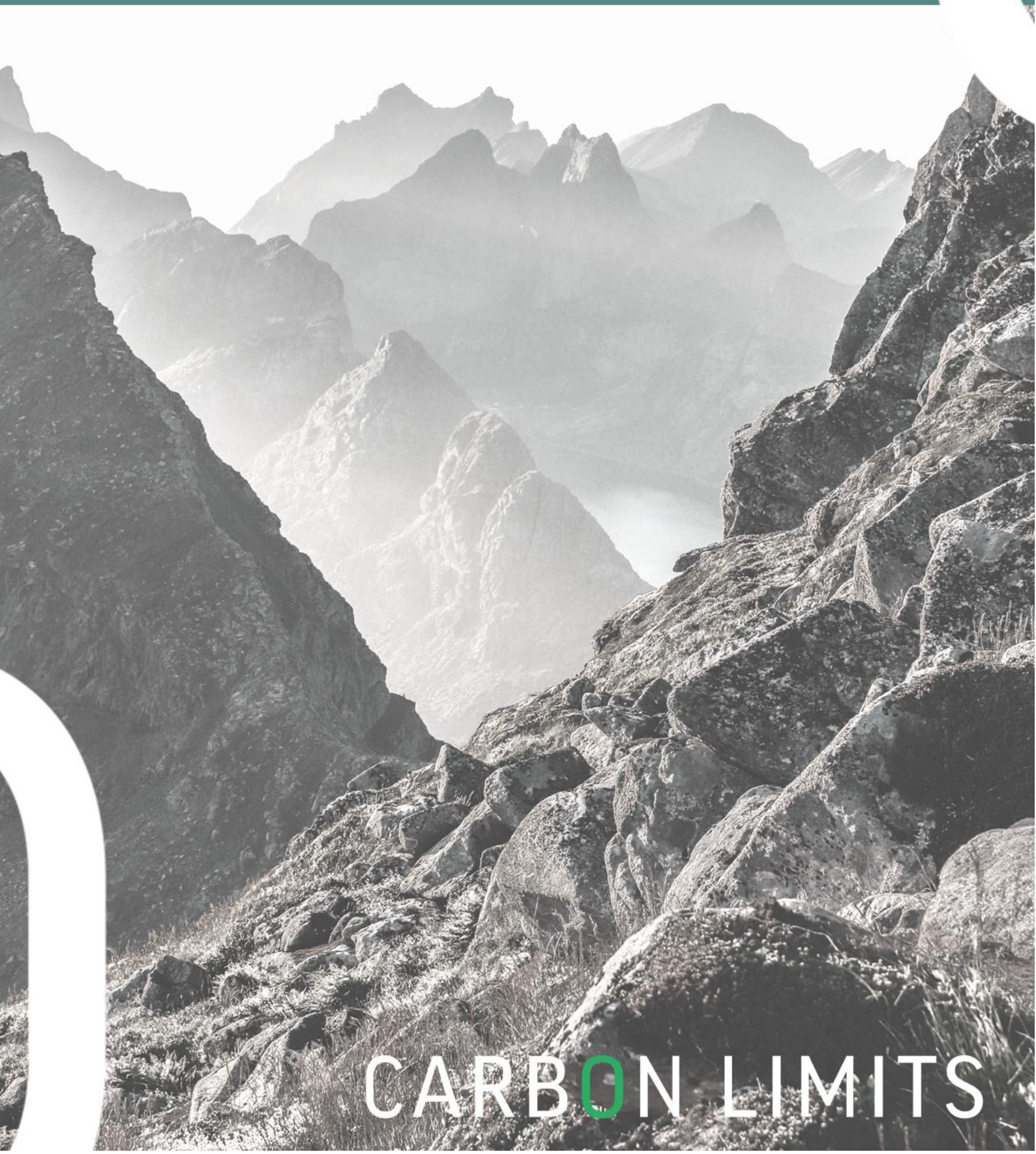
Calculation of atmospheric nitrogen emissions from crop residues in Norwegian agriculture

Technical description of the revised model

Project for Norwegian Environment Agency and SSB

M-2822|2024



CARBON LIMITS

Abstract

Crop residues affect the nitrogen (N) content of the soils, which, in turn, influences the amount of nitrous oxide (N_2O) and ammonia (NH_3) released to the air. The N content returned to soil notably depends on the amount and type of crop, as well as the crop residue management. These parameters need to be taken into consideration when building a model to calculate N content from crop residues.

A revised excel model for calculating N content from crop residues for the Norwegian agriculture has been developed by Carbon Limits. The model is built on the previously used model, developed by Bioforsk and operated by Statistics Norway (SSB). The model allows to calculate N content from different types of crop residues as well as the associated N_2O and NH_3 emissions per year.

The calculations for N_2O emissions follow Tier 1 methodology and are based on the equations updated by the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

The calculations for NH_3 emissions follow a new methodology based on the equations updated by the 2023 EEA Guidebook based on the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* and De Ruijter and Huijsmans (2019).

This report describes the methodology implemented in the updated model, the most important changes from the previous version of the model, as well as the main input data and factors used.

CARBON LIMITS

Stensberggata 25

0170 Oslo

Norge

carbonlimits.no

NO 988 457 930

Carbon Limits works with public authorities, private companies, finance institutions and non-governmental organizations to reduce emissions of greenhouse gases from a range of sectors. Our team supports clients in the identification, development and financing of projects that mitigate climate change and generate economic value, in addition to providing advice in the design and implementation of climate and energy policies and regulations.

Table of Contents

Abstract 2
Table of Contents 3
1. Introduction 5
2. Calculation of N content and gas emissions 6
2.1 Methodology 6
2.1.1 N_2O emissions 6
2.1.2 NH_3 emissions 7
2.2 Inputs to the model 8
2.3 Calculation steps and parameters – N_2O 8
2.3.1 Quantity of harvested crops in dry matter mass 9
2.3.2 Fraction of different practices in crop and crop residues management 10
2.3.3 N content in above-ground residues 10
2.3.4 N_2O emissions from above-ground residues 11
2.3.5 N content in below-ground crop residues 11
2.3.6 N_2O emissions from below-ground residues 11
2.3.7 Total N content and N_2O emissions per crop type 12
2.3.8 Total N content and N_2O emissions 12
2.4 Calculation steps and parameters – NH_3 12
2.4.1 N content in above-ground residues 13
2.4.2 Fraction of $N_Load_{(T)}$ remaining on the surface for 3 or more days 13
2.4.3 NH_3 emissions from above-ground residues remaining on the surface for 3 or more days 14
2.4.4 Total NH_3 emissions 14
2.5 Parameters used 14
3. Changes compared to the previous version of the model. 17
3.1 Change of method in IPCC 18
3.1.1 Expression of the total N content 18
3.1.2 Determination of the ratio of above-ground residue dry matter 18
3.2 Change of method for NH_3 emissions calculations 19
3.3 Other technical adjustments 20

References 21
Appendix 22

1. Introduction

The main objective of the project was to update the existing model for nitrogen (N) content in crop residues developed by Bioforsk in 2014 and operated by Statistics Norway (SSB). The updated model calculates N content in crop residues and the associated emissions of nitrous oxide (N_2O), based on the methodology described by the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter IPCC 2019)[1]. The former model was based on the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[2].

