CLIMATE CHANGE
12/2025

Final Report

Report on typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions or a more disaggregated level in Germany according to RED II

by:
Horst Fehrenbach, Susanne Köppen, Annika Wehrle
ifeu, Heidelberg

publisher:
Umweltbundesamt

CLIMATE CHANGE 12/2025

REFOPLAN des Bundesministeriums für Umwelt,
Naturschutz, nukleare Sicherheit und Verbraucherschutz

Project No. (FKZ) 3723 43 101 0
FB001682

Final Report

Report on typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions or a more disaggregated level in Germany according to RED II

by

Horst Fehrenbach, Susanne Köppen, Annika Wehrle
ifeu, Heidelberg

On behalf of the German Environment Agency

Impressum

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

Report performed by:
Institut für Energie- und Umweltforschung gGmbH
Wilckensstraße 3
69120 Heidelberg

Report completed in:
März 2024

Date of revision:
Oktober 2024

Edited by:
Fachgebiet V 1.3 Erneuerbare Energien
Dr. Katja Hofmeier

DOI:
https://doi.org/10.60810/openumwelt-7645

ISSN 1862-4359

Dessau-Roßlau, April 2025

Abstract: Report on typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions or a more disaggregated level in Germany according to RED II

The report analyzes the greenhouse gas (GHG) emissions from the cultivation of agricultural raw materials in the NUTS2 regions of Germany in accordance with the EU Renewable Energy Directive (RED II). The aim is to update the typical emission values for the production of biofuels, biogas and biomethane for the cultivation phase. Current data and scientific findings are considered. The calculations are based on standardized factors and comprehensive data sources such as yields, fertilizer consumption and diesel consumption. Particular attention was paid to emissions of nitrous oxide (N_2O) and synthetic nitrogen fertilizer, as these cause the greatest emissions. The values are differentiated for mineral and organic soils in order to take regional characteristics into account.

GHG emissions were determined for eleven energy crops in 38 NUTS2 regions. The results show significant differences in the emission values in some cases. This is due in particular to the differences in the emission factors for N_2O, the level of which is highly dependent on regional conditions. The regional differences in the proportion of farm manure are also an important factor, as for methodological reasons no upstream production processes are included in the balance for this fertilizer, unlike for mineral fertilizers. The example of emissions for rapeseed cultivation shows a range of 362 to 531 g CO_2 equivalent per kilogram.The first report on typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions from 2010 did not show such strong regional differences. However, the earlier values were consistently higher than those determined here. The reason for this is the new calculation method for N_2O based on real measurements and a number of other factors.

Kurzbeschreibung: Report on typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions or a more disaggregated level in Germany according to RED II

Der Bericht analysiert die Treibhausgas-(THG)-Emissionen beim Anbau landwirtschaftlicher Rohstoffe in den NUTS2-Regionen Deutschlands gemäß der EU-Richtlinie für erneuerbare Energien (RED II). Ziel ist die Aktualisierung der typischen Emissionswerte für die Herstellung von Biokraftstoffen, Biogas und Biomethan für die Phase des Anbaus. Dabei werden aktuelle Daten und wissenschaftliche Erkenntnisse berücksichtigt. Die Berechnungen basieren auf standardisierten Faktoren und umfassenden Datenquellen wie Erträgen, Düngemittelverbrauch und Dieselverbrauch. Besondere Beachtung fanden dabei die Emissionen von Distickstoffmonoxid (N_2O) und synthetischem Stickstoffdünger, da diese die größten Emissionen verursachen. Die Werte werden für mineralische und organische Böden differenziert, um regionale Besonderheiten zu berücksichtigen.

Für elf Energiepflanzen wurden THG-Emissionen in 38 NUTS2-Regionen ermittelt. Das Ergebnis zeigt z. T. deutliche Unterschiede in den Emissionswerten. Dies liegt insbesondere an den Unterschieden in den Emissionsfaktoren für N_2O, deren Höhe sehr stark von den regionalen Bedingungen abhängig sind. Auch ist der regional unterschiedliche Anteil an Wirtschaftsdünger ein wichtiger Faktor, da methodisch bedingt für diesen Dünger anders als für Mineraldünger keine vorgelagerten Herstellungsprozesse in die Bilanz eingehen. Am Beispiel der Emissionen für den Rapsanbau zeigt sich eine Bandbreite von 362 bis 531 g CO_2-Äquivalent pro Kilogramm. Solch starken regionalen Unterschiede hatte der erste Bericht über typische THG-Emissionswerte für den Anbau von Agrarrohstoffen für NUTS2-Regionen von 2010 nicht gezeigt. Allerdings die früheren Werte durchgängig höher als die hier ermittelten. Grund dafür ist die neue auf realen Messungen beruhende Berechnungsmethode für N_2O und einer Reihe weiterer Faktoren.

Table of contents

List of figures

List of tables

List of abbreviations

Abbreviation	Explanation
AGRUM	Analysis of Agricultural and Environmental Measures in the context of agricultural water protection against the background of the EU Water Framework Directive
BGBl	Bundesgesetzblatt
BMEL	Bundesministerium für Ernährung und Landwirtschaft
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit
CAN	Calcium Ammonium Nitrate
CEPI	Clusters for the regional evaluation and analysis of pesticide use intensity in arable crops
CH_4	Methane
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide Equivalents
EC	European Commission
EU	European Union
Destatis	Statistisches Bundesamt, Wiesbaden Federal Statistical Office of Germany
GHG	Greenhouse gas
GWP100	Global warming potential – timeframe 100 years
IPCC	Intergovernmental Panel on Climate Change
JKI	Julius Kühn-Institut
JEC	Consortium of JRC, Eucar and Concawe
JRC	Joint Research Center
KTBL	Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V.
MS	Member state
N	Nitrogen
N_2O	Nitrous oxide
NIR	National inventory report
NP	Nitrogen and Phosphorous (in context of fertilisers)
NUTS	Nomenclature des unités territoriales statistiques
P	Phosphorous
RED	Renewable Energy Directive - RED I: Directive 2009/28/EC; - RED II: Directive (EU) 2018/2001;

Abbreviation	Explanation
	- RED III: Directive (EU) 2023/2413
THG	Treibhausgas
TI	Johann Heinrich von Thünen-Institut
TM	Trockenmasse
UAN	Urea ammonium nitrate solution
UBA	Umweltbundesamt, Dessau

Summary

Background

According to the Renewable Energy Directive (RED), biofuels, bioliquids and electricity and heating/cooling from biomass fuels can only be counted towards the renewable energy targets if a certain reduction in greenhouse gas (GHG) emissions is achieved. To prove this GHG reduction, either the standard values specified in the RED for the respective bioenergy utilisation can be used or the GHG reduction can be calculated individually. In turn, disaggregated default values can be used for the calculation. In the case of GHG emissions from the cultivation of agricultural raw materials, regionally differentiated, typical values can be used instead of the disaggregated default values published in the annexes to the RED if these have been provided by the Member States (MS) and published by the Commission (COM).

The typical GHG emissions from cultivation in Germany's first report to the Commission were determined on the basis of data from 2004 to 2008. Since then, new scientific findings have been obtained. Input variables such as yields and the use of pesticides, fertilisers and fuel may also have changed since then. It is therefore necessary to update the values for GHG emissions from the cultivation of the relevant energy crops in Germany.

Objective

The objective of this study was to create the basis for updating the typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions in Germany in accordance with the RED II methodology.

For this purpose, the GHG emissions from the cultivation of all relevant energy crops for the production of liquid biofuels (wheat (grains), rye (grains), maize (grains), barley (grains), triticale (grains), sugar beet and rapeseed), biogas and biomethane (maize (whole plant), wheat (whole plant), field grass and grassland cuttings) were calculated for all German 38 NUTS 2 regions on the basis of new scientific findings and currently available data.

Methodology

Above all, this report and the calculations included were performed in line with the Implementing Regulation (EU) 2022/996, Annex VII a, as the central methodological framework for *determining the emissions from the extraction or cultivation of raw materials* with regard to the RED.

Apart from that, the calculation of GHG intensities for bioenergy has a long practical history and can look back on a series of related standard works and tools, such as the well-to-wheels studies by the JEC consortium or the BioGrace tool.

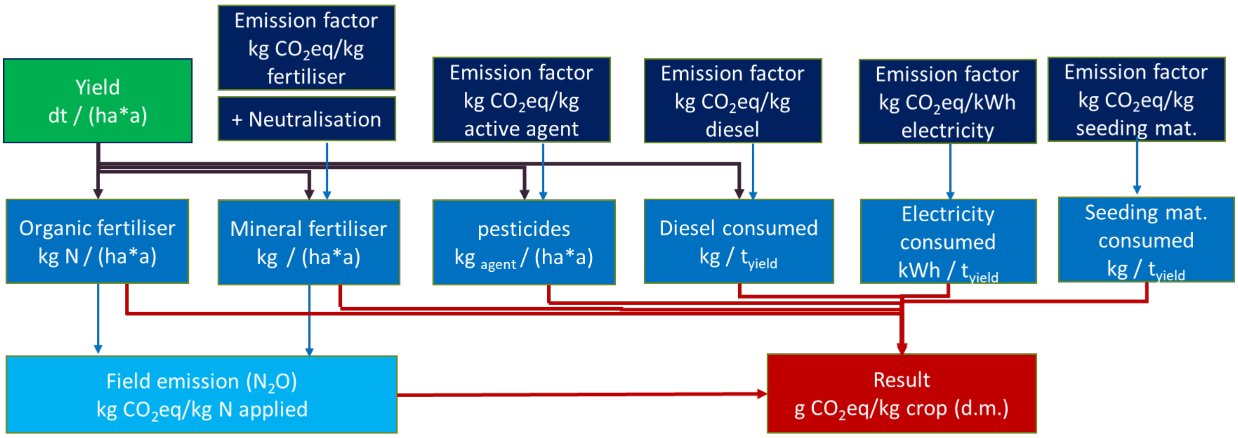
Scope

Figure 1 illustrates the **components** considered for the calculation of GHG intensities, starting with hectare- or yield-related input data. Components with small contribution to final results (below 1 % of the typical total emissions from crops) are disregarded, e.g. the provision of special fertilisers such as sulphur or trace minerals.

The final results are expressed in the **unit** g CO_2eq per kg crop (dry matter) ready for being transported to the downstream processing process. Apart from unit, the result shall correspond to the term e_{ec} given in RED II annex V part D and annex IV part D. Thus, there is no overlap with emissions covered under the terms e_{td} and e_p. The considered diesel consumption includes all applications of agricultural machinery (tillage, fertilizing, spraying pesticides, harvesting etc.),

transport of harvested crops from field to farm, drying of grains, chipping and ensiling of whole plants for subsequent biogas production.

Figure 1: Components included for the calculation of GHG intensities of crops within the framework of RED



Source: illustration by ifeu

For reasons of comparability with other data sources and the disaggregated default values in RED II Annex V Part D and RED II Annex VI Part C, the emission values are also expressed in g CO_2eq./MJ biofuel or biomass such as biogas respectively. However, these values are only given as rough indication, as such a conversion must anticipate the steps of conversion to biofuel or biomass fuel.

The aim was to calculate with data that cover a **temporal period** as current and representative as possible. Average values over the five-year period from 2018 to 2022 were therefore used as the basis. Where this was not possible, a timeline or data background as close as possible to this period was used.

The whole of Germany corresponds to the NUTS 0 level. The next level down (NUTS 1) is equivalent to the 16 federal states (Bundesländer). The **38 NUTS 2 regions** then conform to administrative districts, the so-called Regierungsbezirke. For smaller federal states, such as Schleswig-Holstein or city-states like Berlin or Hamburg, NUTS 1 equals with NUTS 2. This applies to a total of eight regions. The larger federal states are sub-structured by three to seven NUTS 2 regions. Annex A.1 shows a map of the regions.

In line with the Implementing Regulation (EU) 2022/996 Annex IX, the **characterisation factors** for global warming potential referring to 100 year timeframe (GWP 100) are taken from (IPCC 2013a), limited to following greenhouse gases:

- Carbon dioxide, CO_2 1 g CO_2eq. per g
- Methane, CH_4 28 g CO_2eq. per g
- Nitrous oxide, N_2O 265 g CO_2eq. per g

Background activity data

Yield data are taken from the statistic data regularly reported by the Statistical Office of Germany (Destatis). The so called “Regionalstatistik” provides yield data for most agricultural crops even on NUTS 3 level. However, for some raw materials, such as wheat (whole plant), field grass or grassland cuttings, only yield data on NUTS 1 level are available.

