Climate impact of mobile green manures


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Climate impact should be taken into account when evaluating the sustainability of cropping systems. We determined emissions of greenhouse gases during storage and after field application of fertilizer products for organic crop rotations: Grass-clover cuts that were either ensiled or composted, and plant biomass which was co-digested with slurry. Both digestate and grass-clover silage showed positive results with respect to added crop yield and climate impact.

Livestock manure, mostly slurry, is part of fertilizer plans on many organic farms, but often has to be imported from conventional farms. In order to reduce the dependency on conventional manure, alternative strategies to ensure nitrogen (N) supply to crops in organic rotations are currently explored. They include anaerobic digestion of plant biomasses, and so-called mobile green manure.

The N value of limited amounts of available slurry may be increased via co-digestion with plant materials in biogas plants. During this treatment, organically bound N is mineralized from both slurry and plant biomass. Green manure is an important source of N in organic crop rotations, but traditional cuts where the plant material is left to decompose in the field has a high risk of both atmospheric losses and N leaching that will reduce the fertilizer value for a subsequent crop. Harvesting and storage of green manure, either as compost or as silage, are alternative strategies for better N use efficiency, because the green manure can then be reallocated to phases of the crop rotation where it will result in the highest yields.

The greenhouse gas balance, like the N balance, reflects the sustainability of the cropping system. As part of an overall evaluation of mobile green manure and co-digestion it is therefore important to quantify and balance yield increase against climate impact.

Emissions of greenhouse gases

The most important contributions to the greenhouse gas balance of agriculture come from methane and nitrous oxide which are both powerful greenhouse gases compared to CO_2 (25 and 300 times, respectively, over a 100-year period). Methane is produced in the digestive system of livestock and during subsequent storage of the manure. Nitrous oxide is also produced during manure storage, but mainly in agricultural soils where both fertilizer products, N fixed by legumes, and crop residues are important sources. Also, ammonia losses and N leaching are indirect sources of nitrous oxide. Both methane and nitrous oxide are produced by microorganisms in oxygen deficient environments.

The greenhouse gas balance of a farm includes all these sources. Other relevant sources are the use of fossil fuels on the farm, which could partly be compensated by energy from biogas production, and imported feed which could increase if grass-clover or other crops are instead used as fertilizer.

Greenhouse gas balance for storage and field application

As part of the research project HighCrop, a study has been conducted which may help evaluate the climate impact of mobile green manure. Here, grass-clover and lucerne were ensiled in plastic-wrapped bales or composted after admixing of chopped straw. Composting and ensiling took place in the period from August 2011 to April 2012, side by side with slurry co-digested with plant biomass (mostly maize silage in this study) and untreated cattle slurry. Unfortunately it was not possible to include also materials with lucerne in the study of greenhouse gas emis-

Pilot-scale storage facility used in this study.