The new version of the model features several changes in the formulae used to calculate the N content in crop residues, as well as changes in the determination of some parameters. Table 1 below summarizes these changes.

Table 1 – Summary of the modifications in the update of the model.

Modification	Affected crop types	Impact on results
Calculations of N_2O and NH_3 emissions from the N content.	All	Additional results incorporated in the model
Update of the Equation 11.6 from IPCC 2006 to IPCC 2019.	All	Decrease of N content estimate for crops with straw-like residues[3]. Results unchanged for the others.
Change of the method to determine the quantity of above-ground residues.	All	Increase of the estimate for the N content.
Inclusion of the combustion factor in the formulae.	Crops with straw-like residues.	Increase of the estimate for the N content.

In 2024, the model was further updated with a new methodology for the calculation of the associated emissions of ammonia (NH_3). The updated calculations follow the methodology described by the *EMEP/EEA air pollutant emission inventory guidebook 2023*[4] based on De Ruijter and Huijsmans (2019)[5].

[1] Hergoualc'h et al., "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories". *Volume 4: Agriculture, Forestry and Other Land Use*. *Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application*. 2019. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

[2] De Klein et al., "2006 IPCC Guidelines for National Greenhouse Gas Inventories". *Volume 4: Agriculture, Forestry and Other Land Use. Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application*. 2006. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

[3] In this report, "crop with straw-like residues" refers to crop types for which the residues can be used as straw for bedding, forage, construction and/or that are burnt.

[4] Hutchings et al., "EMEP/EEA air pollutant emission inventory guidebook 2023". *Chapter 3.D Agricultural soils*. 2023. Retrieved from: https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/3-agriculture/3-d-agricultural-soils-2023/view .

[5] de Ruijter, F. J., andHuijsmans, J. F. M, 2019, "A methodology for estimating the ammonia emission from crop residues at a national scale", Atmospheric Environment, X, (2)100028. Retrieved from: https://www.sciencedirect.com/science/article/pii/S2590162119300310

Table 2 summarizes the main changes implemented in the updated model for estimation of NH_3 emissions from crop residues.

Table 2 Summary of changes in the estimation of NH_3 emissions from crop residues

Modification	Affected crop types	Impact on results
Calculations of NH_3 emissions	All	Emissions from below-ground residues not included. Emissions from low N concentration residues are not included. Emissions from residues that are incorporated within 3 days are not included.

2. Calculation of N content and gas emissions

2.1 Methodology

2.1.1 N_2O emissions

The N content in crop residues is determined using the Tier 1 methodology from the IPCC guidelines. More specifically, the calculations are based on the updated Equation 11.6 from IPCC 2019:

$$F_{CR} = \sum_{T} \{[AGR_{(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)} - (Frac_{Burnt(T)} \times C_f))] + [BGR_{(T)} \times N_{BG(T)}]\}$$

Where:

F_{CR} = annual amount of N in crop residues (above and below ground), kg N yr^{-1}

T = crop or forage type

$AGR_{(T)}$ = annual total amount of above-ground crop residue for crop T, kg d.m. yr^{-1}

$N_{AG(T)}$ = N content of above-ground residues for crop T, kg N (kg d.m.) $^{-1}$

$Frac_{Remove(T)}$ = fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction, dimensionless

$Frac_{Burnt(T)}$ = fraction of annual harvested area of crop T burnt, dimensionless

C_f = combustion factor (dimensionless)

$BGR_{(T)}$ = annual total amount of belowground crop residue for crop T, kg d.m. yr^{-1}

$N_{BG(T)}$ = N content of below-ground residues for crop T, kg N (kg d.m.)$^{-1}$

NB: d.m. stands for “dry matter”.

According to Equations 11.1 and 11.6 of IPCC 2019, direct emissions of N_2O are calculated by multiplying the N content of crop residues by an emission factor:

$$N_2O - N = F_{CR} \times EF_{N_2O}$$

$$N_2O = N_2O - N \times 44/28$$

Where:

$N_2O - N$	= annual direct N_2O–N emissions from N inputs in crop residues to managed soils, kg N_2O–N yr^{-1}
EF_{N_2O}	= emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$
N_2O	= annual direct N_2O emissions from N inputs in crop residues to managed soils, kg N_2O yr^{-1}

The sources used for each parameter are provided in Table 3.

2.1.2 NH_3 emissions

Methodology for calculation of NH_3 emissions is based on the European Environmental Agency updated methodology based on De Ruijter and Huijsmans (2019). The main differences from IPCC 2019 methodology are:

1. Only above-ground residues are included in the calculation of total NH_3 emissions.
2. No emissions from low N concentration residues ($N_{AG(T)}$ <= 0.0132 kg N/kg d.m.): based on values displayed in Table 15 in Appendix A, NH_3 emissions for wheat, rye, triticale, barley, oat, oil seeds, peas and beans are assumed 0.
3. Residues present for less than 3 days are not included in the calculation of the total NH_3 emissions: new parameters $Frac_{Incorp(T)}$, α and β are introduced.

More specifically, the calculations are based on the following equation:

$$NH_{3_cropresidues} = \frac{17}{14}\sum_T \left\{Area_{(T)} \times N_{Load\,(T)} \times F_{(T)} \times EF_{cropresidue\,(T)}\right\}$$

$$N_{Load\,(T)} = AG_{DM(T)} \times N_{AG(T)}$$

$$F_{(T)} = 1 - Frac_{Incorp(T)} - \alpha Frac_{Remove(T)} - \beta Frac_{Burnt(T)} \times C_f$$

Where:

$Area_{(T)}$	= Area of crop T (ha)
$N_{Load\,(T)}$	= Amount of N in the residues from crop T (kg N/ha)
$AG_{DM(T)}$	= Above-ground residues dry matter for crop T (kg d.m./ha)
$N_{AG(T)}$	= N content of above-ground residues for crop T, kg N (kg d.m.) $^{-1}$
$F_{(T)}$	= Fraction of $N_{Load\,(T)}$ remaining on the surface for 3 or more days

$Frac_{Incorp(T)}$ = Fraction of residues incorporated within 3 days (dimensionless)

α = Fraction of $Frac_{Remove(T)}$ removed within 3 days (dimensionless)

$Frac_{Remove(T)}$ = fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction, dimensionless

β = Fraction of $Frac_{Burnt(T)}$ removed within 3 days (dimensionless)

$Frac_{Burnt(T)}$ = fraction of annual harvested area of crop T burnt, dimensionless

C_f = combustion factor (dimensionless)

NB: d.m. stands for "dry matter".

The sources used for each parameter are provided in Table 3.

2.2 Inputs to the model

The model uses as inputs the annual harvested fresh quantity for each crop, expressed in kg fresh weight. For a crop T, this quantity is noted $Yield\ Fresh_{(T)}$. Note that, contrary to Equations 11.6 and 11.7 of IPCC 2019, the yield is expressed in kg and not kg.ha^{-1}. Hence, the parameter $Area_{(T)}$ is not used in this model.

The types of crops are:

- Hay
- Wheat
- Rye
- Triticale
- Barley
- Oat
- Oil seeds
- Potatoes
- Tubers
- Green forages
- Vegetables
- Peas
- Beans

In the model, the crop "Hay" is divided into two crop types: "Perennial grass" and "Grass-clover mixtures".