Data for **fertiliser application** (N, P, K and Ca) are courteously provided by the Thünen-Institute of Rural Studies. As there are no reliable statistics on fertilizer use for different crops in different regions available in Germany, the only way of providing the needed information was to estimate fertilizer use based on available datasets. This was done as described in the following:

- The data for N fertilizer distinguishes between nitrogen from synthetic fertilisers and nitrogen from organic fertilizers (manure, digestate).
- For P, K and Ca only the input of mineral or synthetic fertiliser is relevant for GHG emissions, since the input of these nutrients via the organic fertilisers goes hand in hand with the use of organic fertilisers, which is free upstream emissions (see Box 1).
- The nitrogen mineral fertiliser use per crop type is determined as follows: firstly, it is assumed that energy crops are fertilised in the same way as "conventional" crops. The requirement for N fertiliser is determined in accordance with the Fertiliser Application Ordinance[1] (Annex 4), taking into account the respective crop and yield-specific nitrogen requirement value for arable crops and grassland as well as the available N from soil mineralisation processes, previous crops and organic fertilisers. These estimations are done prevalently based on data from the AGRUM-DE project[2] (Zinnbauer et al. 2023). A reduction of fertilisation requirements in nitrate polluted areas is not taken into account.
- For P and K, it is assumend that fertilisation levels equal nutrient removals with harvest (mineral fertiliser requirement = removal - supply through organic fertilisers).
- The Ca fertilisation is determined by apportioning the data from the mineral fertiliser statistics. It leads to a standardised fertilisation level of 166 kg CaO per ha utilized agricultural area.

Data for the **application of pesticides** are courteously provided by the Julius Kühn-Institut (JKI), Kleinmachnow. The data were presented not only differentiated by year and crop, but also by spatial application referring to natural area classifications, as represented by the so-called CEPI clusters.[3] This geographical classification follows the conditions considering soil and climate.

The quantities provided by JKI were differentiated according to approx. 680 commercially available products. An exact calculation of the quantities of active substances could not be made due to the abundance of data. Estimates were also made here, whereby the products with a total quantity share of more than 75 % were identified for each field crop. For each of these products, the proportion of active ingredient was taken from available product platforms and used to calculate an average proportion of active agent for the total quantities of products used.

Data for the **consumption of diesel** are provided by the Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL). The data enclose all farming operations performed by machines attributable to the single crops. Regional aspects concerning soil type and yield level are considered. These two parameters were found to have the greatest influence on diesel consumption.

[1] Düngeverordnung (DüV) von 2020 (sowie 2017). https://www.gesetze-im-internet.de/d_v_2017/D%C3%BCV.pdf

[2] https://www.thuenen.de/en/cross-institutional-projects/agrum-germany

[3] CEPI: **C**lusters for the regional **e**valuation and analysis of **p**esticide use **i**ntensity in arable crops

The original data are calculated by applying the KTBL-Diesel demand calculator tool[4] providing results in the unit litre Diesel per tonne of harvested crop.

Crop-related **electricity consumption (**energy for drying and storage beyond the already considered diesel consumption) are also calculated by using a KTBL-online tool, in this case the so-called Leistungs-Kostenrechner[5].

For the calculation of **field emissions** of nitrous oxide (**N_2O**) a Tier-2 approach for calculation is applied, i.e., country-specific and stratified N_2O emission factors, based on a meta-analysis conducted using data collected from 71 individual studies comprising 676 separate emission measurements taken at 43 locations across Germany (Rösemann et al. 2023), (Mathivanan et al. 2021).

Regionalised data study were provided by the Thünen-Institute (TI), which compiles the nationally reported GHG emissions for the sectors Agriculture and LULUCF. For mineral soils, the model distinguishes four environmental zones roughly representing the north-west, north-east, south-east and south-west parts of Germany. The emission factors used do not vary between crops.

The cultivation of **organic soils** as cropland and grassland with continuous drainage accounts for more than 7 % of the emissions of the total German inventory.[6] (Tiemeyer et al. 2020) calculate average emission factors of 11.1 kg N_2O-N ha^{-1} yr^{-1} for cropland and 4.2 kg N_2O-N ha^{-1} yr^{-1} for grassland due to mineralisation of organic matter in drained organic soils. A map showing the distribution of organic soils in Germany (which account for 5.2% of the total area) can be found in Annex A.3. Two different values for overall GHG emissions of crop cultivation are given for mineral and organic soils, respectively.

Background data (i.e. emission factors for the production and provision of synthetic fertilizers, pesticides and diesel (including emissions from fuel use) are taken from Annex IX (*Standard values of emissions factors*) of the Implementing Regulation (EU) 2022/996.

Results

The result is a comprehensive list of GHG emission values (38 NUTS2 areas x 11 crops) differentiated into the individual components, for cultivation on mineral and for organic soil, expressed in different units. The values are therefore summarised in tabular form in the annex to the report. The results for rapeseed are described and presented here as an example.

As shown in Figure 2, the regional results for rapeseed range from 362 to 531 g CO_2eq/kg (dry matter). The lowest value refers to Sachsen-Anhalt, the highest to Saarland. The German average is 430 g CO_2eq/kg rapeseed (dry matter).

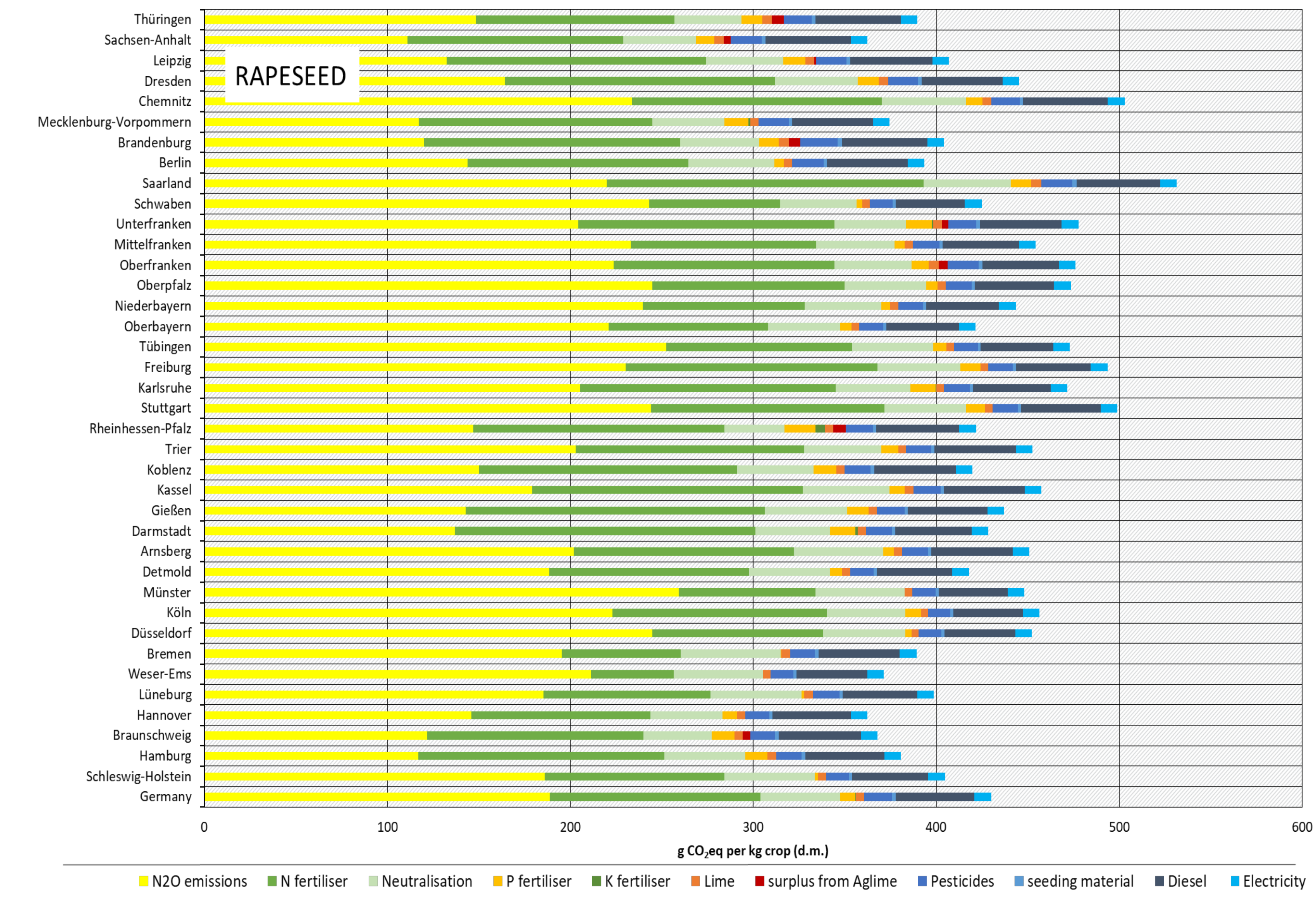
Also, for rapeseed, the overall picture corresponds widely to the results for the cereals. The range is mostly caused by regional differences in N_2O emissions. On German average they take 44 % of the total emission share. Emissions due to production of synthetic N-fertilisers contribute 26.7 % for rapeseed. Emissions from neutralisation contribute 10.4 %. Diesel consumption contributes 10.0 %, pesticides with 3.5 % and P-fertilizer, emissions from electricity consumption with 2.1 % and other fertilizers sum up to 3.1 %.

[4] https://www.ktbl.de/webanwendungen/dieselbedarfsrechner

[5] https://www.ktbl.de/webanwendungen/leistungs-kostenrechnung-pflanzenbau

[6] https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland/emissionen-der-landnutzung-aenderung#moore-organische-boden; see also (UBA 2023)

Figure 2: GHG intensity of rapeseed, per NUTS2 region and system component



Calculation and illustration: ifeu

Discussion of significant parameters and sensitive aspects

The presented GHG emissions from cultivation are depended on a number of components and factors. Of the components (see the overview diagram in Figure 1), two mainly determine the results:

1. The field emissions of nitrous oxide (N_2O) – ranging between 38 and 45 % of the overall GHG emissions, in many cases they take more than 50 %.
2. The emissions from the production of synthetic nitrogen fertilisers - mostly ranging between 22.5 and 31.5 % of overall GHG emissions.

These are followed at some distance by the consumption of diesel, electricity and pesticides. Synthetic P fertilisers, lime and, with a few exceptions, potassium fertilisers have little influence.

The **field emissions** of N_2O is also the most significant parameter regarding the regional variability of the results. Foremost, this is due to the wide range within the regional emission factors for direct N_2O emissions. It should be noted that the same emission factors for direct N_2O field emissions was used for all crops and therefore there is no variability between crops in this respect. On the other hand, the regional differences in N fertilisation have a relevant impact on the level of direct N_2O field emissions.

Between minimum and maximum, there is a factor of 2.3. According to (Mathivanan et al. 2021) the environmental zones have a strong effect on the direct N_2O field emission factor. These were clearly distinguishable from a geographic perspective: Continental South (Bayern, East of Baden-Württemberg) has the highest emission factor, Continental North (Eastern Germany) the lowest. Thus, a clear divide was seen between the emission factors of the environmental zones in northern and southern Germany due to climatic factors.

The second most important component, emissions from the production of applied **synthetic nitrogen fertilisers**, varies also strongly between the NUTS 2 regions. This is driven by two main factors, the quantity and the type of synthetic N fertiliser.

First of all, in regions with a high proportion or density of animal production, large quantities of manure are produced, which leads to a reduced need for synthetic fertiliser. As, according to RED methodology, there are no emission loads for manure before the point of collection, this type of fertiliser is generally associated with lower emission loads than synthetic fertiliser. In consequence, fertiliser production related emissions contribute less to overall GHG emissions in regions with lower animal production.

It must be disputed whether this parameter (high manure/low manure) and this way of GHG calculation leads to meaningful results. Even if the procedure is formally correct, the possible steering effect associated with it must be viewed critically. This could incentivise the preferential production of crops for biofuels in areas with high animal stocking. This could entail an indirect promotion of large-scale livestock farming and lead to an adverse competition for land and consequent rising land rents in these regions. However, for reasons of sustainability and climate protection, this should not be incentivised. This is all the more true as other potential negative environmental impacts of livestock farming such as high nitrogen surpluses with eutrophication effects and groundwater pollution are disregarded when calculating GHG emissions of cultivation.

Moreover, a number of identified **uncertainties** are described and analysed by the study report, such as:

- Yield data (which are taken from national and regional statistics) and data for fertiliser application (derived by models based) origin from different sources and do not guarantee

congruence.
The uncertainties associated with this are considered to be manageable. In the case of grassland, however, the results are no longer considered plausible. For this reason, regionalisation was not used here and a national mean value was used instead.

- Specification of fertiliser types are taken from national statistics, based on market data, which are not necessarily fully identical with actually applied fertiliser types.
- For the application of pesticides, very detailed and comprehensive data needed to be broken down to manageable scale, taking simplifications into account.
- Emissions from neutralisation of the acidification due to fertilizer application and from lime application is now included according to the implementing regulation.
- Also, according to the implementing, emissions due to seeding material production is now included.
- Consumption of Diesel and on-farm electricity origin from data models and are only partly referring to regional difference (in this case only soil type with regard on effort for land machines).

The analyses carried out here integrate various levels and components. For each of them the best available source was used. Whenever applicable, the data used correspond to the official statistical data and the sources for national reporting. Due to the complexity, uncertainties are unavoidable. These have been described and evaluated in detail in the report. In this sense, the results obtained are considered plausible. They are based on a significantly improved and updated database compared to the first calculations of NUTS 2 values for Germany in 2010.

