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How can greenhouse gas emissions from rapeseed cultivation be mitigated?

Rapeseed is the most important energy crop for biofuel production in Germany. In 2016, 3.1 million tons of biodiesel were produced in Germany, about 1.8 million tons of which were consumed in Germany. The share of rapeseed as the feedstock for biodiesel was 43 % in 2016. However, this share is increasingly falling in favor of a higher proportion of feedstocks that offer higher greenhouse gas savings, such as waste and residual materials or palm oil. This makes it all the more important to reduce emissions from rapeseed cultivation.

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Avoiding greenhouse gas emissions has increasingly been the most important factor for biofuels' market access since the greenhouse gas quota was introduced in 2015. The European Union has established sustainability criteria in the Renewable Energies Directive: as of 01.01.2018, biodiesel must provide at least 60 % savings in greenhouse gas emissions compared with fossil fuels (50 % for older plants). There is growing pressure on biodiesel as a rapeseed utilization option. In order to remain competitive, sustainable improvements must be made to the climate protection performance of the rapeseed methyl ester produced.

Where do the emissions originate?

In practice, the climate protection performance achieved for rapeseed cultivation is demonstrated by self-declarations based on standard values for yields and rapeseed production greenhouse gas emissions for the corresponding NUTS2 region.

Using fertilizers produced with low emissions is an important strategy to mitigate greenhouse gas emissions. Without a certification system, however, farmers cannot assess if fertilizer production is climate-friendly.

Germany submitted these default values to the EU Commission in 2010. The values are based on a greenhouse gas balance for rapeseed cultivation in the German regions. The predominant factors in this balance are greenhouse gas emissions from production of the nitrogen fertilizer used and emissions of the strong greenhouse gas nitrous oxide, which are caused by nitrogen conversion processes in soils under cultivation and indirectly by nitrate leaching. Together, these sources account for about 80 % of the total greenhouse gas emissions from rapeseed cultivation (Figure). This points to two important strategies for improving the greenhouse gas balance: use of fertilizers with the lowest possible production emissions and improvements in the nitrogen efficiency of rapeseed cultivation.

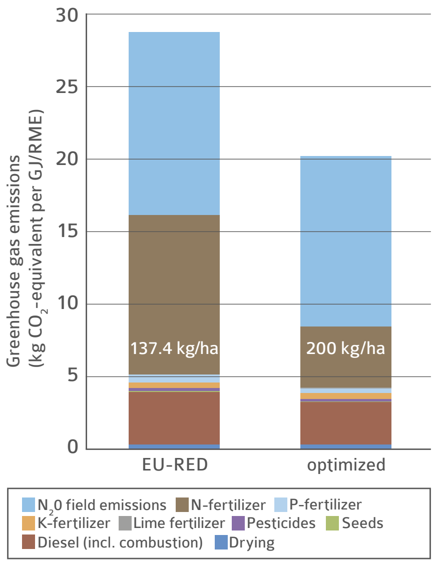
Conscious choice of fertilizers

Over the past decade, many fertilizer manufacturers have significantly reduced greenhouse gas emissions arising from production of nitrogen fertilizers (Table). There are nevertheless still considerable differences between manufacturers. Clear and comparable data on the emissions background of the fertilizers deployed would offer enormous potential for agriculture to reduce its greenhouse gas emissions. For farmers, however, it is currently not apparent if production of a particular fertilizer is climate-friendly, as there is no certification system.

At present, therefore, the amount of N fertilizer used is the most important parameter that farmers can adjust to reduce emissions. However, the type of fertilizer used also offers potential savings. According to the current calculation method, manure from livestock farming and biogas digestates do not generate emissions during production, but considerable differences also exist for synthetic fertilizers. Generally speaking, nitrate-containing fertilizers are produced with higher emission levels than ammonium and urea fertilizers. Urea fertilizers, however, generate significantly higher ammonia emissions and may therefore only be applied in Germany in future in combination with urease inhibitors or if quickly incorporated into the soil.

High nitrogen balance surpluses are typical for rapeseed cultivation, as rape

Greenhouse gas balance for rapeseed quantity required to produce one GJ biodiesel



(Rapeseed oil methyl ester (RME)), the left-hand column shows the greenhouse gas balance, calculated according to the current standard values of the EU's Renewable Energies Directive (EU-RED). The right-hand column was calculated assuming higher N fertilization (200kg N/ha), higher yield (3.8t/ha), low-emission N-fertilizer and incorporating the new results on fertilizer-induced N2O field emissions (optimized).

seed displays an unfavorable ratio between nitrogen removal with the harvested product and total nitrogen uptake/fertilization intensity. In many locations this results in an increased risk of nitrate leaching in autumn and winter after the rapeseed harvest. Nitrate not only pollutes groundwater and water bodies, but is also converted into nitrous oxide by denitrification. Nitrate leaching thus has an indirect greenhouse gas effect. In addition, there are also direct nitrous oxide emissions from the field. The lower the level of nitrogen used per ton of rapeseed harvested, the better the greenhouse gas balance. Good, secure yields, fertilization tailored to plant demand as well as efficient retention and utilization of the increased residual nitrogen in the soil after rapeseed harvest are all essential to attain this goal.