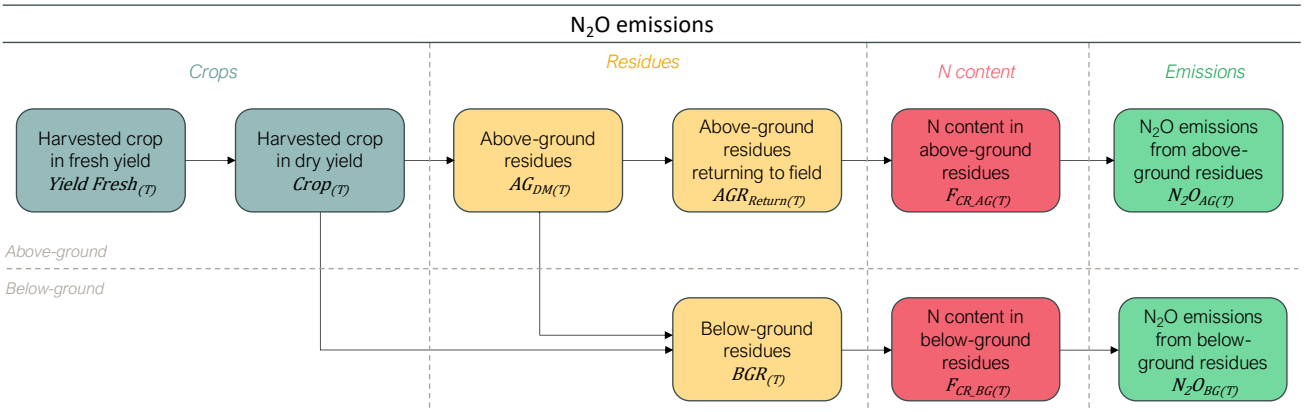
The sources used for each input are provided in Table 3.

2.3 Calculation steps and parameters – N_2O

In the updated model, the calculations based on Equation 11.6 of IPCC 2019 are broken down into several steps to obtain results per crop type, as well as to calculate the emissions separately for above-ground and below-ground residues (where Equation 11.6 from IPCC 2019 only gives the sum through F_{CR}). Therefore, the model introduces notations for parameters that are not directly taken from the IPCC. Table 3, at the end of this section, shows a

summary of the parameters used in the model, indicates the sources used and specifies if the parameter was introduced for the purposes described above or directly taken from the referenced equation. Figure 1 summarizes the main calculation steps used in the model.

Figure 1 – Main calculation steps for N_2O in the model



2.3.1 Quantity of harvested crops in dry matter mass

The first step is to calculate the annual quantity of crops harvested in kg dry matter. For each crop T, this quantity is noted $Crop_{(T)}$ and is obtained by multiplying the quantity in fresh weight $Yield\ Fresh_{(T)}$ by the dry matter fraction of the crop $T(DRY_{(T)})$.

$Yield\ Fresh_{(T)}$ is the main user input in the model ("INPUT-SSB" tab). The dry matter fraction $DRY_{(T)}$ can be changed in the "INPUT – FACTORS" tab. The values for this parameter detailed per crop type are available in Table 6 in Appendix A.

For the crop type "Grass-clover mixtures", the quantity of harvested crop is obtained by multiplying the quantity of harvested hay by the fraction grass-clover mixtures in the hay. This parameter noted $\%clover$ is entered, per year, in the "INPUT – FACTORS" tab. A fixed value of 55% taken from Grønlund et al. (2014)[6] (hereafter "Bioforsk report") was used. The quantity of "Perennial grass" corresponds to the rest of the hay quantity.

The calculations carried out at this first step are based on the following equation:

$$Crop_{(T)} = \begin{cases} Yield\ Fresh_{(Hay)} \times (1 - \%clover) \times DRY_{(T)} & \text{if } T = "Perennial\ grass" \\ Yield\ Fresh_{(Hay)} \times \%clover \times DRY_{(T)} & \text{if } T = "Grass - clover\ mixtures" \\ Yield\ Fresh_{(T)} \times DRY_{(T)} & \text{else} \end{cases}$$

[6] Grønlund et al., «Nitrogen I restavlinger Oppdatering av koeffisienter for beregning av lystgass fra restavlinger», Bioforsk rapport, 2014

2.3.2 Fraction of different practices in crop and crop residues management

The second step is to calculate the quantity of above-ground residues that returns to soil, using the parameters referring to crop and crop residues management.

The model calculates the fraction of total area under crop T that is renewed annually ($Frac_{Renew(T)}$), which is equal to the inverse of the renewing period. The renewing period, noted $P_{Renew(T)}$[7], is entered per year in the "INPUT – FACTORS" tab. A fixed value of 10 years is used for perennial grass and grass-clove mixtures (taken from the Bioforsk report[8]), and 1 year is used for other crops.

$$Frac_{Renew(T)} = 1/P_{Renew(T)}$$

The fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding, and construction ($Frac_{Remove(T)}$) and the fraction of annual harvested area burnt ($Frac_{Burnt(T)}$) are directly entered in the model in the "INPUT – FACTORS" tab. The values of these parameters are entered for each year.

The values used for $Frac_{Remove(T)}$ are available in Table 10 in Appendix A, while the values used for $Frac_{Burnt(T)}$ are provided in Table 12 in Appendix A.

2.3.3 N content in above-ground residues

First, the quantity of above-ground residues due to crop T, $AG_{DM(T)}$, is calculated by multiplying the quantity of crop by the ratio of above-ground residue dry matter to harvested yield. This parameter noted $R_{AG(T)}$ is expressed in kg d.m. (kg d.m.) $^{-1}$ and is entered in the "INPUT – FACTORS" tab. The detail per crop type is given in Table 7 in Appendix A.

The calculation, extracted from Equation 11.6 of IPCC 2019 is represented as follows:

$$AG_{DM(T)} = Crop_{(T)} \times R_{AG(T)}$$

This allows to calculate the annual quantity of above-ground residues for crop T:

$$AGR_{(T)} = Frac_{Renew(T)} \times AG_{DM(T)}$$

This equation is not explicitly described in IPCC 2019. It was deduced by analyzing the physical meaning of the different parameters and was confirmed by the comparison of the former and new equations 11.6 (see Appendix B).

Then, the annual quantity of above-ground residues that is returned to the soil due to crop T, noted $AGR_{Return(T)}$, is calculated according to the following equation:

$$AGR_{Return(T)} = AGR_{(T)} \times (1 - Frac_{Remove(T)} - (Frac_{Burnt(T)} \times C_{f(T)}))$$

This corresponds to the above-ground part of Equation 11.6 in IPCC 2019. The combustion efficiencies $C_{f(T)}$ are entered in the "INPUT – FACTORS" tab. Values used are provided in Table 13 in Appendix A.