Such a comparison shows that for wheat, rye and maize the upper end of the range exceeds the range from 2010. In all other cases the emission values are lower in the study at hand. , with a more or less clear difference between the lowest regional value in 2010 and the highest regional value in 2024.

The reduced emission intensities compared to then can be considered plausible and are based on an improved scientific basis. The significantly larger bandwidths between the regions compared to 2010 are based on improved models that reflect these spatial characteristics.

Outlook - open questions

The NUTS 2 values calculated are considered plausible. Nevertheless, as explained, there are data gaps and uncertainties.

An open question is how a controllable use of the values for organic or mineral soils can be ensured in the practice of origin-related application of the NUTS 2 values.

Finally, it would also have to be examined whether the equal treatment of cultivation applied here, irrespective of the use of the product (food, feed, energy), is actually justified or whether a distinction should be made here.

Zusammenfassung

Hintergrund

Nach der Erneuerbare-Energien-Richtlinie (RED) können Biokraftstoffe, flüssige Biobrennstoffe sowie Strom und Wärme/Kälte aus Biomassebrennstoffen nur dann auf die Ziele für erneuerbare Energien angerechnet werden, wenn eine bestimmte Reduzierung der Treibhausgasemissionen (THG) erreicht wird. Zum Nachweis dieser THG-Reduktion können entweder die in der RED für die jeweilige Bioenergienutzung festgelegten Standardwerte verwendet oder die THG-Reduktion individuell berechnet werden. Für die Berechnung können wiederum disaggregierte Standardwerte verwendet werden. Bei den THG-Emissionen aus dem Anbau von Agrarrohstoffen können anstelle der in den Anhängen der RED veröffentlichten disaggregierten Standardwerte regional differenzierte, typische Werte verwendet werden, wenn diese von den Mitgliedstaaten (MS) zur Verfügung gestellt und von der Kommission (KOM) veröffentlicht wurden.

Die typischen THG-Emissionen aus dem Anbau im ersten Bericht Deutschlands an die Kommission wurden auf der Grundlage von Daten aus den Jahren 2004 bis 2008 ermittelt. Seitdem sind neue wissenschaftliche Erkenntnisse gewonnen worden. Auch Inputvariablen wie Erträge und der Einsatz von Pestiziden, Düngemitteln und Treibstoffen können sich seitdem verändert haben. Daher ist es notwendig, die Werte für die THG-Emissionen aus dem Anbau der relevanten Energiepflanzen in Deutschland zu aktualisieren.

Zielsetzung

Ziel dieser Studie war es, die Grundlage für die Aktualisierung der typischen THG-Emissionswerte für den Anbau von Agrarrohstoffen für NUTS 2-Regionen in Deutschland gemäß der RED II-Methodik zu schaffen.

Dazu wurden die THG-Emissionen aus dem Anbau aller relevanten Energiepflanzen für die Herstellung von flüssigen Biokraftstoffen (Weizen (Körner), Roggen (Körner), Mais (Körner), Gerste (Körner), Triticale (Körner), Zuckerrüben und Raps), Biogas und Biomethan (Mais (Ganzpflanze), Weizen (Ganzpflanze), Ackergras und Grünlandschnitt) für alle 38 deutschen NUTS 2-Regionen auf Basis neuer wissenschaftlicher Erkenntnisse und aktuell verfügbarer Daten berechnet.

Methodik

Dieser Bericht und die darin enthaltenen Berechnungen wurden vor allem in Übereinstimmung mit der Durchführungsverordnung (EU) 2022/996, Anhang VII a, als zentralem methodischen Rahmen für die Ermittlung der Emissionen aus der Gewinnung oder dem Anbau von Rohstoffen im Hinblick auf die RED durchgeführt.

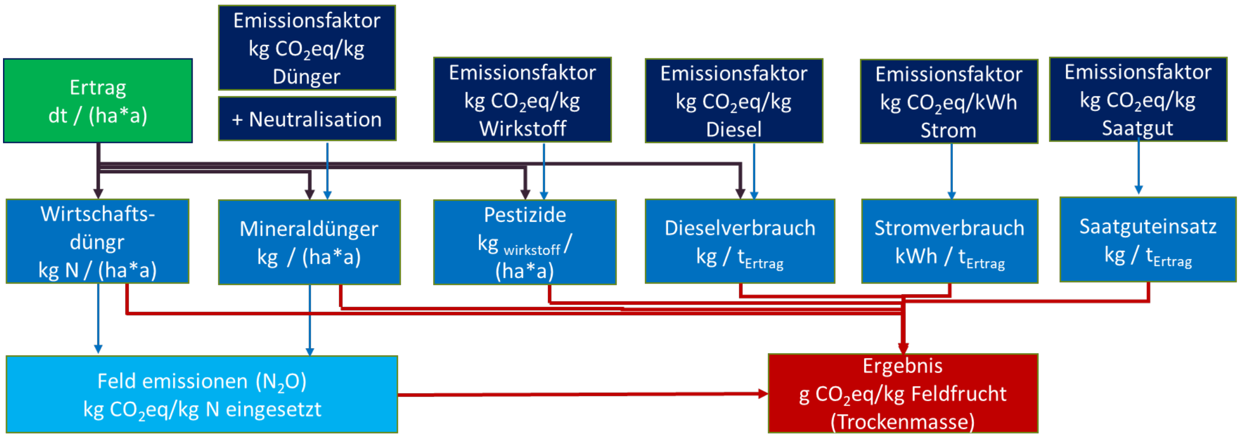
Darüber hinaus hat die Berechnung von THG-Intensitäten für Bioenergie eine lange praktische Geschichte und kann auf eine Reihe von verwandten Standardwerken und Tools zurückgreifen, wie z.B. die Well-to-Wheels-Studien des JEC-Konsortiums oder das BioGrace-Tool.

Umfang

Abbildung 1 veranschaulicht die Komponenten, die bei der Berechnung der Treibhausgasintensitäten berücksichtigt werden, ausgehend von hektar- oder ertragsbezogenen Inputdaten. Komponenten, die nur einen geringen Beitrag zu den Endergebnissen leisten (weniger als 1 % der typischen Gesamtemissionen von Kulturpflanzen), werden nicht berücksichtigt, z. B. die Bereitstellung von Spezialdüngern wie Schwefel oder Spurenelementen.

Die Endergebnisse werden in der Einheit g CO_2Äq pro kg Ernte (Trockensubstanz) ausgedrückt, die für den Transport zum nachgeschalteten Verarbeitungsprozess bereit ist. Abgesehen von der Einheit entspricht das Ergebnis dem Begriff e_{ec} gemäß RED II Anhang V Teil D und Anhang IV Teil D. Es gibt also keine Überschneidungen mit Emissionen, die unter die Begriffe e_{td} und e_p fallen. Der betrachtete Dieselverbrauch umfasst alle Anwendungen von Landmaschinen (Bodenbearbeitung, Düngung, Sprühen von Pestiziden, Ernte usw.), den Transport der geernteten Pflanzen vom Feld zum Betrieb, das Trocknen von Getreide, das Häckseln und Silieren ganzer Pflanzen für die anschließende Biogaserzeugung.

Abbildung 1: Komponenten für die Berechnung der Treibhausgasintensität von Kulturpflanzen im Rahmen der RED



Quelle: eigene Darstellung, ifeu

Aus Gründen der Vergleichbarkeit mit anderen Datenquellen und den disaggregierten Standardwerten in RED II Anhang V Teil D und RED II Anhang VI Teil C werden die Emissionswerte auch in g CO_2Äq/MJ Biokraftstoff bzw. Biomasse wie Biogas angegeben. Diese Werte sind jedoch nur als grober Anhaltspunkt zu verstehen, da eine solche Umrechnung die Schritte der Umwandlung in Biokraftstoff oder Biomasse-Kraftstoff vorwegnehmen muss.

Ziel war es, mit Daten zu rechnen, die einen möglichst aktuellen und repräsentativen Zeitraum abdecken. Daher wurden Durchschnittswerte über den Fünfjahreszeitraum von 2018 bis 2022 zugrunde gelegt. Wo dies nicht möglich war, wurde eine Zeitachse oder ein Datenhintergrund verwendet, der möglichst nahe an diesem Zeitraum liegt.

Das gesamte Bundesgebiet entspricht der Ebene NUTS 0. Die nächst niedrigere Ebene (NUTS 1) entspricht den 16 Bundesländern. Die 38 NUTS-2-Regionen entsprechen dann den Regierungsbezirken, den sogenannten Regierungsbezirken. Für kleinere Bundesländer wie Schleswig-Holstein oder Stadtstaaten wie Berlin oder Hamburg entspricht NUTS 1 der NUTS 2. Dies gilt für insgesamt acht Regionen. Die größeren Bundesländer sind durch drei bis sieben NUTS-2-Regionen untergliedert. Anhang A.1 zeigt eine Karte der Regionen.

In Übereinstimmung mit der Durchführungsverordnung (EU) 2022/996 Anhang IX werden die Charakterisierungsfaktoren für das Treibhauspotenzial bezogen auf einen 100-Jahres-Zeitraum (GWP 100) aus (IPCC 2013a) entnommen, begrenzt auf folgende Treibhausgase:

- Kohlendioxid, CO_2 1 g CO_2Äq. pro g
- Methan, CH_4 28 g CO_2Äq. pro g
- Distickstoffoxid, N_2O 265 g C CO_2Äq. pro g

Hintergrunddaten - Aktivitätsdaten

Die **Ertragsdaten** stammen aus den regelmäßig vom Statistischen Bundesamt (Destatis) gemeldeten statistischen Daten. Die sogenannte „Regionalstatistik" liefert für die meisten landwirtschaftlichen Kulturen Ertragsdaten sogar auf NUTS 3-Ebene. Für einige Rohstoffe, wie z. B. Weizen (ganze Pflanze), Ackergras oder Grünlandschnitt, sind jedoch nur Ertragsdaten auf der Ebene NUTS 1 verfügbar.

Daten zum **Düngereinsatz** (N, P, K und Ca) werden freundlicherweise vom Thünen-Institut für Ländliche Studien zur Verfügung gestellt. Da in Deutschland keine zuverlässigen Statistiken über den Düngemitteleinsatz für verschiedene Kulturen in verschiedenen Regionen verfügbar sind, bestand die einzige Möglichkeit zur Bereitstellung der benötigten Informationen darin, den Düngemitteleinsatz auf der Grundlage der verfügbaren Datensätze zu schätzen. Dies wurde wie im Folgenden beschrieben durchgeführt:

- Bei den Daten für N-Dünger wird zwischen Stickstoff aus synthetischen Düngemitteln und Stickstoff aus organischen Düngemitteln (Gülle, Gärreste) unterschieden.
- Für P, K und Ca ist nur der Eintrag von Mineral- oder Kunstdünger für die THG-Emissionen relevant, da der Eintrag dieser Nährstoffe über organische Düngemittel mit dem Einsatz organischer Düngemittel einhergeht, was freie vorgelagerte Emissionen sind (siehe Kasten 1).
- Der Stickstoff-Mineraldüngereinsatz je Kulturart wird wie folgt ermittelt: Zunächst wird davon ausgegangen, dass Energiepflanzen in gleicher Weise gedüngt werden wie „konventionelle" Kulturen. Die Ermittlung des N-Düngebedarfs erfolgt nach der Düngeverordnung[7] (Anlage 4) unter Berücksichtigung des jeweiligen kultur- und ertragsspezifischen Stickstoffbedarfswertes für Acker- und Grünland sowie des verfügbaren N aus Bodenmineralisierungsprozessen, Vorfrüchten und organischen Düngern. Diese Abschätzungen erfolgen überwiegend auf der Grundlage von Daten aus dem AGRUM-DE-Projekt[8] (Zinnbauer et al. 2023). Eine Verringerung des Düngebedarfs in nitratbelasteten Gebieten wird nicht berücksichtigt.
- Für P und K wird angenommen, dass die Düngung dem Nährstoffentzug bei der Ernte entspricht (Mineraldüngerbedarf = Entzug - Zufuhr durch organische Düngemittel).
- Die Ca-Düngung wird durch Aufteilung der Daten aus der Mineraldüngerstatistik ermittelt. Sie führt zu einem standardisierten Düngungsniveau von 166 kg CaO pro ha landwirtschaftlich genutzter Fläche.

Die Daten zur Anwendung von **Pflanzenschutzmitteln** wurden freundlicherweise vom Julius Kühn-Institut (JKI), Kleinmachnow, zur Verfügung gestellt. Die Daten wurden nicht nur nach Jahren und Kulturen differenziert dargestellt, sondern auch nach der räumlichen Anwendung anhand von naturräumlichen Klassifizierungen, wie sie durch die sogenannten CEPI-Cluster[9] dargestellt werden. Diese geographische Einteilung folgt den bodenkundlichen und klimatischen Bedingungen.