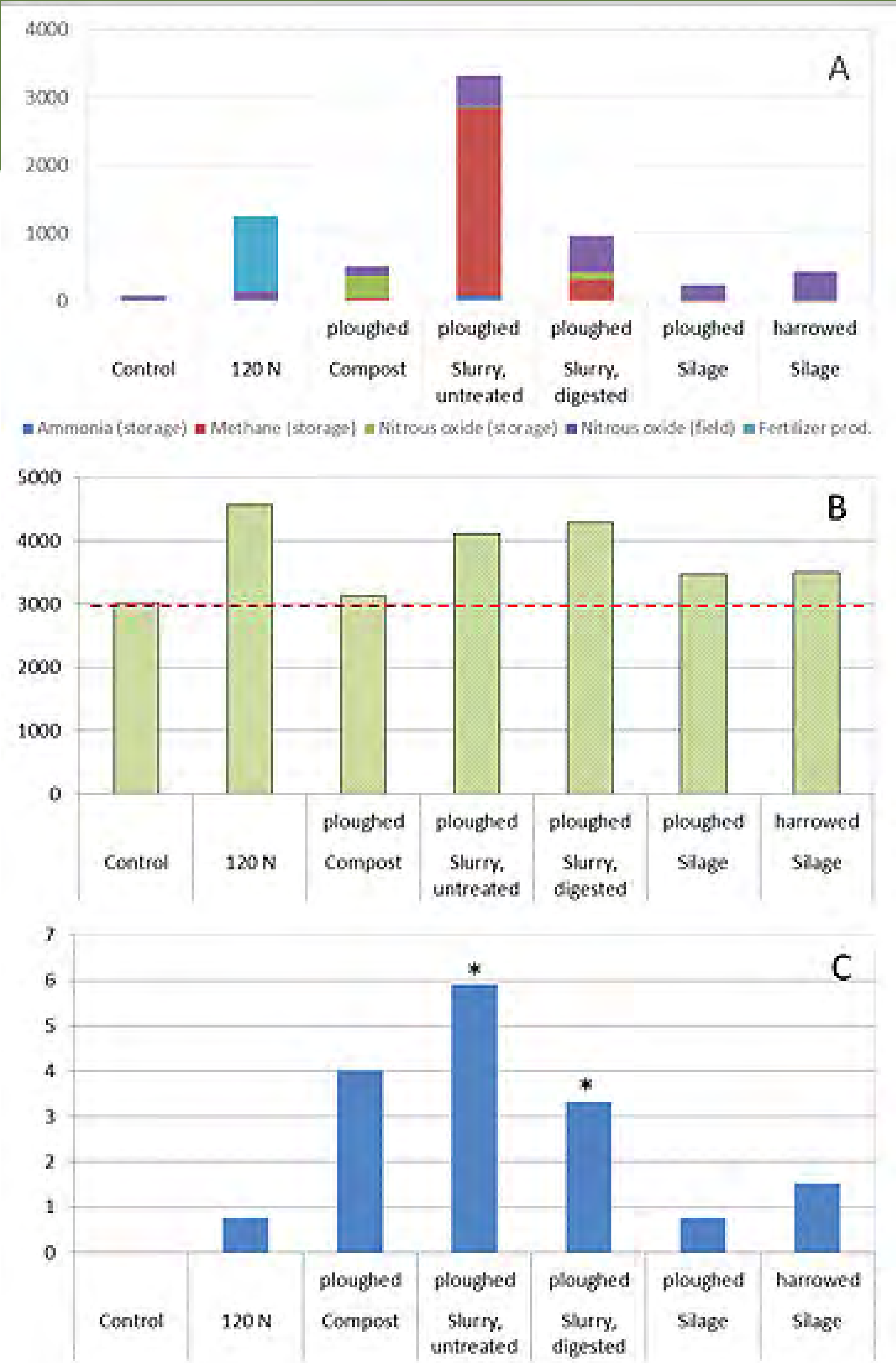

Figure 1.
A. The total climate impact (kg CO_2 equivalents per hectare) as ammonia, methane and nitrous oxide during 7-8 months storage and after field application of compost and silage of grass-clover, untreated cattle slurry, and slurry co-digested with maize silage. The field experiment also included treatments with mineral N fertilizer and an unamended control.
B. Yields of spring barley (kg dry matter in kernels per hectare). The red line marks the yield in the unamended control. Energy use for fertilizer production is included.
C. Climate impact relative to yield increase (kg CO_2eq per kg dry matter in kernels). Compost and silage was surface-applied and incorporated by ploughing unless otherwise stated. Slurries were injected, followed by ploughing.
(A theoretical value for methane emission from cattle was included in the greenhouse gas balance for slurry).*

sions. Emissions of methane, nitrous oxide and ammonia were quantified, and all materials were characterized at start and end of storage.

In April 2012 the four fertilizer materials were used as N source for spring barley with application rates targeting 120 kg N per hectare. An unamended control and a treatment receiving 120 kg N in mineral fertilizer was also included. Emissions of nitrous oxide were monitored during six weeks. By this time the growing crop had depleted plant available N in the soil.

Figure 1A shows the total emission of methane and nitrous oxide during storage and in the field, expressed as CO_2 equivalents per hectare. For mineral fertilizer the energy used for the production was the largest source of greenhouse gases. Untreated slurry was the overall largest emitter of greenhouse gases, especially as a result of methane emissions during storage. The digestate, which released much less methane during storage, formed a thick surface crust partly from maize silage residues.

It is also notable that the emission of nitrous oxide during composting of grass-clover was significant. Composting is a process with a high oxygen demand, and it is well known that oxygen deficiency can develop underneath the compost surface where formation of nitrous oxide can occur.

Climate impact and crop yield increase

Emissions of greenhouse gases can not alone reveal which fertilization strategy is more sustainable. Here it is necessary to also compare with the yield increase resulting from the fertilization. Yield increases in this study

can be seen in Fig. 1B (areas above the dotted line). Only cattle slurry and co-digested slurry gave yields at the same level as mineral fertilizer. The last sub-plot, Fig. 1C, shows the total greenhouse gas emission per kg extra dry matter in kernels. Note that for treatments with slurry a theoretical value for methane emissions from cattle was included. Composting of grass-clover/chopped straw was nearly as critical in terms of climate impact as untreated slurry. Co-digested slurry gave a high added yield with substantially less emission of greenhouse gases compared to untreated slurry. For silage of grass-clover, the emission of greenhouse gases was very low, but the added yield (Fig. 1B) was also moderate.

Shallow incorporation of grass-clover silage by harrowing resulted in higher nitrous oxide emissions than ploughing. This was due to high emission rates in the first few days and may reflect a better contact between silage and soil containing nitrate which is needed for nitrous oxide formation in this early phase.

Both mineral fertilizer and manure are sources of greenhouse gases “up-stream” from the field application. In this study, co-digestion of slurry and plant biomass nearly cut emissions per added yield by 50% compared to untreated slurry, even without accounting for energy substitution. Silage of grass-clover had a lower N fertilizer value than the co-digestate, but also a very low climate impact. It should be mentioned that silage of lucerne had a higher N concentration than silage of grass-clover and gave yields at the same level as the slurries. Unfortunately the lucerne silage could not be included in this study of climate impact.

Silage is characterized by better conservation of nitrogen compared to composting or simple cutting, since environmental losses from the harvested biomass are largely prevented during the winter months. In light of the low climate impact of this material, more knowledge should be acquired on the best agronomic use of ensiled green manure materials.

More information

Read more about the Organic RDD project HighCrop at: http://www.icrofs.dk/Sider/Forskning/organicrdd_highcrop.html

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