[7] This parameter corresponds to the factor X in the description of Equation 11.6 in IPCC 2019
[8] Grønlund et al., «Nitrogen I restavlinger Oppdatering av koeffisienter for beregning av lystgass fra restavlinger», Bioforsk rapport, 2014

Finally, the quantity of nitrogen in above-ground residues, $F_{CR-AG(T)}$, is calculated using the N content of above-ground residues. This parameter, noted $N_{AG(T)}$, is expressed in kg N (kg d.m.) $^{-1}$ and is entered in the "INPUT – FACTORS" tab. The values used are displayed in Table 15 in Appendix A. The calculations are based on Equation11.6 of IPCC 2019 and are summarized by the following equation:

$$F_{CR-AG(T)} = AGR_{Return(T)} \times N_{AG(T)}$$

2.3.4 N_2O emissions from above-ground residues

Emissions of N_2O are calculated by multiplying the N content by an emission factor $EF_{N_2O(T)}$. This parameter is entered in the "INPUT – FACTORS" tab. Emissions from the above-ground residues are calculated as follows:

$$N_2O_{AG(T)} = F_{CR-AG(T)} \times EF_{N_2O(T)} \times 44/28$$

Following the IPCC default factor (taken from Table 11.1 of IPCC 2019), for all crops, the emission factor is: $EF_{N_2O(T)} = 0.006 \text{ kg } N_2O\text{–N } (kg\ N)^{-1}$ presuming 100% wet climate in agricultural land in Norway. The factor $44/28$ converts $\text{kg } N_2O\text{–N}$ into $\text{kg } N_2O$.

2.3.5 N content in below-ground crop residues

The quantity of below-ground crop residues, $BGR_{(T)}$, is calculated from the quantity of above-ground biomass using the ratio of below-ground root biomass to above-ground shoot biomass $RS_{(T)}$. This parameter is expressed in kg d.m. (kg d.m.) $^{-1}$ and is entered in the "INPUT – FACTORS" tab. The values used for this parameter are summarized in Table 14 in Appendix A.

The following equation, taken from Equation 11.6 in IPCC 2019, is used:

$$BGR_{(T)} = (Crop_{(T)} + AG_{DM(T)}) \times RS_{(T)} \times Frac_{Renew(T)}$$

Then quantity of nitrogen in below-ground residues, $F_{CR-BG(T)}$, is calculated using the N content of below-ground residues for crop T. This parameter, noted $N_{BG(T)}$, is expressed in kg N (kg d.m.) $^{-1}$ and is entered in the "INPUT – FACTORS" tab. The values used are displayed in Table 16 in Appendix A. The calculations are based on Equation11.6 of IPCC 2019 and are summarized by the following equation:

$$F_{CR-BG(T)} = BGR_{(T)} \times N_{BG(T)}$$

2.3.6 N_2O emissions from below-ground residues

Emissions of N_2O are calculated the same way as for above-ground residues by multiplying the N content by an emission factor. The emission factor $EF_{N_2O(T)}$ the same as for above-ground residues. Emissions from above-ground residues are thus calculated as follows:

$$N_2O_{BG(T)} = F_{CR-BG(T)} \times EF_{N_2O(T)} \times 44/28$$

2.3.7 Total N content and N_2O emissions per crop type

For each crop type, the total annual N content is the sum of the N content of above-ground residues and of below-ground residues:

$$F_{CR(T)} = F_{CR-AG(T)} + F_{CR-BG(T)}$$

Following the same logic, the model calculates the total N_2O emissions due to crop residues for crop T:

$$N_2O_{(T)} = N_2O_{AG(T)} + N_2O_{BG(T)}$$

2.3.8 Total N content and N_2O emissions

Finally, the total annual N content is calculated as the sum of the N content of residues for all crop types:

$$F_{CR} = \sum_{T} F_{CR(T)}$$

The total annual N_2O emissions due to all crop residues are:

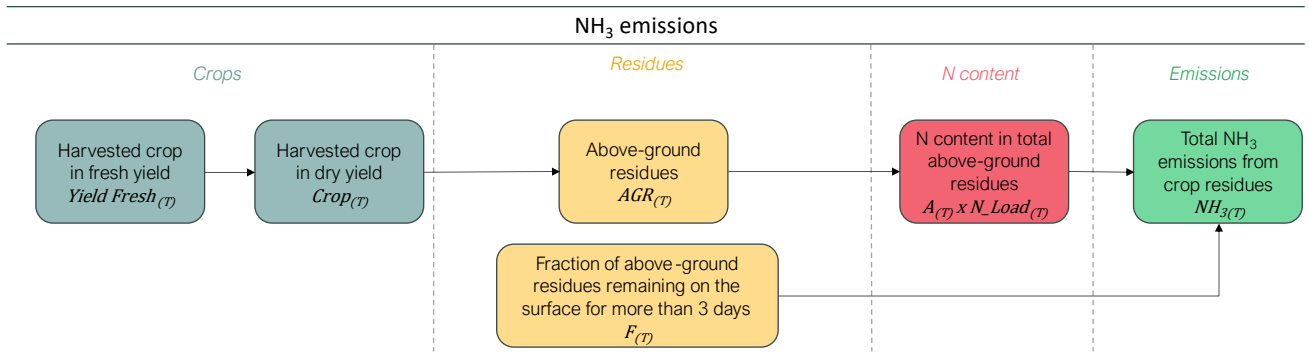
$$N_2O = \sum_{T} N_2O_{(T)}$$

2.4 Calculation steps and parameters – NH_3

In the updated model, the calculations for NH_3 are based on the EEA Guidebook (2023) based on Equation 11.6 of IPCC 2019 and De Ruijter and Huijsmans (2019) as explained in section 0.

The equation presented in section 0 is broken down into several calculation steps in the model to obtain results per crop type. Table 3, at the end of this section, shows a summary of the parameters used in the model, indicates the sources used and specifies if the parameter was introduced for the purposes described above or directly taken from the referenced equation. Figure 2 summarizes the main calculation steps used in the model.

Figure 2 – Main calculation steps in the model – NH_3



The calculations of the annual quantity of crops harvested in kg dry matter follow the same steps as described in sections 2.3.1 and 2.3.2.

2.4.1 N content in above-ground residues

The annual amount of N in above-ground residues of crop T is calculated according to the following equation:

$$Area_{(T)} \times N_Load_{(T)} = AGR_{(T)} \times N_{AG(T)}$$

The methodology to calculate the annual quantity of above-ground residues for crop T, $AGR_{(T)}$, follows the same steps as described in section 2.3.3.

The parameter $N_{AG(T)}$ expressed in kg N (kg d.m.) $^{-1}$ corresponds to the N content of above-ground residues and is entered in the "INPUT – FACTORS" tab. The values used are displayed in Table 15 in Appendix A.

2.4.2 Fraction of $N_Load_{(T)}$ remaining on the surface for 3 or more days

Note that only NH_3 emissions from the residues remaining on the surface for 3 or more days are included in the total NH_3 emissions from crop residues. The fraction of $N_Load_{(T)}$ remaining on the surface for 3 or more days is calculated based on the following equation:

$$F_{(T)} = 1 - (\, Frac_{Incorp(T)} + \alpha \times Frac_{Remove(T)} + \beta \times Frac_{Burnt(T)} \times C_{f(T)}))$$

The fraction of above-ground residues of crop T incorporated within 3 days of harvesting ($Frac_{Incorp(T)}$), the fraction of above-ground residues removed annually within 3 days of harvesting for purposes such as feed, bedding, and construction ($\alpha \times Frac_{Remove(T)}$) and the fraction of annual harvested area burnt within 3 days of harvesting ($\beta \times Frac_{Burnt(T)}$) are directly entered in the model in the "INPUT – FACTORS" tab. The values of these parameters are entered for each year.

