sciendo

Current Agronomy

IUNG

doi: 10.2478/cag-2024-0019

Current Agronomy
(formerly Polish Journal of Agronomy)
2024, 53/1: 213–220

Assessment of soil conditions and nitrous oxide emissions from soil in rapeseed and maize cultivation for energy purposes in Poland

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Abstract. The aim of the study was to determine nitrous oxide (N_2O) emissions in rapeseed and maize grain cultivation in accordance with the requirements of the Renewable Energy Directive (RED2) regarding the cultivation of biofuel crops. The EU Implementing Regulation 2022/996 introducing the updated methodology recommends the use of the Stehfest and Bouwman (S&B) Tier 2 model to determine direct nitrous oxide (N_2O) emissions from soil following fertilizer application and the IPCC (Tier 1) methodology for other sources of N_2O emissions. The study was based on survey data from 1525 farms; while soil parameters required by the S&B model (pH, soil organic carbon content and texture) were supplemented from the IUNG-PIB soil map where survey's data were missing. The calculated N_2O emissions were aggregated to NUTS2 regions for Poland. Differences in emissions were linked to local agricultural practices (mainly fertilization levels) and soil conditions. The use of the S&B model increases the direct N_2O emission factor from fertilizers applied to fine soils or soils with an organic carbon content greater than 3%, compared to the IPCC Tier 1 methodology.

Keywords: nitrous oxide emissions, soil conditions, biofuel crops cultivation

INTRODUCTION

Reducing greenhouse gas (GHG) emissions, as well as increasing the share of renewable energy sources, is one of the main objectives of European energy policy (EU, 2018). Directive 2009/28/EC known as the RED Directive, was a key legal document promoting energy from renewable sources and imposed an obligation to reduce GHG emissions in the life cycle of biofuels (UE, 2009). This requirement implied an assessment of greenhouse gas emissions from the cultivation of crops for energy purposes; however, no detailed guidance on the calculation method was provided.

Poland submitted its first report on GHG emissions from crop cultivation for biofuels in 2011 (RED1 PL, 2011). The report utilized the Biograce tool (Neeft, 2011), which estimates nitrous oxide emissions from soils using the IPCC Tier 1 methodology. Due to the lack of statistical data at the national or NUTS2 level, studies on greenhouse gas emissions from energy crop cultivation in Poland were based on survey data.

In 2012, the Joint Research Centre published the guide "Assessing GHG Default Emissions from Biofuels in EU Legislation", which describes the recommended methodology for calculating greenhouse gas emissions in biofuel crop cultivation. It advised using the Global Nitrous Oxide Calculator (GNOC) to determine N_2O emission from soil (EC & JRC, 2013).

Since then, some studies have been conducted on greenhouse gas emissions in crop cultivation for biofuel purposes in Poland and other countries. Elsgaard et al. (2013) analyzed GHG emissions associated with the cultivation of winter wheat for bioethanol and winter rape for methyl ester under Danish conditions (NUTS2 level) and concluded that N_2O soil emissions are a major contributor to the final emissions. They used the IPCC (Tier1) methodology for estimating N_2O emissions from soil (Elsgaard et al., 2013).

In Poland, a significant part of the research was conducted at the Institute of Soil Science and Plant Cultivation - State Research Institute (IUNG-PIB). Jarosz and Faber (2014) assessed emissions from the cultivation of wheat, grain maize and rapeseed. The N_2O emissions were calculated using the Biograce tool, with values of 707.6, 720.8 and 816.2 kg CO_2-eq. ha^{-1} respectively.

There are also studies comparing the use of different models or emission factors for estimating N_2O emissions from soil. Syp et al. (2016) compared N_2O emissions using four tools: Biograce, Global Nitrous Oxide Calculator (GNOC), Lesschen-EF factors, and DNDC in rapeseed cultivation. The emissions obtained were 1001.7, 940.8, 524.7, and 527.4 kg CO_2-eq. ha^{-1}, respectively. It was also shown that the modification of the Lesschen emission factors according to the Tier 2 method resulted in a significant reduction of calculated N_2O emissions. The calculated fluxes were at the same level as the N_2O emissions simulated by the deterministic DNDC model, but the use of Lesschen factors requires much less data input.

