Fertiliser Value and Environmental Impact of Digestate Application on Permanent Grassland

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Introduction
The production of biogas for renewable energy has increased considerably in several European countries in recent years. The undigested residue leaving the reactor, the digestate, may be used as a fertiliser in agriculture. We are conducting a trial on set-aside grassland in Oak Park, Carlow, in the Republic of Ireland, to quantify the fertiliser replacement value and environmental impact from greenhouse gas emissions (CH$_4$, N$_2$O) of digestate application. Here, we present results from 2009. The trial is on-going.

Methods
The trial was laid out with four replicates on long-term set-aside grassland at the Oak Park station of Teagasc near Carlow, Republic of Ireland. Four levels of mineral N (60, 120, 200, 320 kg N$_{meq}$ ha$^{-1}$) were applied either as chemical fertiliser (calcium ammonium nitrate, CAN) or as digestate three times per year. In addition there was a zero N control and a combined treatment receiving CAN on the 1st and 3rd application of the season and digestate in-between (320 kg N$_{meq}$ ha$^{-1}$ in total).

Measurements
Static chambers were installed in the plots of the following treatments: 0N, 120 kg N$_{meq}$ ha$^{-1}$ (both fertilisers), 320 kg N$_{meq}$ ha$^{-1}$ (all three fertilisation regimes). Samples were taken on a total of 29 occasions, mainly after fertiliser applications. The samples were analysed for CH$_4$ and N$_2$O on a gas chromatograph. Total annual emissions were calculated by linear interpolation between individual sampling occasions. Emissions were converted to CO$_2$eq by multiplying emissions by their respective global warming potentials (298 for N$_2$O, 25 for CH$_4$, IPCC 2006).

Grass was cut three times per year. Fresh weights were recorded and percentage dry matter (DM) was assessed from a sample. Growth response to applied N was characterised by fitting a 2nd order polynomial. The "greenhouse gas cost" of the harvested biomass was assessed by dividing emissions by the corresponding biomass yields.

Results and Discussion
The response in DM production to applied mineral nitrogen (N$_{meq}$) was steeper for CAN than for digestate (Fig. 1) but levelled off at the highest application rate (Fig.2). In contrast, the response curve for digestate still had positive slope at high applications, possibly caused by NH$_3$ volatilisation loss from the digestate, which is an important pathway of N loss from organic fertilisers (Wulf et al. 2002). However, NH$_3$ loss was not measured in this study.

The highest yield was achieved in the combined treatment, which received both digestate and CAN (Fig. 1). The increase in organic carbon in the soil after digestate fertilisation may have led to increased retention of plant-available N.

Fig. 3 shows the specific emissions of greenhouse gases per tonne of harvested biomass. Increasing fertilisation led to an increase in the emissions, and thus the environmental „cost“, per unit (tonne) of product. Moreover, specific emissions from CAN were larger than from digestate. This result was due to high N$_2$O emissions from CAN, especially at the first application of the season in early April under wet and cool conditions. In contrast, the CH$_4$ emissions from digestate only had a small influence on the total greenhouse gas balance (data not shown). Soil water contents were high due to a wet and cool growing season in 2009 (1124 mm precipitation compared to the 30-year average of 785 mm), which may have stimulated high N$_2$O emissions.

Fertilisation with digestate resulted in lower emission of greenhouse gases (CH$_4$ and direct N$_2$O emission) than fertilisation with CAN (Fig. 3). However, we did not measure the full greenhouse gas balance (which would also have to include indirect N$_2$O emissions and possible differences in CO$_2$ sequestration under different fertilisation regimes).

Conclusions
Digestate may have high potential as a low-cost and low-impact fertiliser on agricultural grassland but more data are needed. Important aspects that need to be addressed by future research include soil carbon sequestration under digestate and mineral fertilisation and volatilisation N losses from digestate, which can lead to indirect N$_2$O emissions. The interaction of digestate and chemical fertiliser applied subsequently in the course of the year warrants further investigation as well. Another important aspect, which may provide environmental mitigation at low cost, is the timing of the first application of fertiliser in spring.

Acknowledgements
This investigation is part of a larger project financed by the Department of Agriculture, Fisheries and Food of the Republic of Ireland (Research Stimulus Programme, RSF 07-506). We would also like to thank the technical staff at Teagasc Oak Park for their invaluable help.

References
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