The values used for $Frac_{Incorp(T)}$ are available in Table 8 in Appendix A, the values used for α and $Frac_{Remove(T)}$ are respectively available in Table 9 and Table 10 in Appendix A, and the values used for β and $Frac_{Burnt(T)}$ are respectively provided in Table 11 and Table 12 in Appendix A.

2.4.3 NH_3 emissions from above-ground residues remaining on the surface for 3 or more days

Emissions of NH_3 are calculated by multiplying the N content of the above-ground residues remaining on the surface for 3 or more days by an emission factor $EF_{NH_3(T)}$. This parameter is entered in the "INPUT – FACTORS" tab. Total emissions are calculated as follows:

$$NH_{3(T)} = (Area_{(T)} \times N_Load_{(T)}) \times F_{(T)} \times EF_{NH_3(T)}$$

Following the EEA Guidebook 2023 based on the model of De Ruijter and Huijsmans (2019), for all crops, the emission factor is:

- If the $N_{AG(T)} \leq 0.0132$ kg N (kg d.m.)$^{-1}$: $EF_{NH_3(T)} = 0$
  This applies for wheat, rye, triticale, barley, oat, oil seeds, peas and beans (see $N_{AG(T)}$ in Table 15Table 14 in Appendix A*).*
- Otherwise: $EF_{NH_3(T)}$ = (410 * $N_{AG(T)}$-5.42)/100

2.4.4 Total NH_3 emissions

The total annual NH_3 emissions due to all crop residues are:

$$NH_3 = 17/14 \sum_T NH_{3(T)}$$

The factor $17/14$ converts $\mathrm{kg}\, NH_3\text{–}\,\mathrm{N}$ into $\mathrm{kg}\, NH_3$.

2.5 Parameters used

Table 4 below summarizes the parameters used in the model and mentioned in sections 2.3 and 2.4.

Table 3 – Summary of the parameters in the model

Parameter	Description	Unit	Value from	Reference
$\%clover$	Fraction of grass-clover mixtures in the hay	-	Bioforsk report	Introduced by the model
α	Fraction of $Frac_{Remove(T)}$ removed within 3 days	-	De Ruiter and Huijsmans, 2019	EEA guidebook 2023 (updated) adapted from IPCC 2019, Equation 11.6
β	Fraction of $Frac_{Burnt(T)}$ removed within 3 days	-	De Ruiter and Huijsmans, 2019	EEA guidebook 2023 (updated) adapted from IPCC 2019, Equation 11.6

Parameter	Description	Unit	Value from	Reference
$AG_{DM(T)}$	Above-ground residue dry matter for crop T	kg d.m.	Calculated in the model	IPCC 2019, Equation 11.6
$AGR_{(T)}$	Annual total amount of above-ground crop residue for crop T	kg d.m.	Calculated in the model	IPCC 2019, Equation 11.6
$AGR_{Return(T)}$	Annual total amount of above-ground crop residue returned to the soil for crop T	kg d.m.	Calculated in the model	Introduced by the model
$Area_{(T)}$	Area of crop T	ha	Not used in the model	-
$BGR_{(T)}$	Annual total amount of belowground crop residue for crop T	kg d.m.	Calculated in the model	IPCC 2019, Equation 11.6
$C_{f(T)}$	Combustion factor crop T	-	IPCC 2019	IPCC 2019, Equation 11.6
$Crop_{(T)}$	Harvested dry matter quantity for crop T	kg d.m.	Calculated in the model	IPCC 2019, Equation 11.7
$DRY_{(T)}$	Dry matter fraction of harvested crop T	kg d.m. (kg fresh weight)$^{-1}$	IPCC 2019 and Bioforsk report	IPCC 2019, Equation 11.7
$EF_{N_2O(T)}$	Emission factor for N_2O emissions from N in crop residues for crop T	kg N_2O–N (kg N)$^{-1}$	IPCC 2019	Introduced by the model
$EF_{NH_3(T)}$	Emission factor for NH_3 emissions from N in crop residues for crop T	kg NH_3 (kg N)$^{-1}$	Hutchings et N et al. (2023)	Introduced by the model
$F_{(T)}$	Fraction of $N_{Load\,(T)}$ remaining on the surface for 3 or more days	-	Calculated in the model	EEA guidebook 2023 (updated) adapted from IPCC 2019, Equation 11.6
$F_{CR(T)}$	Annual amount of N in crop residues for crop T	kg N	Calculated in the model	Introduced by the model
F_{CR}	Total annual amount of N in crop residues	kg N	Calculated in the model	IPCC 2019, Equation 11.6
$F_{CR-AG(T)}$	Annual amount of N in above-ground crop residues returned to the soil for crop T	kg N	Calculated in the model	Introduced by the model

Parameter	Description	Unit	Value from	Reference
$F_{CR-BG(T)}$	Annual amount of N in below-ground crop residues for crop T	kg N	Calculated in the model	Introduced by the model
$Frac_{Burnt(T)}$	Fraction of annual harvested area of crop T burnt	-	Note from SLF (2011)	IPCC 2019, Equation 11.6
$Frac_{Incorp(T)}$	Fraction of residues incorporated within 3 days	-	Expert judgement, Bjørn Huso v/Landbruksdirektoratet *and* De Ruiter and Huijsmans, 2019	EEA guidebook 2023 (updated) adapted from IPCC 2019, Equation 11.6
$Frac_{Remove(T)}$	Fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction.	-	Expert judgement (2005)	IPCC 2019, Equation 11.6
$Frac_{Renew(T)}$	Fraction of total area under crop T that is renewed annually	-	Calculated in the model	IPCC 2019, Equation 11.6
N_2O	Emissions of N_2O from crop residues	kg N_2O	Calculated in the model	Introduced by the model
$N_2O_{(T)}$	Emissions of N_2O from crop residues for crop T	kg N_2O	Calculated in the model	Introduced by the model
$N_2O_{AG(T)}$	Emissions of N_2O from above-ground crop residues for crop T	kg N_2O	Calculated in the model	Introduced by the model
$N_2O_{BG(T)}$	Emissions of N_2O from below-ground crop residues for crop T	kg N_2O	Calculated in the model	Introduced by the model
$N_{AG(T)}$	N content of above-ground residues for crop T	kg N (kg d.m.) $^{-1}$	IPCC 2019 and Bioforsk report	IPCC 2019, Equation 11.6
$N_{BG(T)}$	N content of below-ground residues for crop T	kg N (kg d.m.) $^{-1}$	IPCC 2019 and Bioforsk report	IPCC 2019, Equation 11.6
$N_Load_{(T)}$	Amount of N in the residues from crop T	Kg.ha^{-1}	Calculated in the model	EEA guidebook 2023 (updated) adapted from IPCC 2019, Equation 11.6