The RED2 Directive (EU, 2018) and European Commission Implementing Regulation 2022/996 (UE, 2022) establish principles for verifying compliance with sustainability criteria and reducing greenhouse gas (GHG) emissions associated to biofuel production. These regulations require EU Member States to validate and update emission analyses of agricultural raw materials grown for this purpose. Economic operators involved in the collection of agricultural raw materials for biofuels (first collection points) must present the methods and data sources used to determine actual emission levels in cultivation. Since this would require conducting surveys and analyses for all producers supplying raw materials, it is permissible to use calculated or aggregated values, at least at the NUTS2 level.

The Implementing Regulation 2022/996 introduces a number of changes to the previous methodology for determining GHG emissions in crop cultivation for biofuels. It recommends the use of statistical data at least at NUTS2 level regarding both production inputs and yields. Additionally, it advises the use of the S&B model to determine direct N_2O emissions from soils resulting from the application of mineral and organic fertilizers and IPCC equations for other emission sources. In addition, it is recommended that the data and emission models used should be compatible with those used by the national inventorisation bodies, i.e. the National Centre for Emissions Management (KOBiZE) in the case of Poland.

This study focuses on determining soil parameters required for the S&B model and calculating nitrous oxide emissions from soil aggregated to the NUTS2 level for Poland.

MATERIALS AND METHODS

Survey data

The analyses conducted in the study are based on survey data collected from 728 farms cultivating maize for grain and 797 farms cultivating rapeseed in Poland. The surveys cover the years 2020–2023 and were conducted by IUNG-PIB in collaboration with Agricultural Advisory Centers, the Oil and Gas Institute – National Research Institute, and collection points of member companies of the National Biofuels Chamber and the Polish Oil Producers Association. The survey data included, among other, the following information obtained per hectare of a given crop: yield size, grain moisture, quantities of chemical and organic fertilizers, soil acidity (pH), soil organic carbon (SOC), and texture (fine/medium/coarse). Due to the structure of Polish farms, some of which supply only minimal quantities of raw materials to the market or produce solely for their needs, the basis for calculating the representative sample size for each NUTS2 region was the cultivation area from the Agricultural Census conducted in 2020 (GUS, 2020), according to the formula:

$$A_w = \sqrt[3]{P_z}$$

where:

A_w – number of surveys in a given NUTS2 region

P_z – area of rapeseed or maize cultivation in a given region.

Methodology for determining soil parameters

The surveys included questions on soil parameters such as pH, texture and soil organic carbon content. In the absence of data, they were completed using the soil-agricultural map of the IUNG-PIB. Extended soil chemical monitoring data and information from the Agriculture Restructurisation and Modernisation Agency (ARMA) were used to estimate SOC. The acidity map (pH in H_2O) used in this study was published by Smreczak et al. (2020). Average values aggregated at the NUTS3 regional level were obtained by combining rape and maize plot data (ARMA) with the corresponding soil maps. Consequently, average SOC and pH values were calculated as means for the years 2018–2023. To estimate soil texture, a 1:25,000 soil-agricultural map was used. The dominant (most frequently occurring) soil texture values within the NUTS3 regions were assigned as default for missing survey data.

Models applied for calculation of N_2O emissions from soil

Greenhouse gas emission calculations for maize and rapeseed cultivation are consistent with Commission Implementing Regulation 2022/996 (UE, 2022). Emission models and indicators are derived from the IPCC and are consistent with the KOBiZE methodology used in the recent National Inventory Report on Greenhouse Gas Emissions and Removals in Poland (IPCC, 2006; KOBiZE, 2022). The Tier 2 method was used to calculate direct nitrous oxide (N_2O) emissions for mineral and organic fertilizers applied to the soil, using the Stehfest and Bouwman model (JRC, 2019). Direct N_2O emissions caused by nitrogen introduced into the soil with crop residues and indirect emissions were determined according to the 2006 IPCC methodology, using Tier 1 models (IPCC, 2006). The analysis scheme and methods used are presented in Figure 1.

The N_2O emission value determined by the S&B model depends on the level of nitrogen fertilization, soil parameters (pH, texture, and SOC), the type of cultivated plant, and the climate (see Table 1). It can be expressed as:

$$E = \exp(c + \sum ev)$$

where:
E – Direct N_2O emissions; kg N_2O-N ha^{-1} $year^{-1}$
c, ev – constant and the effect values of the S&B model (see Table 1)

The direct emissions factor calculated using the S&B model EF_{1ij} for crop i at location j is determined as:

$$E_{1ij} = \frac{(E_{fert,ij} - E_{unfert,ij})}{N_{app,ij}}$$

where:
$E_{fert,ij}$ = N_2O emissions (in kg N_2O-N ha^{-1}) determined by the S&B model for crop i at location j with applied nitrogen fertilization.
$E_{unfert,ij}$ = N_2O emissions for crop i at location j (in kg N_2O-N ha^{-1}) determined by the S&B model assuming zero fertilization (while maintaining other parameters as above).
$N_{app,ij}$ = Amount of nitrogen applied (mineral and organic fertilizers) (in kg N ha^{-1}) for crop i at location j.