- Die vom JKI gelieferten Mengen wurden nach ca. 680 handelsüblichen Produkten differenziert. Eine genaue Berechnung der Wirkstoffmengen konnte aufgrund der Fülle der

[7] Düngeverordnung (DüV) von 2020 (sowie 2017). https://www.gesetze-im-internet.de/d_v_2017/D%C3%BCV.pdf

[8] https://www.thuenen.de/en/cross-institutional-projects/agrum-germany

[9] CEPI: **C**lusters for the regional **e**valuation and analysis of **p**esticide use **i**ntensity in arable crops

Daten nicht vorgenommen werden. Auch hier wurden Abschätzungen vorgenommen, wobei für jede Feldfrucht die Produkte mit einem Gesamtmengenanteil von mehr als 75 % ermittelt wurden. Für jedes dieser Produkte wurde der Wirkstoffanteil aus verfügbaren Produktplattformen entnommen und daraus ein durchschnittlicher Wirkstoffanteil für die Gesamtmenge der eingesetzten Produkte berechnet.

Die Daten für den **Verbrauch von Diesel** werden vom Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL) bereitgestellt. Die Daten umfassen alle landwirtschaftlichen Arbeitsgänge mit Maschinen, die den einzelnen Kulturen zuzuordnen sind. Regionale Aspekte bezüglich Bodenart und Ertragsniveau werden berücksichtigt. Es wurde festgestellt, dass diese beiden Parameter den größten Einfluss auf den Dieselverbrauch haben.

Die Originaldaten werden mit Hilfe des KTBL-Dieselbedarfsrechners berechnet, der Ergebnisse in der Einheit Liter Diesel pro Tonne Erntegut liefert.[10]

Der erntebezogene Stromverbrauch (Energie für Trocknung und Lagerung über den bereits berücksichtigten Dieselverbrauch hinaus) wird ebenfalls mit einem KTBL-Online-Tool berechnet, in diesem Fall mit dem sogenannten Leistungs-Kostenrechner.[11]

Für die Berechnung der **Feldemissionen von Lachgas** (N_2O) wird ein Tier-2-Ansatz zur Berechnung verwendet, d.h. länderspezifische und geschichtete N_2O-Emissionsfaktoren, die auf einer Meta-Analyse beruhen, die mit Daten aus 71 Einzelstudien mit 676 separaten Emissionsmessungen an 43 Standorten in Deutschland durchgeführt wurde (Rösemann et al. 2023), (Mathivanan et al. 2021).

Regionalisierte Daten wurden vom Thünen-Institut (TI) zur Verfügung gestellt, das die national gemeldeten Treibhausgasemissionen für die Sektoren Landwirtschaft und LULUCF zusammenstellt. Für mineralische Böden unterscheidet das Modell vier Umweltzonen, die grob den nordwestlichen, nordöstlichen, südöstlichen und südwestlichen Teil Deutschlands repräsentieren. Die verwendeten Emissionsfaktoren unterscheiden sich nicht zwischen den Kulturen.

Die **Bewirtschaftung von organischen Böden** als Acker- und Grünland mit kontinuierlicher Entwässerung macht mehr als 7 % der Emissionen des gesamten deutschen Inventars aus.[12] (Tiemeyer et al. 2020) berechnen durchschnittliche Emissionsfaktoren von 11,1 kg N_2O-N pro Hektar und Jahr für Ackerland und 4,2 kg N_2O-N pro Hektar und Jahr für Grünland aufgrund der Mineralisierung organischer Substanz in entwässerten organischen Böden. Eine Karte mit der Verteilung der organischen Böden in Deutschland (die 5,2 % der Gesamtfläche ausmachen) ist in Anhang A.3 zu finden. Es werden zwei verschiedene Werte für die Gesamt-THG-Emissionen des Pflanzenanbaus für mineralische bzw. organische Böden angegeben.

Hintergrunddaten (d.h. Emissionsfaktoren für die Herstellung und Bereitstellung von synthetischen Düngemitteln, Pestiziden und Diesel (einschließlich Emissionen aus der Kraftstoffnutzung) sind dem Anhang IX (Standardwerte für Emissionsfaktoren) der Durchführungsverordnung (EU) 2022/996 entnommen.

Ergebnisse

Das Ergebnis ist eine umfassende Liste von THG-Emissionswerten (38 NUTS2-Gebiete x 11 Kulturen), differenziert nach den einzelnen Komponenten, für den Anbau auf mineralischen und

[10] https://www.ktbl.de/webanwendungen/dieselbedarfsrechner

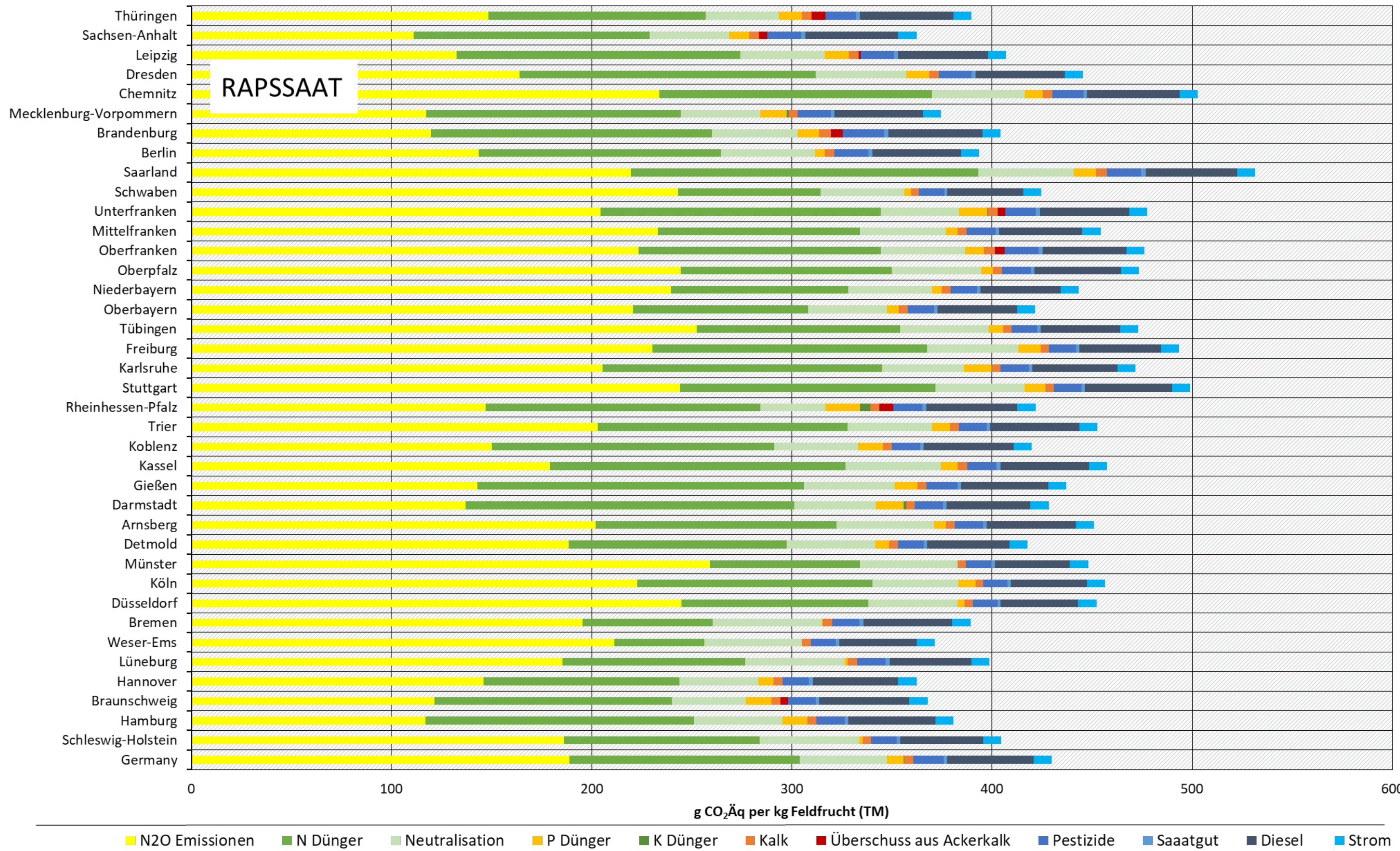
[11] https://www.ktbl.de/webanwendungen/leistungs-kostenrechnung-pflanzenbau

[12] https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland/emissionen-der-landnutzung-aenderung#moore-organische-boden; see also (UBA 2023)

für den Anbau auf organischen Böden, ausgedrückt in verschiedenen Einheiten. Die Werte sind daher im Anhang des Berichts in tabellarischer Form zusammengefasst. Beispielhaft werden hier die Ergebnisse für Raps beschrieben und dargestellt.

Wie in Abbildung 2 dargestellt, liegen die regionalen Ergebnisse für Raps zwischen 362 und 531 g CO_2Äq/kg (Trockenmasse). Der niedrigste Wert bezieht sich auf Sachsen-Anhalt, der höchste auf das Saarland. Der deutsche Durchschnitt liegt bei 430 g CO_2Äq/kg Raps (Trockensubstanz).

Abbildung 2: Treibhausgasintensität von Raps, nach NUTS2-Region und Systemkomponente



Berechnung und Darstellung: ifeu

Auch bei Raps stimmt das Gesamtbild weitgehend mit den Ergebnissen für Getreide überein. Die Schwankungsbreite ist vor allem auf regionale Unterschiede bei den N2O-Emissionen zurückzuführen. Im deutschen Durchschnitt haben sie einen Anteil von 44 % an den Gesamtemissionen. Die Emissionen aus der Herstellung von synthetischen N-Düngemitteln tragen bei Raps 26,7 % bei. Die Emissionen aus der Neutralisation tragen 10,4 % bei. Der Dieselverbrauch trägt mit 10,0 % bei, Pestizide mit 3,5 % und P-Dünger, Emissionen aus dem Stromverbrauch mit 2,1 % und andere Düngemittel summieren sich auf 3,1 %.

Diskussion der wichtigsten Parameter und sensiblen Aspekte

Die dargestellten Treibhausgasemissionen aus dem Anbau sind von einer Reihe von Komponenten und Faktoren abhängig. Von den Komponenten (siehe das Übersichtsdiagramm in Abbildung 1) bestimmen hauptsächlich zwei die Ergebnisse:

1. Die Feldemissionen von Lachgas (N_2O) - sie machen zwischen 38 und 45 % der gesamten THG-Emissionen aus, in vielen Fällen sogar mehr als 50 %.
2. Die Emissionen aus der Herstellung von synthetischen Stickstoffdüngern - meist zwischen 22,5 und 31,5 % der gesamten THG-Emissionen.

Mit einigem Abstand folgen der Verbrauch von Diesel, Strom und Pestiziden. Synthetische P-Dünger, Kalk und, mit wenigen Ausnahmen, Kaliumdünger haben nur einen geringen Einfluss.

Die N_2O-Emissionen auf den Feldern sind auch der wichtigste Parameter für die regionale Variabilität der Ergebnisse. Dies ist in erster Linie auf die große Bandbreite der regionalen Emissionsfaktoren für direkte N_2O-Emissionen zurückzuführen. Es ist anzumerken, dass für alle Kulturen dieselben Emissionsfaktoren für direkte N_2O-Feldemissionen verwendet wurden, so dass es in dieser Hinsicht keine Variabilität zwischen den Kulturen gibt. Andererseits haben die regionalen Unterschiede bei der Stickstoffdüngung einen erheblichen Einfluss auf die Höhe der direkten N_2O-Feldermissionen.

Zwischen dem Minimum und dem Maximum liegt ein Faktor von 2,3. Nach (Mathivanan et al. 2021) haben die Umweltzonen einen starken Einfluss auf den direkten N_2O-Feldemissionsfaktor. Diese ließen sich geografisch klar unterscheiden: Der kontinentale Süden (Bayern, östlich von Baden-Württemberg) hat den höchsten Emissionsfaktor, der kontinentale Norden (Ostdeutschland) den niedrigsten. Es zeigt sich also ein deutliches Gefälle zwischen den Emissionsfaktoren der Umweltzonen in Nord- und Süddeutschland aufgrund klimatischer Faktoren.

Die zweitwichtigste Komponente, die Emissionen aus der Produktion von ausgebrachten synthetischen Stickstoffdüngern, variiert ebenfalls stark zwischen den NUTS-2-Regionen. Hierfür sind vor allem zwei Faktoren verantwortlich, nämlich die Menge und die Art der synthetischen N-Dünger.

Erstens fallen in Regionen mit einem hohen Anteil oder einer hohen Dichte der Tierproduktion große Mengen an Dung an, was zu einem geringeren Bedarf an synthetischem Dünger führt. Da nach der RED-Methodik keine Emissionsbelastungen für Gülle vor dem Sammelpunkt anfallen, ist diese Art von Dünger im Allgemeinen mit geringeren Emissionsbelastungen verbunden als synthetischer Dünger. Folglich tragen die mit der Düngemittelproduktion verbundenen Emissionen weniger zu den gesamten Treibhausgasemissionen in Regionen mit geringerer Tierproduktion bei.