Parameter	Description	Unit	Value from	Reference
NH_3	Emissions of NH_3 from crop residues	kg NH_3	Calculated in the model	Introduced by the model
$NH_{3(T)}$	Emissions of NH_3 from crop residues for crop T	kg NH_3	Calculated in the model	Introduced by the model
$P_{Renew(T)}$	Renewing period for crop T	year	Bioforsk report	Introduced by the model (corresponds to parameter X in the text of Equation 11.6 in IPCC 2019)
$R_{AG(T)}$	Ratio of above-ground residue dry matter to harvested yield for crop T	kg d.m. (kg d.m.)$^{-1}$	IPCC 2019 and Bioforsk report	IPCC 2019, Equation 11.6
$RS_{(T)}$	Ratio of below-ground root biomass to above-ground shoot biomass for crop T	kg d.m. (kg d.m.)$^{-1}$	IPCC 2019	IPCC 2019, Equation 11.6
$Yield\ Fresh_{(T)}$	Annual harvested fresh quantity for crop T	kg fresh weight	Input from Statistics Norway	IPCC 2019, Equation 11.7

3. Changes compared to the previous version of the model.

The updated model to calculate N content in crop residues features several updates compared to the version previously used by SSB. Therefore, for the same input data, results may differ between the two versions. For instance, depending on the crop type, the calculated N content for year 2021 is up to 131% larger in the updated version than it was in the former version (see Table 4). The possible explanations behind these differences are detailed in the following sections.

Table 4 – Total N content of crop residues, per crop, for year 2021 calculated by the previous and the updated versions of the model. Results are expressed in kg N.

Crop type	Total N content – Former version	Total N content – Updated version	Difference
Perennial grass	2,237,352	2,237,352	0%
Grass-clover mixtures	3,297,232	3,297,232	0%
Wheat	1,529,776	1,563,725	+2.2%
Rye	303,857	312,664	+2.9%
Triticale	0.00	0.00	0%

Barley	4,201,431	5,913,688	+41%
Oat	1,332,767	1,753,535	+32%
Oil seeds	118,694	139,215	+17%
Potatoes	404,167	934,940	+131%
Tubers	0.00	0.00	0%
Green forages	2,116,951	2,116,951	0%
Vegetables	222,061	513,682	+131%
Peas	57,711	101,117	+75%
Beans	4,234	7,419	+75%

3.1 Change of method in IPCC

3.1.1 Expression of the total N content

In the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Equation 11.6 was updated. The previous version of the model uses Equation 11.6 provided in IPCC 2006:

$$F_{CR} = \sum_{T} \{Crop_{(T)} \times Frac_{Renew(T)} \times [(Area_{(T)} - Area_{Burnt(T)} \times C_f) \times R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + (Area_{(T)} \times R_{BG(T)} \times N_{BG(T)}]\}$$

The updated version of the model uses Equation 11.6 provided in IPCC 2019:

$$F_{CR} = \sum_{T} \{[AGR_{(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)} - (Frac_{Burnt(T)} \times C_f))] + [BGR_{(T)} \times N_{BG(T)}]\}$$

A detailed comparison of the two equations is available in Appendix B. Equation 11.6 in IPCC 2019 is mostly a re-writing of Equation 11.6 in IPCC 2006 with some changes in notations. However, there has been a small change in the expression: a factor $Frac_{remove} \times Frac_{burnt} \times C_f$ has been removed from the formula for the N content of above-ground residues (see Appendix B for more details). This causes the estimation of N content in above-ground residues to be slightly lower (by 1 to 7%), for some crops, when using the updated version of Equation 11.6 compared to the previous one.

3.1.2 Determination of the ratio of above-ground residue dry matter

In the previous version of the model, the ratio of above-ground residue dry matter $AG_{DM(T)}$ is calculated using the following formula, extracted from Table 11.2 of IPCC 2006:

$$AG_{DM(T)} = Crop_{(T)}/1000 \times slope_{(T)} + intercept_{(T)}$$

Where $slope_{(T)}$and $intercept_{(T)}$ are parameters given in Table 11.2.

In IPCC 2019, in addition to the above equation, an alternate method to determine $AG_{DM(T)}$ is made available:

$$AG_{DM(T)} = Crop_{(T)} \times R_{AG(T)}$$

Where $R_{AG(T)}$ is a parameter given in Table 11.A.

In the updated model, the latter method is preferred because, as $Crop_{(T)}$ is directly calculated in kg d.m. instead of kg d.m. ha^{-1}, using the first method would require to adjust the values of $intercept_{(T)}$ by adapting the units.

The change in method to determine $AG_{DM(T)}$ leads to an increase of the estimation of the N content.

3.2 Change of method for NH_3 emissions calculations

Methodology for calculation of NH_3 emissions is based on the European Environmental Agency updated methodology based on de Ruijter and Huijsmans (2019). The main differences from IPCC 2019 methodology are:

1. Only above-ground residues are included
2. No emissions from low N concentration residues ($N_{AG(T)}$ <= 0.0132 kgN.kgDM^{-1})
3. Residues present for less than 3 days are ignored.

More specifically, new parameters are included such as α, β, and $Frac_{Incorp(T)}$. The new calculations are based on equations presented in section 0.

The differences between the calculated NH_3 emissions for 2022 in the previous version of the model and the new updated 2024-version are shown in Table 5 below.

Table 5 Total NH_3 emissions, per crop, for year 2022, calculated by the previous and the updated versions of the model. Results are expressed in kg NH_3.

Crop type	Total NH3 emissions – Former version	Total NH3 emissions – Updated version	Difference
Perennial grass	1,816,23	5,504	-97%
Grass-clover mixtures	267,662	27,666	-90%
Wheat	221,055	0	-100%
Rye	43,820	0	-100%
Triticale	0	0	0%
Barley	529,945	0	-100%
Oat	181,570	0	-100%

Oil seeds	13,006	0	-100%
Potatoes	78,769	4,528	-94%
Tubers	0	0	0%
Green forages	177,585	6,638	-96%
Vegetables	42,415	5,852	-86%
Peas	8,349	0	-100%
Beans	613	0	-100%

3.3 Other technical adjustments

In the previous version of the model, the combustion factor C_f is omitted in the implementation of Equation 11.6. This leads to an underestimation of the N content in crop residues. As the updated model includes the combustion factor, the calculated values for the N content are higher for the crop types that have a share burnt.

In addition, in the previous version of the model, the share of area burnt was applied to both above and below-ground residues. The updated model applies the share of area burnt only to the above-ground residues as per equation 11.6 of IPCC 2006, leading to an increase in the estimation of the total N content.

References

Aalde et al., “2006 IPCC Guidelines for National Greenhouse Gas Inventories”. *Volume 4: Agriculture, Forestry and Other Land Use. Chapter 2: Generic methodologies applicable to multiple land-use categories*. 2006. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

De Klein et al., “2006 IPCC Guidelines for National Greenhouse Gas Inventories”. *Volume 4: Agriculture, Forestry and Other Land Use. Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application*. 2006. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

de Ruijter, F. J., andHuijsmans, J. F. M, 2019, “A methodology for estimating the ammonia emission from crop residues at a national scale”, Atmospheric Environment, X, (2)100028. Retrieved from: https://www.sciencedirect.com/science/article/pii/S2590162119300310

Grønlund et al., “Nitrogen i restavlinger Oppdatering av koeffisienter for beregning av lystgass fra restavlinger”. *Bioforsk rapport*. 2014

Hergoualc’h et al., “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories”. *Volume 4: Agriculture, Forestry and Other Land Use*. *Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application*. 2019. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Hutchings et al., “EMEP/EEA air pollutant emission inventory guidebook 2019”. *Chapter 3.D Agricultural soils*. 2023. Retrieved from: https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/3-agriculture/3-d-agricultural-soils-2023/view

SLF, “Vurdering av omfang av halmbrenning pr 2011”. 201. Notat fra Statens landsbruksforvaltning.