Table 1. Coefficients of S&B model for calculating N_2O emissions form agricultural soils.

Coefficient description	Coefficient name	Range of explanatory variable	Coefficient value
Fertilization	*ev_fert*		0.0038×N
Soil organic carbon	*ev_SOC*	<1	0
		1–3	0.0526
		>3	0.6334
Soil pH	*ev_pH*	<5.5	0
		5.5–7.3	-0.0693
		>7.3	-0.4836
Soil texture	*ev_texture*	coarse	0
		medium	-0.1528
		fine	0.4312
Climate	*ev_climate*	Temperate continental climate	0
Crop	*ev_crop*	maize	0.442
		rapeseed	0
Length of experiment	*ev_length_of_experiment*	1 yr	1.991
Constant	*c*		-1.516

Source: Stehfest, Bouwman (2006)

In accordance with implementing Regulation (EU) 2022/996, a global warming potential (GWP) for N_2O of 265 kg CO_2-eq. for 1 kg N_2O was used in the calculations, as well as a 44/28 factor to convert from kg N_2O-N to kg N_2O.

The nitrogen content in organic fertilizers was adopted according to the Polish Agricultural Production Standards (CDR, 2018) as follows: 4.7 kg N t^{-1} for cattle manure, 5.1 kg N t^{-1} for pig manure, 3.5 kg N t^{-1} for slurry, 16 kg N t^{-1} for poultry manure, and 5 kg N t^{-1} for digestate.

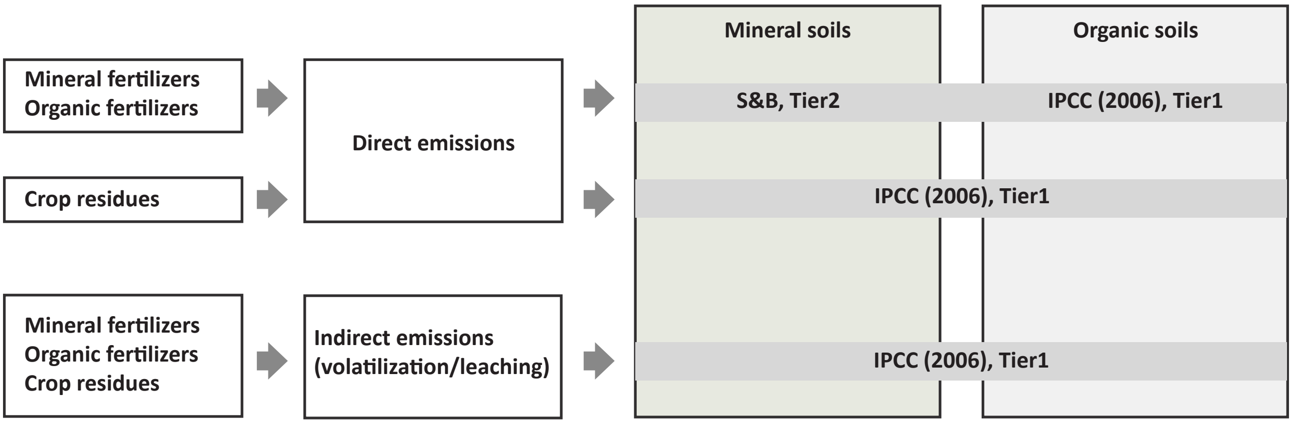

Figure 1. Models applied for estimating N_2O emissions from soils. Source: compiled on the basic of JRC (2019).

RESULTS

Summary of inventory data

The Tables 2 and 3 present the main inventory data broken down by NUTS2 regions. Both the average crop areas and the yields achieved are higher for the two studied crops than those reported in national statistics (GUS, 2024). Total nitrogen fertilization in rapeseed cultivation ranges from 142 to 190 kg N ha^{-1} depending on the region, with the average share of organic fertilization at 9.5%. This share was highest in the following NUTS2 regions: Śląskie (29%), Łódzkie (18%), and Podlaskie (15%).