Ob dieser Parameter (hohe Gülle/niedrige Gülle) und diese Art der THG-Berechnung zu aussagekräftigen Ergebnissen führt, ist zu bezweifeln. Selbst wenn das Verfahren formal korrekt ist, muss die damit verbundene mögliche Lenkungswirkung kritisch gesehen werden. So könnte ein Anreiz geschaffen werden, in Gebieten mit hohem Tierbesatz bevorzugt Pflanzen für

Biokraftstoffe anzubauen. Dies könnte eine indirekte Förderung der Massentierhaltung nach sich ziehen und zu einer negativen Flächenkonkurrenz und damit steigenden Bodenrenten in diesen Regionen führen. Aus Gründen der Nachhaltigkeit und des Klimaschutzes sollte dies jedoch nicht gefördert werden. Dies gilt umso mehr, als andere potenzielle negative Umweltauswirkungen der Tierhaltung wie hohe Stickstoffüberschüsse mit Eutrophierungseffekten und Grundwasserverschmutzung bei der Berechnung der THG-Emissionen des Anbaus unberücksichtigt bleiben.

Darüber hinaus werden in dem Studienbericht eine Reihe von Unsicherheiten beschrieben und analysiert, wie z. B.:

- Ertragsdaten (die nationalen und regionalen Statistiken entnommen werden) und Daten zum Düngemitteleinsatz (die anhand von Modellen abgeleitet werden) stammen aus unterschiedlichen Quellen und garantieren keine Übereinstimmung.
  Die damit verbundenen Unsicherheiten werden als überschaubar angesehen. Im Falle des Grünlandes werden die Ergebnisse jedoch als nicht mehr plausibel angesehen. Aus diesem Grund wurde hier auf eine Regionalisierung verzichtet und stattdessen ein nationaler Mittelwert verwendet.
- Die Angaben zu den Düngemitteltypen stammen aus nationalen Statistiken auf der Grundlage von Marktdaten, die nicht unbedingt vollständig mit den tatsächlich ausgebrachten Düngemitteltypen übereinstimmen.
- Für die Anwendung von Pestiziden mussten sehr detaillierte und umfassende Daten unter Berücksichtigung von Vereinfachungen auf einen handhabbaren Maßstab heruntergebrochen werden.
- Emissionen aus der Neutralisierung der Versauerung durch Düngemittelausbringung und aus der Kalkausbringung sind nun gemäß der Durchführungsverordnung enthalten.
- Auch die Emissionen aus der Saatgutproduktion werden nun gemäß der Durchführungsverordnung einbezogen.
- Der Verbrauch von Diesel und Betriebsstrom stammt aus Datenmodellen und bezieht sich nur teilweise auf regionale Unterschiede (in diesem Fall nur die Bodenart in Bezug auf den Aufwand für Landmaschinen).

Die hier durchgeführten Analysen umfassen verschiedene Ebenen und Komponenten. Für jede dieser Ebenen wurde die beste verfügbare Quelle verwendet. Wo immer möglich, entsprechen die verwendeten Daten den offiziellen statistischen Daten und den Quellen für die nationale Berichterstattung. Aufgrund der Komplexität sind Unsicherheiten unvermeidbar. Diese wurden in dem Bericht ausführlich beschrieben und bewertet. In diesem Sinne werden die erzielten Ergebnisse als plausibel angesehen. Sie beruhen auf einer deutlich verbesserten und aktualisierten Datenbasis im Vergleich zu den ersten Berechnungen der NUTS-2-Werte für Deutschland im Jahr 2010.

Ein solcher Vergleich zeigt, dass bei Weizen, Roggen und Mais das obere Ende der Spanne über der Spanne von 2010 liegt. In allen anderen Fällen liegen die Emissionswerte in der vorliegenden Studie niedriger. Mit einem mehr oder weniger deutlichen Unterschied zwischen dem niedrigsten regionalen Wert im Jahr 2010 und dem höchsten regionalen Wert im Jahr 2024.

Die im Vergleich zu damals reduzierten Emissionsintensitäten können als plausibel angesehen werden und basieren auf einer verbesserten wissenschaftlichen Grundlage. Die deutlich größeren Bandbreiten zwischen den Regionen im Vergleich zu 2010 beruhen auf verbesserten Modellen, die diese räumlichen Besonderheiten widerspiegeln.

Ausblick - offene Fragen

Die berechneten NUTS 2-Werte werden als plausibel angesehen. Dennoch gibt es, wie erläutert, Datenlücken und Unsicherheiten.

Eine offene Frage ist, wie in der Praxis der herkunftsbezogenen Anwendung der NUTS-2-Werte eine kontrollierbare Verwendung der Werte für organische oder mineralische Böden sichergestellt werden kann.

Schließlich wäre auch zu prüfen, ob die hier vorgenommene Gleichbehandlung des Anbaus unabhängig von der Verwendung des Produkts (Lebensmittel, Futtermittel, Energie) tatsächlich gerechtfertigt ist oder ob hier eine Differenzierung vorgenommen werden sollte.

1 Rationale of this study and objective

1.1 Background

According to the Renewable Energy Directive (RED), biofuels, bioliquids and electricity and heating/cooling from biomass fuels can only be counted towards the renewable energy targets if a certain reduction in greenhouse gas (GHG) emissions is achieved. To prove this GHG reduction, either the standard values specified in the RED for the respective bioenergy utilisation can be used or the GHG reduction can be calculated individually. In turn, disaggregated default values can be used for the calculation. In the case of GHG emissions from the cultivation of agricultural raw materials, regionally differentiated, typical values can be used instead of the disaggregated default values published in the annexes to the RED if these have been provided by the Member States (MS) and published by the Commission (COM).

After the Renewable Energy Directive (2009/28/EC - RED I for short) came into force, such typical GHG emissions from the cultivation of raw materials relevant to Germany for the production of bioenergy sources - differentiated according to the NUTS 2 regions - were compiled and submitted to the EU Commission for the first time in 2010. These values were published by the Commission in an implementing act following its decision and have since been used by the industry as an alternative to the actual values for emissions from the cultivation of agricultural biomass.

Since the revised Renewable Energy Directive RED II (2018/2001/EU) has come into force, these values can no longer be applied. However, RED II also allows the same procedure with regard to the development, verification and publication of typical cultivation emissions, see Article 31 (1) c and d and Article 31 (2) and (4). By extending the scope of the GHG reduction criterion to solid and gaseous biomass fuels for electricity and heating/cooling generation, additional energy crops are also relevant compared to the first report to the Commission.

The typical GHG emissions from cultivation in Germany's first report to the Commission were determined on the basis of data from 2004 to 2008. Since then, new scientific findings have been obtained. Input variables such as yields and the use of pesticides, fertilisers and fuel may also have changed since then. It is therefore necessary to update the values for GHG emissions from the cultivation of the relevant energy crops in Germany.

1.2 Objective and scope

The objective of this study was to create the basis for updating the typical GHG emission values for the cultivation of agricultural raw materials for NUTS 2 regions in Germany in accordance with the RED II methodology.

For this purpose, the GHG emissions from the cultivation of the following energy crops (for the production of the specified energy sources) were calculated for all German 38 NUTS 2 regions on the basis of new scientific findings and currently available data:

- For the production of bioethanol:
  - wheat (grains)
  - rye (grains)
  - maize (grains)
  - barley (grains)

- triticale (grains)
- sugar beet

► For the production of biodiesel od hydrotreated vegetable oil (HVO):

- Rapeseed

► For the production of biogas or biomethane

- Maize (whole plant)
- Wheat (whole plant)
- Field grass
- Grassland cuttings

In this selection, only crops that account for more than 0.5 % of the bioenergy sources recognised according to the BLE's Nabisy[13] register (average within the timeframe from January 2023 until April 2023) in accordance with the RED are included.

The scope of the calculation of GHG intensities includes the production and provision of fertilizer (mineral and organic) and pesticides, field emissions from fertilizing and cultivation (nitrous oxide, N_2O) and diesel consumption by the applied machinery. As ruled by the RED II Annex V part C and Annex VI part B, estimates of emissions from agriculture biomass cultivation derived from the regional averages for cultivation emissions maybe used as an alternative to actual values.

Further details according methodology and data can be found in the subsequent chapter 2.

[13] Nabisy - Nachhaltige Biomasse System (Sustainable Biomass System): the governmental web application for sustainable biomass, operated by the Federal Office for Agriculture and Food (BLE); https://nabisy.ble.de/app/locale;jsessionid=F51472699CC13B87135C153454E0E718?set=en

2 Method and data

The goal was to compute emission intensities covering the specific conditions for the selected crops and the regional circumstances as far as possible.

2.1 Methodical approach

2.1.1 Guiding frameworks

Above all, this report and the calculations included were performed in line with the Implementing Regulation (EU) 2022/996, Annex VII a, as the central methodological framework for *determining the emissions from the extraction or cultivation of raw materials* with regard to the RED.

Apart from that, the calculation of GHG intensities for bioenergy has a long practical history and can look back on a series of related standard works and tools, such as:

- The well-to-wheels studies by the JEC consortium (apart from the methodological deviation concerning the consideration of co-products – which has no significant relevance for the cases under study)
- The BioGrace tool (which has been recognized as a partial voluntary system under RED until June 2021 – the recognition has expired due to lack of formal aspects, which haven't been updated.
- The RSB GHG calculator tool: (https://rsb.org/certification/ghg-calculator/)
- The CORSIA GHG Calculation methodology (ICAO 2019)
- The "Leitfaden Nachhaltige Biomasseherstellung" (BLE 2010)

2.1.2 Components considered for the calculation of GHG intensities

Figure 3 illustrates the components considered for the calculation of GHG intensities, starting with hectare- or yield-related input data, such as

- Yield in decitonne (dt)[14] per hectare (ha) and year (a)
- Application of fertilisers (N, P, K) and lime (Ca) in kg per hectare (ha) and year (a); N and P fertilisers are further differentiated here according to fertiliser type.
- CO_2 soil emissions from neutralisation of fertiliser acidification and liming[15].
- Field emissions of N_2O following a tier 2 approach under IPCC calculation rules.
- Application of pesticides (active agent) in kg per hectare (ha) and year (a)
- Consumption of seeding material in kg per hectare (ha) and year (a).
- On-Farm consumption of Diesel in kg per tonne harvested crop.

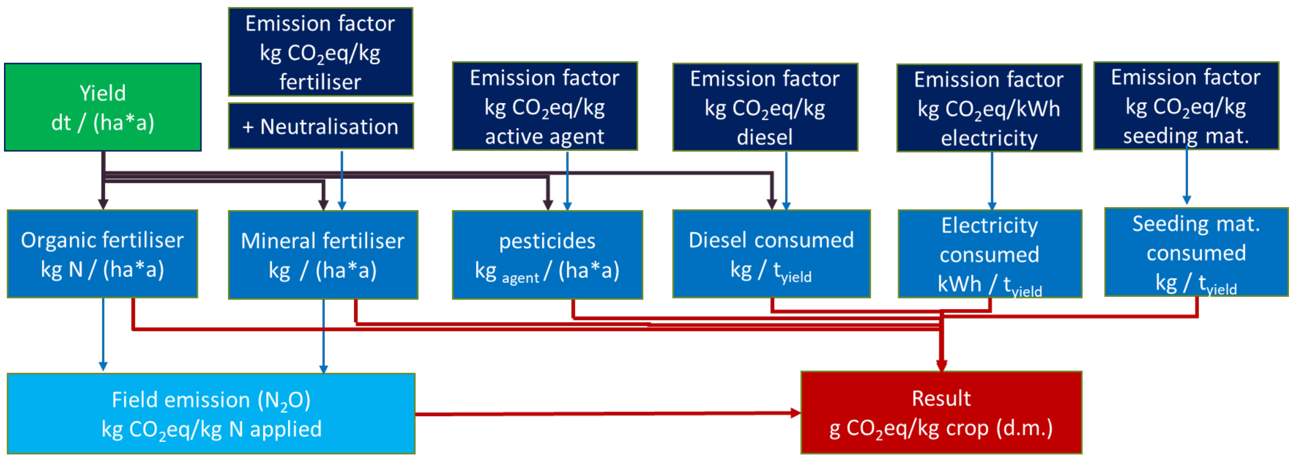
[14] This is the unit commonly used in agricultural statistics in Germany (1 dt = 100 kg)

[15] According to Implementing Regulation (EU) 2022/996, Annex VII, section 1.4.1 and 1.4.2

The latter includes all applications of agricultural machinery (tillage, fertilizing, spraying pesticides, harvesting etc.), transport of harvested crops from field to farm, drying of grains, chipping and ensiling of whole plants for subsequent biogas production.

There are no regionalised data available concerning seeding material and crop-related electricity consumption (e.g. energy for drying and storage beyond the already considered diesel consumption). The contributions of electricity to the GHG balance are added by using generic data (see chapter 2.2).

Figure 3: Components included for the calculation of GHG intensities of crops within the framework of RED



Source: own illustration, ifeu

The aim was to calculate with data that cover a period as current and representative as possible. Average values over the five-year period from 2018 to 2022 were therefore used as the basis. Where this was not possible, a timeline or data background as close as possible to this period was used.

2.1.3 Scope of NUTS 2 regions in Germany

The whole of Germany corresponds to the NUTS 0 level. The next level down (NUTS 1) is equivalent to the 16 federal states (Bundesländer). The 38 NUTS 2 regions then conform to administrative districts, the so-called Regierungsbezirke. For smaller federal states, such as Schleswig-Holstein or city-states like Berlin or Hamburg, NUTS 1 equals with NUTS 2. This applies to a total of eight regions. The larger federal states are sub-structured by three to seven NUTS 2 regions. Annex A.1 shows a map of the regions.