Appendix

A. Values of parameters

Table 6 – Values of the dry matter fraction of harvested crop for each crop type. Values noted "IPCC 2019" are taken from Table 11.1A of IPCC 2019. Values noted "National factor (Bioforsk report)" are taken from Grønlund et al. (2014).

Crop type	$DRY_{(T)}$ (kg d.m. (kg fresh weight)$^{-1}$)	Origin of the value
Perennial grass	0.90	IPCC 2019
Grass-clover mixtures	0.90	IPCC 2019
Wheat	0.85	National factor (Bioforsk report)
Rye	0.85	National factor (Bioforsk report)
Triticale	0.85	National factor (Bioforsk report)
Barley	0.85	National factor (Bioforsk report)
Oat	0.85	National factor (Bioforsk report)
Oil seeds	0.85	National factor (Bioforsk report)
Potatoes	0.22	IPCC 2019
Tubers	0.22	IPCC 2019
Green forages	0.90	IPCC 2019
Vegetables	0.22	IPCC 2019
Peas	0.91	IPCC 2019
Beans	0.91	IPCC 2019

Table 7 – Values of the ratio of above-ground residue dry matter to harvested yield for each crop type. Values noted "IPCC 2019" are taken from Table 11.1A of IPCC 2019. Values noted "National factor (Bioforsk report)" are taken from Grønlund et al. (2014).

Crop type	$R_{AG(T)}$ (kg d.m. (kg d.m.)$^{-1}$)	Origin of the value
Perennial grass	0.30	IPCC 2019
Grass-clover mixtures	0.30	IPCC 2019
Wheat	0.95	National factor (Bioforsk report)
Rye	1.10	National factor (Bioforsk report)
Triticale	1.30	IPCC 2019
Barley	1.20	IPCC 2019
Oat	1.30	IPCC 2019
Oil seeds	1.30	IPCC 2019
Potatoes	0.40	IPCC 2019
Tubers	0.40	IPCC 2019
Green forages	0.30	IPCC 2019
Vegetables	0.40	IPCC 2019
Peas	2.10	IPCC 2019
Beans	2.10	IPCC 2019

Table 8 – Values of the fraction of above-ground residues incorporated within 3 days ($Frac_{Incorp(T)}$).

Crop type	Value	Origin of the value
Potatoes	0.75	Expert judgement, Bjørn Huso v/Landbruksdirektoratet
Tubers	0.15	Expert judgement, Bjørn Huso v/Landbruksdirektoratet

Vegetable	0.4	Expert judgement, Bjørn Huso v/Landbruksdirektoratet
Peas	0.25	De Ruiter and Huijsmans (2019)
Beans	0.33	De Ruiter and Huijsmans (2019)
Other crops	0	-

Table 9 – Values of the fraction of $Frac_{Remove(T)}$ removed within 3 days (α). Default values from De Ruiter and Huijsmans (2019).

Crop type	Value
Wheat, Rye, Triticale, Barley, Oat, Oil seeds	1
Other	0

Table 10 – Values of the fraction of above-ground residues of crop removed annually for purposes such as feed, bedding and construction ($Frac_{Remove(T)}$). Values from an interview with expert Tore Krogstad (2005).

Crop type	Value 1990 - 2000	Value 2001 - 2021
Wheat, Rye, Triticale, Barley, Oat	15%	13%
Oil seeds	15%	15%
Other	0%	0%

Table 11 – Values of the fraction of $Frac_{Burnt(T)}$ removed within 3 days (β). Default values from De Ruiter and Huijsmans (2019).

Crop type	Value
All relevant crops (high N concentration)	0

Table 12 – Fraction of annual harvested area burnt for each crop ($Frac_{Burnt(T)}$). Values are taken from a note by Statens landsbruksforvaltning (2011).

Years	Value for wheat, rye, triticale, barley, oat and oil seeds	Value for others
1990	30%	0%
1991	25%	0%
1992-1996	20%	0%
1997-2000	15%	0%
2001	12.5%	0%
2002	10%	0%
2003-2004	7.5%	0%
2005	7%	0%
2006	6.5%	0%
2007	6%	0%
2008	5.5%	0%
2009	5%	0%
2010	4.5%	0%
2011-2021	4%	0%

Table 13 – Values of the combustion factor for each crop type. Values are extracted from Table 2.6 of IPCC 2019[9]. The combustion factor is not applicable when there are no burnt residues.

Crop type	$C_{f(T)}$
Perennial grass	Non applicable
Grass-clover mixtures	Non applicable

[9] Aalde et al., "2006 IPCC Guidelines for National Greenhouse Gas Inventories". *Volume 4: Agriculture, Forestry and Other Land Use. Chapter 2: Generic methodologies applicable to multiple land-use categories*. 2006. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Wheat	0.90
Rye	0.85 (assumed “Other crops”)
Triticale	0.90 (assumed “Wheat”)
Barley	0.85 (assumed “Other crops”)
Oat	0.85 (assumed “Other crops”)
Oil seeds	0.85 (assumed “Other crops”)
Potatoes	Non applicable
Tubers	Non applicable
Green forages	Non applicable
Vegetables	Non applicable
Peas	Non applicable
Beans	Non applicable

Table 14 – Values for the ratio of below-ground root biomass to above-ground shoot biomass for each crop type. Values are extracted from the Bioforsk rapport.

Crop type	$RS_{(T)}$ (kg d.m. (kg d.m.)$^{-1}$)
Perennial grass	0.80
Grass-clover mixtures	0.80
Wheat	0.24
Rye	0.22
Triticale	0.23
Barley	0.22
Oat	0.25
Oil seeds	0.22

Potatoes	0.20
Tubers	0.20
Green forages	0.54
Vegetables	0.20
Peas	0.19
Beans	0.19

Table 15 – Values of the N content of above-ground residues for each crop type. Values noted "IPCC 2019" are taken from Table 11.1A of IPCC 2019. Values noted "National factor (Bioforsk report)" are taken from Grønlund et al. (2014).

Crop type	$N_{AG(T)}$ (kg N (kg d.m.)$^{-1}$)	Origin of the value
Perennial grass	0.0150	National factor (Bioforsk report)
Grass-clover mixtures	0.0190	National factor (Bioforsk report)
Wheat	0.0042	National factor (Bioforsk report)
Rye	0.0050	IPCC 2019
Triticale	0.0060	IPCC 2019
Barley	0.0050	National factor (Bioforsk report)
Oat	0.0033	National factor (Bioforsk report)
Oil seeds	0.0060	National factor (Bioforsk report)
Potatoes	0.0190	IPCC 2019
Tubers	0.0190	IPCC 2019
Green forages	0.0150	IPCC 2019
Vegetables	0.0190	IPCC 2019
Peas	0.0080	IPCC 2019
Beans	0.0080	IPCC 2019

Table 16 – Values of the N content of below-ground residues for each crop type. Values noted "IPCC 2019" are taken from Table 11.1A of IPCC 2019. Values noted "National factor (Bioforsk report)" are taken from Grønlund et al. (2014).