For grain maize, the average fertilisation rate ranged from 139 to 211 kg N ha^{-1} depending on the region, with the average organic fertilisation rate being significantly higher than for rape, at an average of 29% of total nitrogen fertilization.

The determined soil parameters agregated to NUTS3 regions

The values of soil parameters (pH, SOC, texture) aggregated to NUTS3 areas; are shown in Figures 2 and 3. Soil acidity in Poland is influenced by natural conditions (over 90% of soils were formed on acidic rocks deposited by glaciers) as well as human activity (Hołubowicz-Kliza et al., 2021). Analyses show that soils in some parts of eastern and central Poland are more acidic (pH < 5.5) for both crops studied. This is particularly true for the regions of Podkarpackie, parts of Lubelskie and Podlaskie, as well as Łódzkie. The SOC content ranged from 0.8% to 2.9%, with an average of 1.3%. Polish soils have a relatively low soil organic carbon content, which is confirmed by studies conducted by Siebielec et al. (2020). For texture, the predominant texture for most NUTS3 regions for both rapeseed and grain maize was coarse soils.

Table 2. Averaged main inventory data for rapeseed cultivation.

NUTS2 name	Area [ha]	Yield [t ha^{-1}]	Moisture [%]	Mineral N-fertilisation [kg N ha^{-1}]	Organic N-fertilisation [kg N ha^{-1}]
Dolnośląskie	42.9	4.0	7.7	137.3	4.3
Kujawsko-pomorskie	35.0	4.2	7.8	171.0	7.1
Lubelskie	39.1	4.4	7.9	156.2	11.8
Lubuskie	39.5	3.9	8.0	143.8	10.1
Łódzkie	27.7	4.4	7.8	148.3	32.6
Małopolskie	28.9	4.3	7.5	156.8	7.2
Mazowieckie	25.4	4.4	7.8	172.0	18.9
Opolskie	58.9	4.2	7.5	161.3	6.2
Podkarpackie	21.9	4.0	8.3	151.3	0.0
Podlaskie	24.3	4.0	7.7	142.0	25.6
Pomorskie	69.9	4.4	8.3	173.9	3.6
Śląskie	41.9	4.1	7.3	124.0	50.8
Świętokrzyskie	32.9	4.6	7.3	135.8	21.9
Warmińsko-mazurskie	77.5	4.3	8.5	147.3	12.4
Warszawski-stołeczny	38.8	4	7.8	134.5	18.8
Wielkopolskie	53.0	4.1	7.7	157.8	23.7
Zachodniopomorskie	45.4	3.8	7.9	147.0	18.7
Average	41.4	4.2	7.8	150.6	16.1

Source: own study

Table 3. Averaged main inventory data for maize cultivation.

NUTS2 name	Area [ha]	Yield [t ha^{-1}]	Moisture [%]	Mineral N-fertilisation [kg N ha^{-1}]	Organic N-fertilisation [kg N ha^{-1}]
Dolnośląskie	89.3	13.2	26.7	131.2	80.0
Kujawsko-pomorskie	49.3	11.0	28.3	111.4	40.8
Lubelskie	23.3	13	27.7	119.9	19.5
Lubuskie	27.4	10.4	27.4	106.4	47.4
Łódzkie	18.9	11.5	28.6	103	56.1
Małopolskie	47.2	13.4	27.2	134.7	9.8
Mazowieckie	23.6	12.1	28.8	111.0	34.2
Opolskie	104.2	13.2	27.3	136.5	10.0
Podkarpackie	36.7	13.5	25.6	132.5	78.7
Podlaskie	15.0	10.9	30.2	89.3	75.0
Pomorskie	32.2	13.7	29.1	92.4	69.4
Śląskie	62.8	13.7	27.8	110.5	63.0
Świętokrzyskie	29.8	14.2	28.1	131.4	23.5
Warmińsko-mazurskie	32.9	11.4	29.8	89.6	62.4
Warszawski-stołeczny	43.0	11.5	25.5	132.1	33.6
Wielkopolskie	36.1	10.7	28.5	87.9	59.2
Zachodniopomorskie	54.2	11.3	28.7	89.0	49.6
Average	42.7	12.3	28.0	112.3	47.8

Source: own study

Nitrous oxide emissions from soil aggregated to NUTS2

The calculated N_2O emission values broken down by NUTS2 regions are presented in Table 4 (rapeseed) and Table 5 (grain maize). Total N_2O emissions in rapeseed cultivation range from 1007 to 1302 kg CO_2-eq. ha^{-1} depending on the region, with the average share of emissions from fertilization accounting for 50%, nitrogen losses from crop residues for 24%, gaseous losses for 7%, and the remainder consisting of nitrogen losses to groundwater and surface water. In relation to dry yield mass, the lowest emissions were recorded in the Dolnośląskie region (271 kg CO_2-eq. t^{-1}), while the highest were observed in the Śląskie region (341 kg CO_2-eq. t^{-1}).

