail hoses and 3) soil temperatures were predominantly in the range 0 to 5 °C. The preliminary results show very low N_2O losses.

The greenhouse gas balance for co-production of bio-ethanol and bio-gas from unfertilized maize was compared to a rough balance for unfertilized rye and grass-clover as alternative raw materials. The N_2O emission during the cultivation of the three crops was estimated to be more or less similar if the emissions related to ploughing down of the N-rich grass-clover residues was taken into account. However, the annual whole crop yields were about 30-40% lower in rye and grass-clover as compared to maize and furthermore, the conversion of plant biomass into bio-ethanol and bio-gas was less efficient. All together the fossil CO_2 avoided by producing rye and grass-clover bio-fuels appeared to be less than half as compared to maize bio-fuels. Thus, based on these rough greenhouse gas balances rye and grass-clover did not seem to be better alternatives than maize. However, a more thorough investigation is needed when data becomes available.

To summarize, our study emphasizes the risk of large greenhouse gas emissions in relation to management of wastes from biogas plants, which may negate the potential global warming savings.

References

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