Crop type	$N_{BG(T)}$ (kg N (kg d.m.)$^{-1}$)	Origin of the value
Perennial grass	0.0110	National factor (Bioforsk report)
Grass-clover mixtures	0.0130	National factor (Bioforsk report)
Wheat	0.0090	National factor (Bioforsk report)
Rye	0.0110	IPCC 2019
Triticale	0.0090	IPCC 2019
Barley	0.0140	IPCC 2019
Oat	0.0080	IPCC 2019
Oil seeds	0.0090	IPCC 2019
Potatoes	0.0140	IPCC 2019
Tubers	0.0140	IPCC 2019
Green forages	0.0120	IPCC 2019
Vegetables	0.0140	IPCC 2019
Peas	0.0080	IPCC 2019
Beans	0.0080	IPCC 2019

B. Comparison of Equations 11.6 in IPCC 2006 and IPCC 2019

In the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Equation 11.6 that was used to estimate the N content in crop residues was:

$$F_{CR} = \sum_{T}\{Crop_{(T)} \times Frac_{Renew(T)} \times \left[(Area_{(T)} - Frac_{Burnt(T)} \times C_f) \times R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + (Area_{(T)} \times R_{BG(T)} \times N_{BG(T)}\right]\}$$

In the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Equation 11.6 was updated to:

$$F_{CR} = \sum_{T}\{\left[AGR_{(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)} - (Frac_{Burnt(T)} \times C_f))\right] + \left[BGR_{(T)} \times N_{BG(T)}\right]\}$$

This section compares the two equations to evaluate the impacts the update may have on the results.

In all the following calculations, the N content of a single crop type is examined. Therefore, the subscript *(T)* is omitted for simplicity.

According to IPCC 2006, the N content of crop residues is:

$$F_{CR_2006} = Crop \times Frac_{renew} \times \left[\left(Area - Area_{burnt} \times C_f\right) \times R_{AG} \times N_{AG} \times (1 - Frac_{remove}) + Area \times R_{BG} \times N_{BG}\right]$$

And according to IPCC 2019, the same quantity is:

$$F_{CR_2019} = AGR \times N_{AG} \times \left(1 - Frac_{remove} - Frac_{burnt} \times C_f\right) + BGR \times N_{BG}$$

Considering that:

$Area$	= total annual area harvested, as per IPCC 2006 and IPCC 2019
$Area_{burnt}$	= annual area of crop burnt, as per IPCC 2006
$Frac_{burnt}$	= fraction of annual harvested area of crop burnt, as per IPCC 2019

It can be deduced that $Area_{burnt} = Area \times Frac_{burnt}$ assuming that there is no crop area that is burnt without being harvested.

And, as per IPCC 2006, $R_{BG} = \frac{AG_{DM}+Crop}{Crop}$, assuming that AG_{DM} is expressed[10] in kg d.m. ha^{-1}

Thus:

$$F_{CR_2006} = Crop \times R_{AG} \times F_{renew} \times N_{AG} \times (1 - Frac_{remove}) \times Area \times \left(1 - Frac_{burnt} \times C_f\right) + Crop \times Frac_{renew} \times Area \times \frac{AG_{DM} + Crop}{Crop} \times R_{BG-BIO} \times N_{BG}$$

With:

[10] AG_{DM} is calculated in ton d.m. ha^{-1} in IPCC 2006 thus making a factor 1000 appear in the expression, not reported here.

AG_{DM} = $Crop \times R_{AG}$, as per IPCC 2019

BGR = $(Crop + AG_{DM}) \times RS \times Area \times Frac_{renew}$, as per IPCC 2019

Thus:

$$F_{CR_2006} = AG_{DM} \times Frac_{renew} \times Area \times N_{AG} \times (1 - Frac_{remove})(1 - Frac_{burnt} \times C_f) + BGR \times \frac{R_{BG-BIO}}{RS} \times N_{BG}$$

With $R_{BG-BIO} = RS$ by comparison of definition and tables in IPCC 2006 and 2019. Hence:

$$F_{CR_2006} = AG_{DM} \times Frac_{renew} \times Area \times N_{AG} \times \left(1 - Frac_{remove} - Frac_{burnt} \times C_f + Frac_{remove} \times Frac_{burnt} \times C_f\right) + BGR \times N_{BG}$$

At this point, it can be observed that F_{CR_2006} and F_{CR_2019} have the same expression for the N content of below-ground residues ($BGR \times N_{BG}$).

By comparison of the expressions of F_{CR_2006} and F_{CR_2019}, and by similarity to BGR, it can be inferred that: $AGR = AG_{DM} \times Area \times Frac_{renew}$.

Thus:

$$F_{CR_2006} = AGR \times N_{AG} \times \left(1 - Frac_{remove} - Frac_{burnt} \times C_f + Frac_{remove} \times Frac_{burnt} \times C_f\right) + BGR \times N_{BG}$$

The difference between F_{CR_2006} and F_{CR_2019} is that F_{CR_2006} has an additional term $Frac_{remove} \times Frac_{burnt} \times C_f$ for the N content in above-ground residues. This only impacts the results for crops that have straw-like residues. For the other types of crops, $Frac_{remove} = Frac_{burnt} = 0$ and there is no difference between the two equations.

Table 17 – Impact of the difference in expression of the N content of above-ground residues between Equation 11.6 in IPCC 2006 and Equation 11.6 in IPCC 2019. The values are given for wheat.

Parameter	1990	2000	2020
$\boldsymbol{Frac_{remove}}$	15%	15%	13%
$\boldsymbol{Frac_{burnt}}$	30%	15%	4%
$\boldsymbol{C_f}$	0.9	0.9	0.9
$\boldsymbol{1 - Frac_{remove} - Frac_{burnt} \times C_f}$	58%	71.5%	83.4%
$\boldsymbol{1 - Frac_{remove} - Frac_{burnt} \times C_f + Frac_{remove} \times Frac_{burnt} \times C_f}$	62.05%	73.53%	83.87%
$\boldsymbol{\frac{1 - Frac_{remove} - Frac_{burnt} \times C_f + Frac_{remove} \times Frac_{burnt} \times C_f}{1 - Frac_{remove} - Frac_{burnt} \times C_f}}$	1.07	1.03	1.01

As displayed in Table 17, the estimation of N content in (straw-like) above-ground residues is 1 to 7% larger with the Equation 11.6 from IPCC 2006 than with the Equation 11.6 from IPCC 2019. The smallest the fraction of the area burnt, the smaller the difference.

Equation 11.6 in IPCC 2019 is mostly a re-writing of Equation 11.6 in IPCC 2006 with changes in notations. However, due to the change in expression, the estimation of N content in above-ground residues is slightly lower, for some crops, using the updated version of Equation 11.6 compared to the previous one.

CARBON LIMITS

October 2024

Carbon Limits AS
@CarbonLimitsAS

Stensberggata 25
0170 Oslo
Norge

+47 988 457 930
www.carbonlimits.no