In maize cultivation, average nitrous oxide emissions ranged from 1306 to 1905 kgCO_2-eq. ha^{-1} and were the highest in the Śląskie region. The greenhouse gas emissions per tonne of maize grain, depending on the region, ranged from 138 to 199 kg CO_2-eq. Similar to rapeseed cultivation, GHG emissions in maize cultivation related to dry yield mass were the lowest in the Dolnośląskie region and the highest in the Podlaskie region.

The level of nitrous oxide emissions is directly influenced by the level of nitrogen fertilization. Rapeseed cultivation in regions with the lowest nitrogen fertilization (Dolnośląskie, Lubuskie, Podkarpackie) results in lower N_2O emissions, whereas high nitrogen doses (Łódzkie, Mazowieckie, Wielkopolskie) lead to higher emissions per hectare of cultivation. Similar patterns can be observed in maize cultivation; however, soil texture also affects N_2O emissions. Relatively high N_2O emissions in the Śląskie region compared to other regions for maize cultivation are associated with the relatively high proportion of coarse soils reported by farmers. Survey data indicate that coarse soils account for 52% of the total, contributing to a high direct N_2O emission factor from fertilization, as determined by the S&B model.

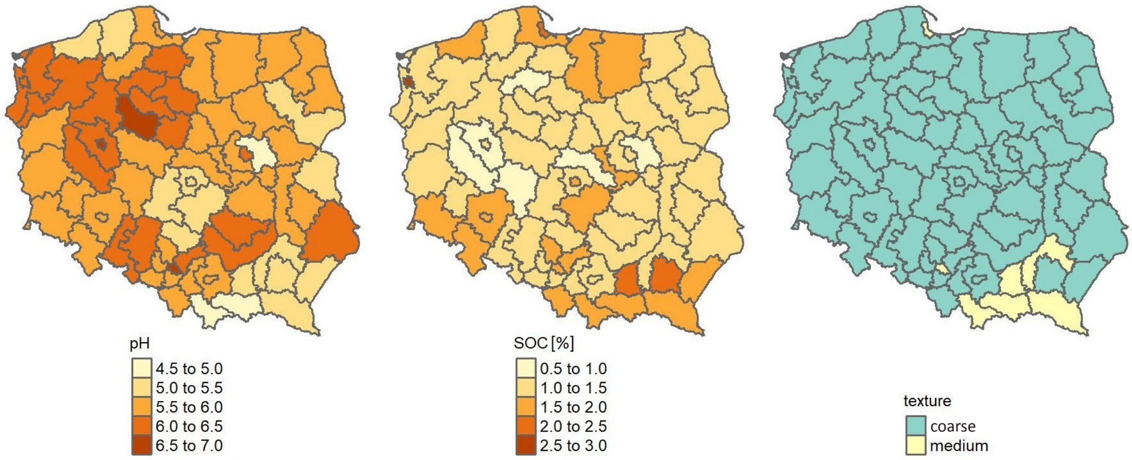

Figure 2. Soil parameters aggregated to NUTS3 based on soil map analysis under rapeseed cultivation. Source: own study.