Evidence from experimental studies

In fertilization experiments as part of the joint project "Mitigation of greenhouse gas emissions in rapeseed cultivation with a particular focus on nitrogen fertilization", the increase in mass yields above N fertilization of 120 kg per hectare was almost offset by the decrease in oil content as nitrogen fertilization increased. Thus, if higher prices could be attained for rapeseed oil with improved climate performance, it might even make economic sense to fertilize slightly below the fertilization recommendations. The greenhouse gas quota, which stipulates greenhouse gas savings targets for fuel producers, presents an incentive to adopt this approach.

Direct nitrous oxide emissions were also measured in the aforementioned fertilizer increase experiments. The results demonstrate that emissions are overestimated in the assumption underlying the NUTS2 values that on average 1 % of fertilizer nitrogen is emitted as nitrous oxide. The study demonstrated that 0.6 % is a more accurate value even with relatively intensive fertilization (200 kg N). However, this proportion varies considerably between sites; values from 0.3 % to over 1.2 % were measured in the project. Strong year-on-year fluctuations in nitrous oxide emissions were also observed. Nitrous oxide emissions depend primarily on the availability of mineral nitrogen in the soil as well as on soil moisture, temperature and the

GHG emissions in production of N-fertilizers

Nitrogen fertilizer	Production emissions (kg CO_2-equivalent per kg nitrogen)
Ammonium sulphate	2.7
Ammonium nitrate	3.5
Calcium ammonium nitrate	3.7
Calcium nitrate	4.4
Urea	2.0
Generic N-fertilizer (2009)*	5.9
Generic N-fertilizer (2017)*	4.0

* Figure assumed by EU for purposes of calculation if fertilizer type unknown
(Sources: International Fertiliser Society, 2014, Renewable Energies Report 2009, JRC-Report 2017)

availability of readily degradable carbon in the soil. The highest emissions in the joint project were observed when fertilizing quite humid soil. However, increased nitrous oxide emissions were also observed in the post-harvest period with turnover of crop residues. Farmers can therefore reduce nitrous oxide emissions by optimum adaption of fertilization to crop requirements and weather, using precision farming techniques and by binding the available residual nitrogen as quickly and completely as possible in the succession or catch crop after harvest. The usual succession crop, winter wheat, can only achieve this to a limited extent due to its low nitrogen uptake in autumn.

How much potential exists for emissions savings?

The current method for calculating greenhouse gas emissions from rapeseed production (Figure, EU-RED) assumes unrealistically positive figures for nitrogen efficiency and a nitrogen fertilizer rate far below normal practice and fertilizer recommendations. The calculations are based on nitrogen input of 34 kg per ton of rapeseed. If realistic N-fertilizer quantities are assumed, the figure would indicate total emissions of around 38 kg CO_2 equivalent per GJ RME on the basis of the currently valid emissions calculation (EU-RED).

The right-hand column (optimized) indicates the considerable potential to mitigate greenhouse gas emissions from rapeseed production. The calculation here assumes realistic N-fertilization, low production-emissions N-fertilizer, a slight increase in yield and the updated emission factors for N2O field emissions. Taking these factors into account, a much more favorable greenhouse gas balance of about 20 kg CO_2 equivalents per GJ of rapeseed methyl ester would be obtained. This shows that there is still considerable potential for reduction compared to the 29 kg CO_2 equivalents per GJ of rapeseed methyl ester assumed in the NUTS2 values.

One advantage of integrating rapeseed into cereal-rich crop rotations is its positive preceding crop effect. The common succession crop, winter wheat, benefits from rapeseed's N surplus and propagation of typical cereal weeds and pathogens is also interrupted. This not only reduces nitrogen fertilization for wheat crops after rapeseed, but at the same time also achieves higher yields; both effects are not currently factored into greenhouse gas accounting. In the joint project, questionnaire data from farmers were evaluated with regard to this phenomenon and a statistical comparison carried out for wheat grown after rapeseed and after cereals. On average, the yield per hectare of rapeseed wheat was 5.6 dt higher and nitrogen fertilization was 5 kg per hectare lower. However, there were significant differences between wheat classes. The yield advantage for bread-quality wheat grown after rapeseed was as much as 7.7 dt per hectare. In scientific field trials, even higher nitrogen-saving potential was demonstrated for rapeseed wheat compared to stubble wheat than is currently realized in practice. This indicates that there is also still considerable potential in this area to reduce emissions when integrating rapeseed into crop rotations.

Creating and using potential

Commercial crop-growing, including rapeseed cultivation, faces considerable challenges, both against the backdrop of the Renewable Energies Directive and as a result of the German Federal Government's 2050 Climate Protection Plan. As in other areas of agriculture, potential to mitigate greenhouse gas emissions must be created and exploited. This entails developing new technical approaches and consistently implementing existing measures such as needs-based fertilization or application of manure also in crop-growing regions. Results show that emission assessments should encompass not only individual crops but must increasingly include crop rotation systems in order to address crop rotation effects and provide incentives to optimize crop rotation from the perspective of nutrient efficiency and climate protection.

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The final project report is available via the following link: https://www.opena- grar.de/receive/openagrar_mods_000358422

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