2.1.4 How German averages are calculated

In addition to the regional values, for each crop also average values were calculated for Germany. These are based on an area-weighted average for each crop using the shares of the NUTS 2 regions in the arable land in Germany. In this way, regions with a high proportion of arable land nationwide, such as Mecklenburg-Vorpommern or Brandenburg, are weighted correspondingly higher than regions with small proportions, such as Berlin, Hamburg or Bremen. The German average value for GHG emissions from grassland cultivation was calculated in the same way using the shares of the NUTS 2 regions in the grassland, respectively.

This averaging does not take into account if certain crops are grown predominantly or only rarely in certain regions.

Data for arable land and for grassland per NUTS 2 region are taken from national statistics (Destatis).[16]

2.1.5 Conversion from emissions per crop-mass to emissions per energy content of biofuel or biomass fuel

For reasons of comparability with other data sources and the disaggregated default values in RED II Annex V Part D and RED II Annex VI Part C, the emission values are also expressed in g CO_2eq./MJ biomass feedstock and g CO_2eq./MJ biofuel or biomass such as biogas respectively. However, these values are only given as rough indication, as such a conversion must anticipate the steps of conversion to biofuel or biomass fuel.

There is no recognised standard calculation scheme available for the standard values of RED II as there was for the initial calculation of the NUTS 2 values in the form of the formerly recognised voluntary BioGrace subsystem. The conversion is therefore carried out on an informal basis using the conversion factors of the calculation tool from the BioEm project (Fehrenbach et al. 2016).

2.1.6 Characterisation factors for global warming potential

In line with the Implementing Regulation (EU) 2022/996 Annex IX, the characterisation factors for global warming potential referring to 100 year timeframe (GWP 100) are taken from (IPCC 2013a), limited to following greenhouse gases:

- Carbon dioxide, CO_2 1 g CO_2eq. per g
- Methane, CH_4 28 g CO_2eq. per g
- Nitrous oxide, N_2O 265 g CO_2eq. per g

2.2 Data sources

The challenge was to obtain solid empirical data on a regionalised basis (NUTS 2 level). To this end, the research institutions in Germany with core expertise in the relevant data backgrounds were asked for support. These are various specialised institutes within the Johann Heinrich von Thünen Institute (TI), the Julius Kühn Institute (JKI) and the KTBL (see also list in Table 1).

2.2.1 Yield data

Yield data are regularly reported by the Statistical Office of Germany (Destatis). The so called "Regionalstatistik" provides yield data for most agricultural crops even on NUTS 3 level. However, for some raw materials, such as wheat (whole plant), field grass or grassland cuttings, only yield data on NUTS 1 level are available.

The statistical yield data are expressed in fresh matter. Actually, the real moisture content varies but is not systematically measured. Thus, the official statistics (Destatis 2023a) refer to standard values, which are applied to derives values for dry matter. The standard moisture content for cereal grains is 14 %, for oilseeds (such as rapeseed) 9 % and for whole plant (maize, wheat, field grass) 65 %. Those standard moisture contents were also used for the calculation of GHG

[16] https://www.regionalstatistik.de/genesis//online?operation=table&code=41120-01-02-4-B&bypass=true&levelindex=1&levelid=1709649625296#abreadcrumb Yield data are regularly reported by the Statistical Office of Germany (Destatis). The so called "Regionalstatistik" provides yield data for most agricultural crops even on NUTS 3 level. However, for some raw materials, such as wheat (whole plant), field grass or grassland cuttings, only yield data on NUTS 1 level are available.

emissions per kg dry matter in this report. For sugar beet, the statistics do not show a standard value for dry matter. A value of 77 % is used here. The yields per hectare for cuttings from grassland are already shown in the statistics in dry matter.

Where crops or cuttings are ensiled on farm for biogas production, losses of organic matter occur. These losses need to be included in the calculation of GHG emissions of crop cultivation and are estimated at 10 % in analogy to the energetic silage losses as applied by (Prussi et al. 2020).

2.2.2 Fertiliser application

Data for **fertiliser application** (N, P, K and Ca) are courteously provided by the Thünen-Institute of Rural Studies. As there are no reliable statistics on fertilizer use for different crops in different regions available in Germany, the only way of providing the needed information was to estimate fertilizer use based on available datasets. This was done as described in the following:

- The data for N fertilizer distinguishes between nitrogen from synthetic fertilisers and nitrogen from organic fertilizers (manure, digestate).
- For P, K and Ca only the input of mineral or synthetic fertiliser is relevant for GHG emissions, since the input of these nutrients via the organic fertilisers goes hand in hand with the use of organic fertilisers, which is free upstream emissions (see Box 1).
- The nitrogen mineral fertiliser use per crop type is determined as follows: firstly, it is assumed that energy crops are fertilised in the same way as "conventional" crops. The requirement for N fertiliser is determined in accordance with the Fertiliser Application Ordinance[17] (Annex 4), considering the respective crop and yield-specific nitrogen requirement value for arable crops and grassland as well as the available N from soil mineralisation processes, previous crops and organic fertilisers. These estimations are done prevalently based on data from the AGRUM-DE project[18] (Zinnbauer et al. 2023). A reduction of fertilisation requirements in nitrate polluted areas is not taken into account.
- For P and K, it is assumed that fertilisation levels equal nutrient removals with harvest (mineral fertiliser requirement = removal - supply through organic fertilisers).
- The Ca fertilisation is determined by apportioning the data from the mineral fertiliser statistics. It leads to a standardised fertilisation level of 166 kg CaO per ha utilized agricultural area (see subsequent chapter 2.2.4).

In order to be able to calculate GHG emissions from production using the fertiliser data, the specific type of fertiliser must be defined. Unfortunately, the available data on regionalised fertiliser use does not provide any information on this. However, the range of fertiliser types actually used can be approximated on the basis of sales statistics (Destatis 2022), (Destatis 2023b). These statistics are available at federal state level (NUTS 1) and do not provide any information on the use of the specific fertilizer types for different crops. Uncertainties therefore remain here, but a more precise assignment is not possible. In any case, the multi-year average minimises the possible error due to cross-year stock purchases by farmers. Furthermore, the fact, that the usual crop rotation partly decouples the connections regarding possible preference for specific fertiliser types of certain crops.

[17] Düngeverordnung (DüV) von 2020 (sowie 2017). https://www.gesetze-im-internet.de/d_v_2017/D%C3%BCV.pdf

[18] https://www.thuenen.de/en/cross-institutional-projects/agrum-germany

The application of this approach shows a particular uncertainty for **grassland**: firstly, as mentioned above, yield data are only available at NUTS1 level, but the fertiliser values are differentiated according to NUTS2, which leads to inconsistencies between the regions within a federal state. More importantly, however, the method of calculation leads to large differences between regions that have a high fertiliser requirement according to the Fertiliser Application Ordinance and at the same time a high volume of farm manure compared to those that have a rather low fertiliser requirement and where hardly any farm manure is available.

However, the yields according to statistics do not reflect this low or high fertiliser application, which therefore may lead to under- or overestimation of GHG emissions.

In order to consider regional differences but also prevent over- and underestimation we now refer to a narrowed corridor of Yield/N-Input-ratios, we deem to be more realistic. We figured these out for all NUTS2 regions and narrowed the effective ratio by >30percentile and <70percentile. The result resembles the pattern of most other crops because the outliers then are smoothed by the percentiles (see also chapter 2.3).

2.2.3 CO_2 soil emissions from neutralisation of fertiliser acidification and liming

According to Implementing Regulation (EU) 2022/996, emissions resulting from acidification caused by nitrogen fertiliser use in the field are accounted in line with Annex VII No. 1.4.1: For nitrate fertilisers, the emission factor from the neutralisation of nitrogen fertilisers in the soil is 0.783 kg CO_2/kg N; for urea fertilisers the emission factor is 0.806 kg CO_2/kg N.[19]

These emissions can be augmented by CO_2 soil emissions from liming (aglime), in line with Annex VII No. 1.4.2, which is explained in the context of the subsequent chapter on application of lime.

2.2.4 Application of lime

For the use of lime in agriculture in Germany, there is only data on the total quantity used, which amounts to 2.78 million tonnes CaO per year (Destatis 2022). This is mainly ground limestone ($CaCO_3$), from which CO_2 is released when worked into acidic soils. According to Annex VII No. 1.4.2, different emission factors are defined for soils of a pH less than 6.4 and soils of a pH 6.4 and higher. Despite available information on acidity levels in arable and grassland soils in Germany, there is no information on where lime is actually used. In order to align with this requirement, following approximate calculation approach is applied here:

1. As explained above, the amount of lime used according to the sales statistics is distributed evenly over the agricultural area, resulting in an average value of 166 kg CaO per hectare and year
2. As it is assumed that this quantity of lime is used exclusively on soils with pH<6.4, the emission factor of 0.44 kg CO_2eq per kg $CaCO_3$ is applied to the entire quantity.
3. In line with Implementing Regulation (EU) 2022/996, Annex VII No. 1.4.2, only the difference from this CO_2 emission minus the emission from acidification (No. 1.4.1) listed in chapter 2.2.2 is added to the overall result for the respective crop per NUTS2 area (in the illustration of the results in chapter 3 it is termed “surplus from aglime”).

[19] The most common nitrogen fertilisers used in Germany are calcium ammonium nitrate (CAN), urea ammonium nitrate solution (UAN) and urea. UAN is counted here as 50% urea. Unspecified N-fertiliser as well as manure-N is handled as nitrate-N.

2.2.5 Application of pesticides

Data for the **application of pesticides** are courteously provided by the Julius Kühn-Institut (JKI), Kleinmachnow. The data were presented not only differentiated by year and crop, but also by spatial application. For the latter, however, there is no differentiation according to the NUTS system, but rather according to natural area classifications, as represented by the so-called CEPI clusters.[20] This geographical classification follows the conditions considering soil and climate (Dachbrodt-Saaydeh et al. 2020). The data provided by JKI respect different pesticide applications according to the six CEPI clusters. A map is given in Annex 0. In some cases, NUTS 2 areas fall entirely within a CEPI cluster (e.g. Mecklenburg-Vorpommern or Münster). In most cases, the statistical areas overlap with several CEPI clusters (e.g. the areas in Rheinland-Pfalz or Hessen). In these cases, the authors of this study estimated proportions of CEPI clusters within the single NUTS 2 area. These estimated proportions are documented in Annex A.2, Table 5.

The quantities provided by JKI were differentiated according to approx. 680 commercially available products. An exact calculation of the quantities of active substances could not be made due to the abundance of data. Estimates were also made here, whereby the products with a total quantity share of more than 75 % were identified for each field crop. For each of these products, the proportion of active ingredient was taken from available product platforms[21] and used to calculate an average proportion of active agent for the total quantities of products used. The mean value determined in this way is 0.36 kg active agent per litre (since most products are liquid solutions) or kg product. Most preparations contain between 0.15 and 0.7 kg of active ingredient per litre or kg. Some very potent substances are traded in concentrations of less than 0.1 kg per litre.

The most important active agents are:

- Wheat: Chlormequat (growth regulator), Prosulocarb (and many other fungicides), glyphosate (herbicide)
- Maize: Terbuthylazin and Glyphosate (herbicides)
- Barley: Prosulfocarb (and many other fungicides), Pendimethalin and Glyphosate (herbicides)
- Sugar beet: Metamitron, Phenmedipham and Glyphosate (all herbicides)
- Rapeseed: Metazachlor, Dimethenamid and Glyphosate (all herbicides)

Calculations by the UBA show that the average annual use of plant protection products in German agriculture is 8.8 kg or 2.8 kg of active agent per hectare of cultivated land, based on figures from 2014.[22] This results in a content of 0.31 kg active agent per kg product, thus, slightly lower than the value used for further calculation (0.36 kg active agent per litre or kg product, see above).

For each region and crop the application rate in kg active agent / (ha*a) was deducted by multiplication of the average content of active agent per kg of pesticide and the pesticide requirement; this application rate is multiplied with the emission factor for active agents (8.233 g $CO2_{e\,qu}$/kg active agent; ecoinvent).

[20] CEPI: **C**lusters for the regional **e**valuation and analysis of **p**esticide use **i**ntensity in arable crops

[21] In particular: https://www.raiffeisen.com/agrar_sdb/

[22] https://www.umweltbundesamt.de/daten/land-forstwirtschaft/pflanzenschutzmittelverwendung-in-der#absatz-von-pflanzenschutzmitteln

Data on pesticide requirements are available for the crops listed above. Maize is not differentiated between that for grain production and that for silage. The data is therefore used for both types of cultivation. The same applies to wheat, where the data for grain wheat is also used for whole crop production. For rye and triticale, a mix of the data for wheat and barley is assumed. No data is available for arable grass. This gap must be considered when discussing the results. Data on pesticide use is also missing for grassland. However, pesticides are only used in special cases (control of individual invasive species such as thistles).

Compared to calculations for the first German NUTS 2 report (German Government 2010), the approach used here is far more detailed and region-specific. An assessment of the assumptions and simplifications made is carried out in Chapter 4.1 in light of the significance of this component for the overall balance of crops.