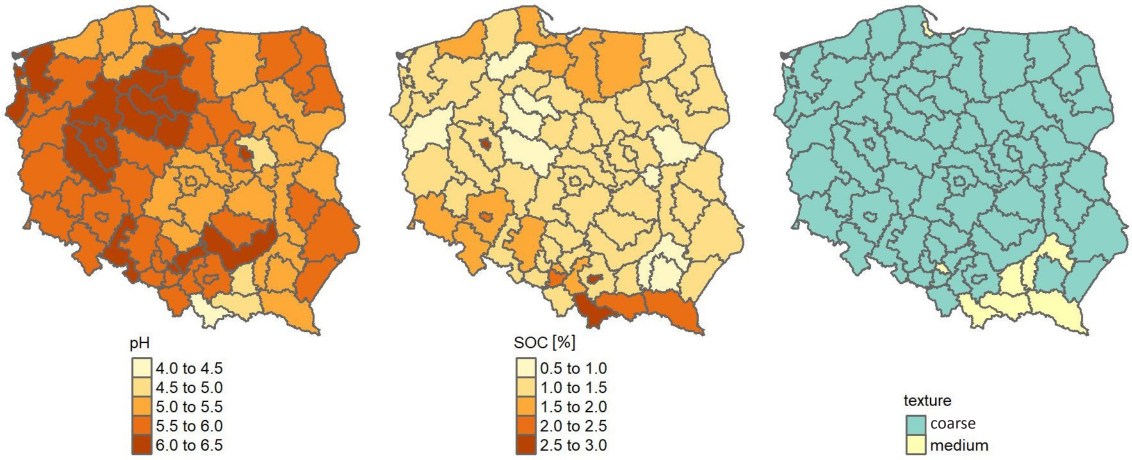

Figure 3. Soil parameters aggregated to NUTS3 based on soil map analysis under grain maize cultivation. Source: own study.

Table 4. Emissions of N_2O from rapeseed cultivation related to area of cultivation and dry yield mass. The table shows the mean values and standard deviations.

NUTS2 region	N_2O emissions per hectare [kg CO_2-eq. ha^{-1}]	N_2O emissions per tonne of dry mass [kg CO_2-eq. t^{-1}]
Dolnośląskie	1007.4 (±345.9)	271.1 (±96.6)
Kujawsko-pomorskie	1149.5 (±225.2)	301.3 (±60.4)
Lubelskie	1234.8 (±410.6)	310.6 (±101.3)
Lubuskie	1065.5 (±338.0)	298.2 (±95.9)
Łódzkie	1279.5 (±416.5)	318.7 (±101.4)
Małopolskie	1231.0 (±262.9)	314.3 (±73.6)
Mazowieckie	1301.7 (±296.3)	323.6 (±76.5)
Opolskie	1181.9 (±293.8)	306.7 (±63.5)
Podkarpackie	1060.1 (±243.2)	291.6 (±68)
Podlaskie	1134.3 (±439.1)	311.6 (±139.8)
Pomorskie	1288.4 (±411.4)	317.5 (±90.6)
Śląskie	1277.8 (±521.4)	340.7 (±135.4)
Świętokrzyskie	1177.9 (±652.8)	274.2 (±124.4)
Warmińsko-mazurskie	1116.0 (±418.9)	286.8 (±111)
Warszawski-stołeczny	1024.5 (±346.1)	283.9 (±87.8)
Wielkopolskie	1196.9 (±300.0)	322.3 (±83.5)
Zachodniopomorskie	1109.6 (±365.8)	314.0(±96.3)
Average	1166.9 (±369.9)	305.1 (±94.5)

Source: own study

Table 5. Emissions of N_2O from maize cultivation related to area of cultivation and dry yield mass. The table shows the mean values and standard deviations.

NUTS2 region	N_2O emissions per hectare [kg CO_2-eq. ha^{-1}]	N_2O emissions per tonne of dry mass [kg CO_2-eq. t^{-1}]
Dolnośląskie	1305.5 (±509.2)	137.9 (±60.4)
Kujawsko-pomorskie	1363.0 (±572.1)	176.3 (±72.8)
Lubelskie	1349.2 (±519.5)	142.7 (±49.3)
Lubuskie	1357.8 (±566.7)	184.8 (±84.2)
Łódzkie	1456.2 (±595.9)	183.3 (±73.5)
Małopolskie	1577.1 (±861.3)	163.7 (±94.4)
Mazowieckie	1450.3 (±1222.4)	171.5 (±146.4)
Opolskie	1382.6 (±563.6)	145.9 (±62)
Podkarpackie	1437.6 (±647.4)	140.8 (±44)
Podlaskie	1519 (±670.2)	198.9 (±82.3)
Pomorskie	1676.6 (±799.2)	177.3 (±94.3)
Śląskie	1904.5 (±1047.6)	189.5 (±95.3)
Świętokrzyskie	1520.9 (±511.5)	150.1 (±52.1)
Warmińsko-mazurskie	1459.2 (±904.2)	179.8 (±94.5)
Warszawski-stołeczny	1478.8 (±431.1)	178.8 (±57.6)
Wielkopolskie	1375.4 (±462.6)	183.5 (±65.9)
Zachodniopomorskie	1423.5 (±1017.7)	174.6 (±109.9)
Average	1472.8 (±700.1)	169.4 (±78.8)

