Summary of the "Climate and Nitrogen Effects of Harvesting Cover Crops for Biomass Use" Advisory report from DCA – Danish Centre for Food and Agriculture, Aarhus University

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A review has been carried out of existing knowledge regarding the effects of harvesting cover crops, with particular focus on impacts on biomass yield and nitrogen uptake, nitrogen leaching and emissions.

Dry matter yield and nitrogen uptake in the aboveground biomass of cover crops vary considerably between species, locations and years. Overall, a substantial uncertainty must therefore be expected in the potential biomass yield when harvesting cover crops. Dry matter yield, nitrogen uptake and the reduction in nitrogen leaching increase when cover crops are established early after harvest of the main crop, and cover crop growth is expected to increase further if the main crop is harvested earlier than at full maturity. Fertilisation of cover crops can in many cases increase dry matter yield, but the yield response varies markedly, presumably because other growth factors may be limiting under some conditions. Additional nitrogen uptake in harvestable cover crop biomass also varies and is always lower than the amount of nitrogen applied as fertiliser. Cover crop dry matter yield increases through the autumn, especially when harvest is postponed from late September to late October, but only to a limited extent from October to November. However, harvesting in late October compared with late September may entail a greater risk of damaging soil structure due to wetter field conditions. There is a need for more knowledge on how to increase yield and yield stability of cover crops under different conditions.

There is very limited knowledge about the effect of harvesting cover crops on nitrate leaching, as cover crop biomass has normally been left on the field in previous studies and therefore not removed. The amount of nitrogen that is harvested with the biomass in autumn will naturally not be leached during winter, and nitrogen leaching can therefore in principle be expected to be reduced compared with no harvest. However, it is also conceivable that the effect of harvest depends on cover crop species, and that harvest may accelerate the mineralisation of nitrogen in the remaining biomass for certain species. When cover crops are fertilised, there is a potential risk of increased nitrogen leaching, especially if cover crop growth is poor and additional nitrogen uptake is low. More knowledge is needed on the overall effect of harvesting cover crops on both nitrogen leaching and nitrogen carry-over effects on the subsequent crop, under different conditions and for different cover crop species. At present, there is no basis for quantifying the effect or for differentiating between soil types or farm types.

Harvesting cover crops may potentially affect emissions of methane, carbon dioxide and nitrous oxide. Methane emissions from fields are generally low and are not expected to be significantly affected by harvesting cover crops. When cover crop biomass is harvested, carbon that would otherwise contribute to soil carbon stocks is removed, and this may potentially lead to increased carbon dioxide emissions. However, the extent of this change depends, among other factors, on how the biomass is used. If the biomass is used for biogas production, nutrients and the more recalcitrant carbon compounds are returned to the field with the digestate, and there are

indications that carbon in digestate contributes relatively more to stable soil carbon pools than carbon in undigested biomass. Harvesting cover crops for biogas production may therefore have only a limited effect on soil carbon content. However, further studies are needed to assess the effects of harvesting cover crops on soil carbon stocks and thus on carbon dioxide emissions.

There is only very limited knowledge regarding the effect of harvesting cover crops on nitrous oxide emissions. One Danish study shows significantly higher emissions from oilseed radish compared with winter-hardy cover crops such as ryegrass, red clover and winter vetch. For oilseed radish, there was a non-significant tendency toward higher nitrous oxide emissions when biomass was harvested in autumn compared with spring incorporation of the whole biomass, whereas harvesting had no notable effect on emissions from winter-hardy cover crops. The choice of cover crop species is therefore assumed to be important for the effect of harvest on nitrous oxide emissions. A few studies are ongoing, but there is a clear need for more research on nitrous oxide emissions related to the cultivation and management of cover crops.

A preliminary calculation has been made of the potential climate effect of harvesting cover crops and using the biomass for biogas production, compared with incorporating the biomass into the soil. The calculation is based on several assumptions and average values regarding yield, nitrogen uptake and methane production for cover crops with and without nitrogen-fixing species. Harvesting cover crops leads to increased emissions due to reduced soil carbon sequestration, increased use of mineral fertiliser and thereby higher direct and indirect nitrous oxide emissions, as well as increased emissions from the energy used for harvesting. Conversely, harvesting reduces nitrous oxide emissions from crop residues and most importantly reduces emissions due to substitution of natural gas with methane from biogas production. Overall, emissions are reduced by 360 kg CO_2e/ha/year for harvested cover crops without nitrogen-fixing species, while the reduction is 416 kg CO_2e/ha/year for cover crops with nitrogen-fixing species. A supplementary analysis of three scenarios for cover crops without nitrogen-fixing species but with three different levels of nitrogen uptake in aboveground biomass (10, 28 and 80 kg N/ha) and corresponding dry matter yields (0.67, 1.87 and 5.33 tonnes DM/ha) shows total emission reductions of 96, 360 and 1,121 kg CO_2e/ha/year when the biomass is harvested.

Proposals have been developed for field trials to address key knowledge gaps, focusing on cover crop type, fertilisation, harvest timing and interactions with the preceding main crop, with measurements of yield, nitrate leaching, nitrogen carry-over and nitrous oxide emissions.

A preliminary perspective on the business potential of harvesting cover crops indicates that the biomass can potentially be used for various purposes, with biogas production being the most obvious use at present, and protein extraction a possibility in the longer term. Economic analyses clearly show the need to achieve substantial dry matter yields to make harvesting cover crops profitable. It is therefore important to continue development aimed at increasing yield and yield stability. In addition, there is a need to assess the environmental and climate effects of harvesting cover crops, as well as to adjust regulatory frameworks for cover crops in relation to nutrient cycling when cover crops are harvested.