2.2.6 Consumption of diesel

Data for the **consumption of diesel** are courteously provided by the Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL). The data enclose all farming operations performed by machines attributable to the single crops. Regional aspects concerning soil type and yield level are considered. These two parameters were found to have the greatest influence on diesel consumption. For other parameters the assumptions made are:

- field size of 5 ha;
- distance from field to farm of 2 km;
- mechanization stage of 102 kilowatts,
- conventional management including ploughing.

Even though these parameters may differ widely with respect to different regions, they were not varied in this study due to a poor data basis with regard to field sizes. In addition, the effect of some parameters on diesel consumption are contrary (e.g. large fields induce less diesel consumption on the field but also a larger distance from field to farm and thus more diesel consumption on the road). The original data are calculated by applying the KTBL-Diesel demand calculator tool[23] providing results in the unit litre Diesel per tonne of harvested crop. Background information about the applied calculation method and data can be taken from (Fröba und Funk 2004) and from the KTBL-online tool for service cost calculation (Leistungs-Kostenrechner).[24]

For each crop, the typically required work processes were considered (for work processes and crops see KTBL-Leistungs-Kostenrechner). Fuel requirements for all typically required work processes are the product of the engine power used, specific fuel consumption and working time. This calculation was done considering the mentioned field size, distance from field to farm, mechanization stage and management type, as well as times of individual operations with adjusted engine loadings and corresponding specific fuel consumption (Fröba and Funk, 2004).

For grassland cuttings, a diesel consumption of 11.6 l/t was assumed, reflecting a medium intensive grassland cultivation calculated with the KTBL-Diesel demand calculator tool.

There are no regionalised data for crop-related **electricity consumption**, such as energy for drying and storage beyond the already considered diesel consumption. The contributions of

[23] https://www.ktbl.de/webanwendungen/dieselbedarfsrechner

[24] https://www.ktbl.de/webanwendungen/leistungs-kostenrechnung-pflanzenbau

these components to the GHG balance are added by extracting data from the KTBL- Leistungs-Kostenrechner. These data are cross-checked against respective data given by (Prussi et al. 2020).

2.2.7 Consumption of seeding material

There is no “official” data source for the quantity of seeding material applied in the agriculture in Germany, and even less broken down by regional differences. Thus, data are taken from literature, mostly giving estimations and recommendation for farmers. A useful source is the website of the Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (BVL).[25]

Data for field grass and grassland is drawn from www.agrarheute.de. [26] For permanent grassland, we note that sowing is only required in the initial phase (i.e. once for long-term use) or in the case of gaps for reseeding (only on a case-by-case basis). Attributing these demands to an annual harvest will result in minor quantities, significantly lower than those of arable grass.[27] Therefore, we consider the neglect of seeding material to be justified.

2.2.8 Field emissions

Field emissions of nitrous oxide (N_2O) contribute significantly to the overall emission intensity of crops and biofuels, as previous GHG balances have shown. The data applied within this study were provided by the Thünen-Institute (TI), which compiles the nationally reported GHG emissions for the sectors Agriculture and LULUCF. TI has derived a Tier-2 approach for calculation of N_2O emissions from nitrogen inputs, i.e., country-specific and stratified N_2O emission factors, based on a meta-analysis conducted using data collected from 71 individual studies comprising 676 separate emission measurements taken at 43 locations across Germany (UBA 2024), (Vos et al. 2024), (Mathivanan et al. 2021).

In contrast to the stratified IPCC emission factors (IPCC 2019) Table 11.1), (Mathivanan et al. 2021) concluded that the national data do not support different *emission factors* of direct N_2O field emissions for synthetic and organic fertilisers. Instead, the emission factors differ between application to mineral and to organic soils. For mineral soils, the model distinguishes four environmental zones roughly representing the north-west, north-east, south-east and south-west parts of Germany. Corresponding emission factors ranged from 0.39 % to 0.88 %, with the lower values being in the north and larger values being in the south. A value of 1.011 % was derived by Mathivanan et al. (2021) as emission factor for N inputs to organic soils for the entire country. The emission factors used do not vary between crops.

In addition to the direct emissions related to the applied amount of N fertiliser, *indirect N_2O* emissions have to be considered. They comprise N_2O deriving from leached and run-off nitrate (NO_3^-)(Eysholdt et al. 2022) and from volatilized ammonia (NH_3), according to the EMEP/EEA Guidebook (European Environment Agency 2023).

The cultivation of **organic soils** as cropland and grassland with continuous drainage is a significant source of GHG in Germany. It accounts for more than 7 % of the emissions of the total

[25] https://www.bvl.bund.de/DE/Arbeitsbereiche/04_Pflanzenschutzmittel/03_Antragsteller/04_Zulassungsverfahren/03_Wirksamkeit_Anwendung/psm_wirksamk_anwend_aufw_saatgutbeh_basepage.html;

[26] https://www.agrarheute.com/sites/agrarheute.com/files/2019-03/tabelle3-mehrjaehrige-ackergras-kleegrasmischungen.pdf

[27] for reseeding, 5 to 10 kg/ha is often sufficient: Source: https://www.agrarheute.com/pflanze/gruenland/checkliste-so-saeen-gruenland-richtig-543374

German inventory.[28] (Tiemeyer et al. 2020) calculate average emission factors of 11.1 kg N_2O-N ha^{-1} yr^{-1} for cropland and 4.2 kg N_2O-N ha^{-1} yr^{-1} for grassland due to mineralisation of organic matter in drained organic soils. A map showing the distribution of organic soils in Germany (which account for 5.2% of the total area) can be found in Annex A.3. The areas of the federal states of Niedersachsen, Mecklenburg-Vorpommern and Schleswig-Holstein each have more than 10 % organic soil. Brandenburg has 9 %, the federal states Sachsen-Anhalt, Bayern, Baden-Württemberg Nordrhein-Westfalen, Bremen and Hamburg each have between 1 and 5 % on organic soils (Tegetmeyer et al. 2020).

A decisive point is how organic soil is defined. The definition according to the emissions reporting (IPCC 2013b) is wide enough for the application of the German soil classification system, representing the baseline for the purposes of national emissions reporting. Actually, the German soil classification includes a complex definition of organic soils, whose inventory has been updated recently by (Wittnebel et al. 2023).

Due to the scientific evidence of vast differences regarding N_2O emissions from the cultivation of mineral versus organic soils, for each NUTS 2 area separate values of field emissions of N_2O are used for mineral soils and for organic soils. In consequence, two different values for overall GHG emissions of crop cultivation are given for mineral and organic soils, respectively. The resulting GHG emissions of crop cultivation on organic soils are remarkably high (see Chapter 3) and the potential of GHG reduction by sourcing biomass from organic soils and using it for energy provision very limited. Considering cultivation of organic soils in a different way, e.g. by using an area-weighted, mean would neglect the differences in GHG emissions even though regional differentiation and transparency are comprehensible reasons for providing single NUTS 2 specific GHG emissions from cultivation. Moreover, information on the share of specific crop`s cultivation on organic soils in the individual NUTS 2 regions is missing, and thus the data basis is missing for weighting the mean of GHG emissions for cultivation on organic and mineral soils.

2.2.9 Background data

The emission factors for the production and provision of synthetic fertilizers, pesticides and diesel (including emissions from fuel use) are taken from Annex IX (*Standard values of emissions factors*) of the Implementing Regulation (EU) 2022/996.

In principle, emission factors from other databases are also available. For example, the LCA database ecoinvent provides factors for 44 pesticide active substances. A precise assignment of these factors to the products and active agents actually used according to JKI exceeded the capacity of this study and would also remain incomplete. The uncertainties arising from the simplified approach of selecting the emission factors from Annex IX are discussed in Chapter 4.

2.2.10 Overview of data sources

Table 1 gives an overview of the applied data sources.

Table 1: Overview of the central data sources

Data points	Source	Comment/link
Yield data	Destatis Federal Statistical Office of Germany	https://www-genesis.destatis.de/genesis/online https://www.regionalstatistik.de/genesis//online?operation=table&code=41241-01-03-

[28] https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland/emissionen-der-landnutzung-aenderung#moore-organische-boden; see also (UBA 2023)

Data points	Source	Comment/link
		4&bypass=true&levelindex=1&levelid=1707418655842#abreadcrumb
Application of fertilisers	Thünen-Institut	Data originally prepared and provided for this study
Specification of fertiliser types	Destatis	https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/Publikationen/Downloads-Fachstatistiken/duengemittelversorgung-jahr-2040820217004.html (Destatis 2022), (Destatis 2023b)
Application of pesticides	Julius Kühn-Institut	Data originally prepared and provided for this study; Background information: (Dachbrodt-Saaydeh et al. 2020)
Consumption of Diesel	KTBL	Data originally prepared and provided for this study
On-farm electricity consumption	JEC well-to-wheels v5	(Prussi et al. 2020)
Seeding material	BVL	https://www.bvl.bund.de/DE/Arbeitsbereiche/04_Pflanzenschutzmittel/03_Antragsteller/04_Zulassungsverfahren/03_Wirksamkeit_Anwendung/psm_wirksamk_anwend_aufw_saatgutbeh_basepage.html; for field grass:_ https://www.agrarheute.com/sites/agrarheute.com/files/2019-03/tabelle3-mehrjaehrige-ackergras-kleegrasmischungen.pdf
Field emissions (N_2O)	Thünen-Institut	Data originally prepared and provided for this study; Background information: (Fuß et al. 2023), (Eysholdt et al. 2022), (Mathivanan et al. 2021), (Tiemeyer et al. 2020)
Background data	Commission Implementing Regulation (EU) 2022/996	Annex IX: STANDARD VALUES OF EMISSIONS FACTORS

Compilation by ifeu

2.3 Judgement of data quality, uncertainties and gaps

While various limiting factors have already been mentioned above, these are systematically summarised again in this section. Table 2 provides an overview.

As a general limitation has to be stated, that the data do not allow to distinguish between crops produced for food or feed and for biofuel production. There is a certain probability that in practice there are differences concerning yield or crop quality on the one hand and the type of utilisation on the other. However, the data basis for such possible differences is lacking. They can therefore not be taken into account here.

Since different sources - those with the respective key competence - were used for each of the necessary input data, unfortunately it is in the nature of things that the individual data - yields, fertiliser application, pesticide and machine use - are not exactly aligned with each other. Unlike in an overall model, in which fertiliser application and yield are in a direct functional relationship, different sources are combined here. In particular, the yield data from "real" surveys contain natural disturbance effects (e.g. dry years with poor harvests) that do not match the data on fertilisation. However, this is part of the "reality" of the calculations. These uncertainties are mitigated by the 5-year averaging (see also chapter 0).

However, it must already be stated here that this described incongruence for grassland cut leads to differences between NUTS 2 regions that can no longer be considered plausible. For this reason, only a national average value is generated for this biomass instead of the regionalised values.

Table 2: Overview of data quality, uncertainties and gaps

Data points	Time frame	Type of source	Relia-bility[29]	Limitations	Gaps
Yield data	Average of years 2018 -2022	Official source, national and regional statistics	High	Only NUTS 1 level for field grass and grassland cuttings. Conversion from fresh matter to dry matter by standard factors.	No data for the federal city states (Berlin, Hamburg, Bremen)
Application of fertilisers	Average of years 2018 -2022	Normative demand, model based calculation	Medium to high	No empirical data available on fertilisation or soil nutrient levels No regionalised data for lime application Data for grassland adapted in order to prevent over- and underestimations (see chapter 2.2.2)	
Specification of fertiliser types	Average of financial years 2017/18 -2021/22	Official source, national and regional statistics, rely on market data	Medium	Data only NUTS 1 level, no information on really applied fertilisers	Not all fertiliser types covered
Application of pesticides	Average of years 2018 -2022	Data from BMEL-JKI project „Netz Vergleichsbetriebe Pflanzenschutz“	Medium to high	Attribution to NUTS2 only by estimation. Compilation of active agent also by rough estimation.	No data for rye and triticale; assumption: average from wheat and barley
Consumption of seeding material	Not specified	literature	Medium to high	No regional distinctions	

[29] Assessment by the authors of this report

Data points	Time frame	Type of source	Relia-bility[29]	Limitations	Gaps
Consumption of Diesel	Average of years 2017 -2021	Model based	Medium to high	Focus on soil type; machinery and field sizes equal for all regions.	
On-farm electricity consumption	Not specified	Model based	medium	No regional distinctions	
Field emissions (N_2O)	Average of years 2018 -2022	Model based, official data for national inventory reporting.	Medium to high	Tier 2 approach	
Background data		Official standard emission factors by the EU for RED-related GHG calculations	medium	Other sources may provide more specific values	

Compilation by ifeu

2.4 Compilation of the components

The NUTS 2 emission values are displayed in g CO_2eq per kg product (dry matter). The total sum of each (E_{ec}) adds the single components of fertiliser provision and application ($E_{fertiliser}$), emissions from fertiliser acidification and liming application ($E_{neutralisation}$), pesticide provision and application ($E_{pesticides}$), diesel provision and use (E_{diesel}), Electricity for drying and processing the harvested crops or grass on farm ($E_{on\text{-}farm\ electricity}$), provision of seeding material ($E_{seeding\ material}$) and the N_2O field emission on mineral soils ($E_{field\ em.\ min.\ soil}$):

$$E_{ec} = E_{fertiliser} + E_{neutralisation} + E_{pesticides} + E_{diesel} + E_{on\text{-}farm\ electricity} + E_{seeding\ material} + E_{field\ em.\ min.\ soil}$$

The N_2O emissions from drained cropland and grassland on organic soils ($E_{field\ em.\ organic\ soil}$) is reported separately for the sake of transparency.