Source: own study

DISCUSSION

The N_2O emission values obtained in this study are significantly higher than reported by Jarosz and Faber (2014). They estimated N_2O emissions from rapeseed and grain maize using survey data from 1,218 rapeseed farms and 275 maize farms producing for energy purpose using the Biograce tool. The tool estimates N_2O emissions from soil based on the IPCC (Tier1) methodology. In terms of carbon dioxide equivalent (assuming GWP factor for nitrous oxide as 265 kilograms of CO_2 equivalent for 1 kilogram of N_2O) calculated emissions of N_2O equals to 720.8 and 816.2 kg CO_2-eq. ha^{-1} for maize and rapeseed cultivation, respectively (Jarosz, Faber, 2014). The significant differences in N_2O emission levels are primarily due to variations in nitrogen fertilization rates and used emission factors. The average nitrogen fertilisation rates in their study were 124 kg N ha^{-1} (maize) and 170 kg N ha^{-1} (rapeseed), which were 25% lower than those used in this study for maize and comparable for oilseed rape. It should also be noted that in the cited study the use of organic fertiliser was not taken into account. In addition, the direct N_2O emission factor used was 0.01 of applied nitrogen (Biograce tool), whereas an exponential S&B model was used in this study, which may lead to a higher direct nitrous oxide emission factor.

Syp et al. (2016) compared various methods for determining soil N_2O emissions, including default IPCC Tier 1 factors (Biograce tool), the GNOC tool based on the S&B model, the Lesschen-EF factors, and the deterministic DNDC model, applied to a 50 km × 50 km grid covering Poland (Syp et al., 2016). The estimated N_2O emissions in rapeseed cultivation were: 3.78 kg N_2O ha^{-1}, 3.55 kg N_2O ha^{-1}, 1.98 kg N_2O ha^{-1}, and 1.99 kg N_2O ha^{-1}, respectively. In CO_2 equivalent term it means emissions ranging from 524.7 to 1001.7 kg CO_2-eq. ha^{-1}. However, deeper comparisons of results are not possible due to the lack of reported nitrogen fertilization rates in the study, which are critical for soil N_2O emissions. It can be observed anyway that there are significant differences in the estimated N_2O emissions depending on the emission models adopted.

The Figures 4 and 5 compare the direct N_2O emission factors as a function of soil parameters and nitrogen fertilization levels. It can be observed that for both studied crops, the resulting S&B model direct emission factors are higher than IPCC default value (0.01) for soils with organic carbon content exceeding 3% and for coarse soils. Additionally, following the practices described in JRC guideline, rapeseed is classified as a cereal crop, which yields a lower *ev_crop* emission factor, while maize is categorized as a row crop, resulting in a higher S&B model factor (JRC, 2019). The application of the S&B model to determine N_2O emissions from fertilization, in the case of rapeseed cultivation on coarse or medium

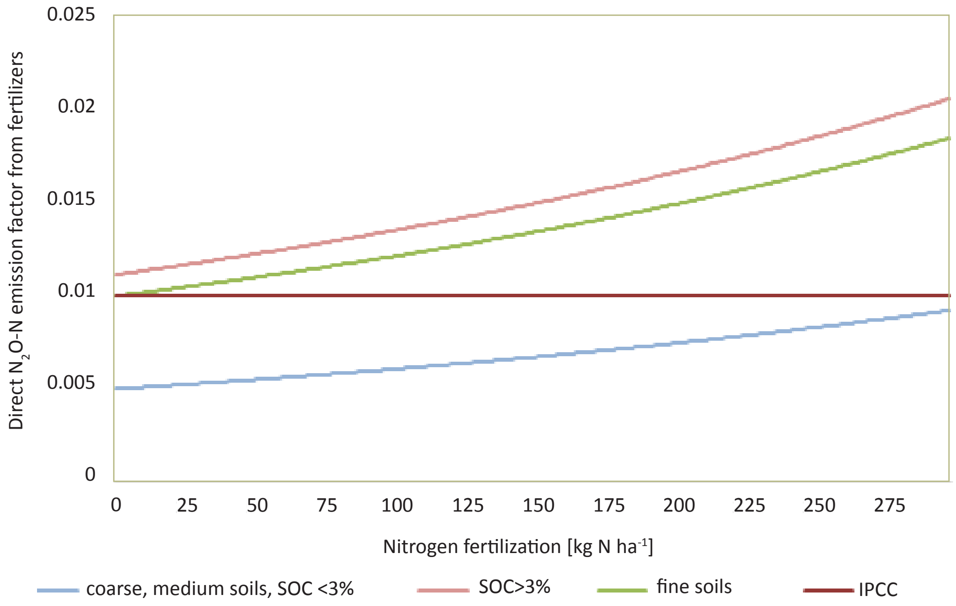

Figure 4. Comparison of the direct N_2O-N emission factor for fertiliser resulting from the application of the S&B exponential model and the IPCC factor (dark red horizontal line) for rapeseed cultivation. The averaged values of the emission factors for the described soil parameters are shown for clarity.
Source: own study.

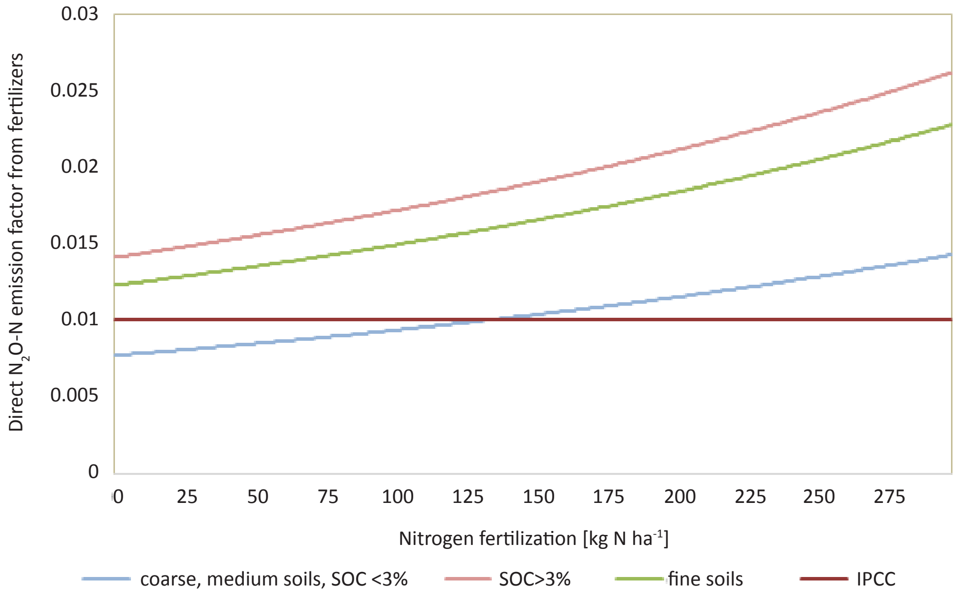

Figure 5. Comparison of the direct N_2O-N emission factor for fertiliser resulting from the application of the S&B exponential model and the IPCC factor (dark red horizontal line) for maize cultivation. The averaged values of the emission factors for the described soil parameters are shown for clarity.
Source: own study.

soils with SOC < 3%, results in a lower direct emission factor than the default IPCC value for the entire considered fertilization range (0–300 kg N ha^{-1}). However, in the case of grain maize, it leads to a higher direct emission factor in all combinations, except for coarse or medium soils with SOC < 3% and fertilization not exceeding 131 kg N ha^{-1}.

SUMMARY

The methodology described in Regulation 996/2022 was applied in this study to determine nitrous oxide (N_2O) emissions from rapeseed and maize cultivation for biofuels. The recommended S&B model for estimating direct soil N_2O emissions from fertilization requires the use of soil parameters such as soil organic carbon (SOC), soil texture and soil pH. In this study, these parameters were determined at NUTS3 level and used to fill data gaps in the survey. Due to the exponential nature of the S&B model, the direct N_2O emission factor from fertilization is higher than the standard IPCC factor for soils classified as coarse, with an SOC content above 3% or in the case of high fertilization. The resulting fertilizer emission factor in the S&B model is lower than the IPCC default value only for rapeseed cultivation on coarse or medium soils with an organic carbon content not exceeding 3%.

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received 23 December 2024
reviewed 25 February 2025
accepted 27 February 2025

Authors declare no conflict of interest.

Research was funded by Polish Ministry of Agriculture and Rural Development, as part of task DC 2.4. “Research on the potential for reducing greenhouse gas emissions in agricultural crops for energy purposes”.