2.4.1 Calculation of the emissions due to fertiliser input:

For mineral fertiliser the emission from production and provision to the farm are calculated for each crop and each NUTS 2 area. For the input of organic fertiliser (manure etc.) no emissions are accounted since this input is recognised as a residue whose emissions beyond the point of collection are ignored according to the rules of the RED. Spreading of manure is covered by the data on diesel consumption and field emissions from its application are included in chapter 2.4.7. Thus, the calculation of the emissions due to fertiliser input proceeds as follows:

$$E_{fertilizer} = \Sigma\ (m_{fertiliser\ i} \bullet EF_{fertiliser\ i})$$

Where:

$m_{fertiliser\ i}$ = amount of fertiliser type I [kg · kg crop d.m.$^{-1}$]

$EF_{fertiliser\ I}$ = emission factor of the production of fertiliser type I [g CO_2eq · kg fertiliser i^{-1}]

$$m_{fertiliser\ i} = m_{a\ fertiliser\ i}\ /\ (YIELD \bullet 0.1 \bullet DRY \cdot loss)$$

Where:

$m_{a\ fertiliser\ I}$ = area-related amount of fertiliser type I [kg · ha^{-1} · a^{-1}]

YIELD = crop yield, fresh matter [dt · ha^{-1} · a^{-1}]

DRY = dry matter [kg d.m. · kg fresh $matter^{-1}$]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg $d.m^{-1}$]

2.4.2 Calculation of emissions due to neutralisation of fertiliser acidification and liming application:

For each crop and each NUTS 2 area it is calculated:

$$E_{neutralisation} = (m_{N\text{-}fertiliser\ non\ urea} \bullet EF_{acidification\ non\text{-}urea\ N} + m_{N\text{-}urea} \bullet EF_{acidification\ urea\ N}) / (YIELD \bullet 0.1 \bullet DRY \bullet loss)$$

Where:

$m_{N\text{-}fertiliser\ non\ urea\ N}$ = amount of applied N fertiliser apart from urea fertiliser [kg · (kg crop d.m.) $^{-1}$]

$m_{N\text{-}fertiliser\ N\text{-}urea}$ = amount of applied N from urea fertiliser [kg · (kg crop d.m.) $^{-1}$]

$EF_{acidification\ non\text{-}urea\ N}$ = 0,783 kg CO_2eq · kg^{-1} N

$EF_{acidification\ urea\ N}$ = 0,806 kg CO_2eq · kg^{-1} N

YIELD = crop yield, fresh matter [dt · ha^{-1} · a^{-1}]

DRY = dry matter [kg d.m. · kg fresh $matter^{-1}$]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg $d.m^{-1}$]

In addition, soil emissions from liming (CO_2 from applied $CaCO_3$) when applied on acidic soil are calculated and added with the amount that exceeds the emission through $E_{neutralisation}$:

$$E_{surplus\ aglime} = (m_{aglime} \bullet EF_{aglime}) - E_{neutralisation}$$

Where:

m_{aglime} = amount of applied lime (as $CaCO_3$) [kg · (kg crop d.m.) $^{-1}$]

EF_{aglime} = 0,44 kg CO_2eq · kg^{-1} $CaCO_3$ (Conservatively, the E-factor is attributed to acidic soils, as it can be assumed that liming is preferably carried out on acidic soils)

If the value for the emission due to neutralisation ($E_{neutralisation}$) is higher than the emission from liming, the surplus ($E_{surplus\ aglime}$) is set to zero.

2.4.3 Calculation of the emissions due to pesticide input:

For each crop and each NUTS 2 area it is calculated:

$$E_{pesticides} = \Sigma\ (m_{pesticide\_agent\ i} \bullet EF_{pesticide\_agent\ i})$$

Where:

$m_{pesticide\ agent\ i}$ = amount of pesticide active agent i [kg · kg crop d.m. $^{-1}$]

$EF_{pesticide\ agent\ i}$ = emission factor of the production of pesticide active agent i [g CO_2eq · kg $agent^{-1}$]

$$m_{pesticide\ agent\ i} = m_{a\ pesticide\ agent} / (YIELD \bullet 0.1 \bullet DRY \bullet loss)$$

Where:

$m_{a\ pesticide\ agent\ i}$ = area-related amount of pesticide active agent i [kg · ha^{-1} · a^{-1}]

YIELD = crop yield, fresh matter [dt · ha^{-1} · a^{-1}]

DRY = dry matter [kg d.m. · kg fresh matter^{-1}]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg d.m^{-1}]

2.4.4 Calculation of the emissions due to diesel provision and use:

For each crop and each NUTS 2 area it is calculated:

$$E_{diesel} = (m_{diesel} \bullet EF_{diesel}) / (DRY \bullet loss)$$

Where:

m_{diesel} = amount of diesel [kg · (kg crop d.m.)$^{-1}$]

EF_{diesel} = emission factor of diesel (use and upstream emissions) [g CO_2eq · (kg diesel)$^{-1}$]

DRY = dry matter [kg d.m. · kg fresh matter^{-1}]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg d.m^{-1}]

2.4.5 Calculation of the emissions due to electricity use for drying and processing the harvested crops or grass on farm:

For each crop and each NUTS 2 area it is calculated:

$$E_{on\text{-}farm\ electrity} = (m_{on\text{-}farm\ electrity} \bullet EF_{electricity}) / (DRY \bullet loss)$$

Where:

$m_{on\text{-}farm\ electrity}$ = amount of electricity on farm [MJ · (kg crop d.m.)$^{-1}$]

$EF_{electricity}$ = emission factor of electricity (Germany) [g CO_2eq · (MJ electricity)$^{-1}$][30]

DRY = dry matter [kg d.m. · kg fresh matter^{-1}]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg d.m^{-1}]

2.4.6 Calculation of the emissions due to provision of seeding material:

For each crop and each NUTS 2 area it is calculated:

$$E_{seeding\ material} = (m_{seeding\ material} \bullet EF_{seeding\ material}) / (DRY \bullet loss)$$

Where:

$m_{seeding\ material}$ = amount of seeding material [kg · (kg crop d.m.)$^{-1}$]

$EF_{seeding\ material}$ = emission factor of seeding material [g CO_2eq · kg^{-1}]

DRY = dry matter [kg d.m. · kg fresh matter^{-1}]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg d.m^{-1}]

[30] emission factor of electricity in Germany (398,0 g CO_2eq/MJ) is taken from the Implementation Regulation (EU) 2022/996, annex IX

2.4.7 Calculation of the field emissions (N_2O) on mineral soils:

In line with the Implementation Regulation (EU) 2022/996, annex VII, point 1.5, direct and indirect N_2O emissions are taken into account following the IPCC methodology on a tier 2 level.

For each crop and each NUTS 2 area it is calculated:

$$E_{\text{field em. min. soil}} = (E_{N_2O\ \text{direct}} + E_{N_2O\ \text{indirect}}) / (DRY \bullet loss) \bullet GWP_{N_2O}$$

Where:

$E_{N_2O\ \text{direct}}$ = direct annual N_2O emissions produced from managed soils; [kg $N_2O \cdot ha^{-1}\ a^{-1}$]

Calculated as: $[(F_{SN} + F_{ON} + F_{CR}) \bullet EF_{1ij} + EF_{OS}] \bullet 44/28$

With:

F_{SN} = annual synthetic nitrogen fertiliser input (see 2.2.2); kg $N \cdot ha^{-1}\ a^{-1}$

F_{ON} = annual animal manure N applied as fertiliser (see 2.2.2); kg $N \cdot ha^{-1}\ a^{-1}$

F_{CR} = annual amount of N in crop residues (above + below ground); kg $N \cdot ha^{-1}\ a^{-1}$
Remark: The N input from crop residues is calculated according to IPCC Vol. 4 chapter 11, table 11.6; crop specific values are given in annex C.2

EF_{1ij} = Crop and site-specific emission factors for N_2O emissions from synthetic fertiliser and organic N application (including crop residues) to mineral soils (kg $N_2O–N \cdot$ (kg N input)$^{-1}$)

EF_{OS} = emission factor for direct annual N_2O emissions due to mineralization of soil organic matter if cultivation is on drained organic soils, differentiated between cropland and grassland; [kg N_2O-$N \cdot ha^{-1}\ a^{-1}$]

And:

$E_{N_2O\ \text{indirect}}$ = annual indirect N_2O emissions (that is to say, the annual amount of N_2O produced from atmospheric deposition of N volatilised from managed soils and annual amount of N_2O produced in waterbodies from leaching and run-off of N additions to managed soils in regions where leaching/run-off occurs); [kg $N_2O \cdot h^{-1}\ a^{-1}$]
Calculated by: $[N_2O_{ATD}\text{-}N + N_2O_L\text{-}N] \bullet 44/28$

Where:

N_2O_{ATD}-N = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils;
Calculated by : $[(F_{SN} \bullet Frac_{GASF}) + ((F_{ON}+F_{PRP}) \bullet Frac_{GASM})] \bullet EF_4$

N_2O_L-N = annual amount of N_2O–N produced from leaching and run-off of N additions to managed soils in regions where leaching/run-off occurs
Calculated by : $[(F_{SN} + F_{ON} + F_{CR}) \bullet Frac_{LEACH-(H)})] \bullet EF_5$

Where:

F_{SN} = annual synthetic nitrogen fertiliser input (see 2.2.2); kg $N \cdot ha^{-1}\ a^{-1}$

F_{ON} = annual animal manure N applied as fertiliser (see 2.2.2); kg N $ha^{-1} \cdot a^{-1}$

F_{CR} = annual amount of N in crop residues (above ground + ground); kg N $ha^{-1} \cdot a^{-1}$
Remark: The input data provided by Thünen-Institut (see 2.2.8) aggregate the nitrogen fertiliser input factors F_{ON} and F_{CR} *reflecting regional data*

$Frac_{GASF}$ = fraction of synthetic nitrogen fertiliser N that volatilises as NH_3 or NOx, according to EMEP (2023), depending on fertilizer mix, kg N of N applied.

$Frac_{GASM}$ = volatilized fraction of applied organic N fertiliser materials, values for NH_3 were derived as mean of the years 2018-2022 from national inventory, which calculates NH_3 emissions with a Tier-2 approach, values for NO are according to EMEP (2023), (kg N of N applied)

$Frac_{LEACH-(H)}$ = Fractions of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, calculated regionally with a Tier-3 approach, Eysholdt (2022), mean over years 2018-2023 was used; kg N · (kg N additions) $^{-1}$
Remark: The last three input data are provided by Thünen-Institut (see 2.2.8) reflecting regional data

EF_4 = emission factor for N_2O emissions from atmospheric deposition of N; kg N_2O-N (kg NH_3-N + kg NO_x-N)$^{-1;}$

EF_5 = Emission factor for N_2O emissions from N leaching and runoff (kg N leached and runoff)$^{-1}$
Remark: EF_4 (0,01) and EF_5 (0,011) were taken from (IPCC 2019)

And:

DRY = dry matter [kg d.m. · kg fresh matter^{-1}]

Loss = loss of dry matter due to digestion (for biogas production) [kg d.m. · kg d.m^{-1}]

GWP_{N_2O} Global warming potential (100 years) [kg CO_2eq · kg N_2O $^{-1}$]

2.4.8 Calculation of the field emissions (N_2O) on organic soils:

The emissions from drained cropland and grassland on organic soils are calculated following this formula:

$$E_{field\ emission\_org\_soil} = [(F_{SN} + F_{ON}) \bullet EF_1] + [F_{CR} \bullet E_{F1}] + [(F_{OS,CG,Temp} \bullet EF_{2CG,\ Temp}]$$

Where:

F_{SN} = annual synthetic nitrogen fertiliser input; kg N ha^{-1} a^{-1}

F_{ON} = annual animal manure N applied as fertiliser; kg N ha^{-1} a^{-1}

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

$F_{OS,CG,Temp}$ = annual area of managed/drained organic soils under cropland in temperate climate; ha^{-1} a^{-1}

EF_1 = 0,011 [kg N_2O–N (kg N input) $^{-1}$]

$EF_{2CG,Temp}$ = Tier 1 factor: 8 kg N ha^{-1} a^{-1} for temperate organic crop and grassland soils
for Tier 2: regional data from Thünen-Institut (see section 2.2.8)

3 Results

Comprehensive result tables can be found in Annex B (Table 6 and **Fehler! Verweisquelle konnte nicht gefunden werden.**). The following section 3.1 gives an illustrative overview of the results crop by crop, with regard to cultivation on mineral soils. The results refer to dry mass of crops. Section 3.2 gives on overview on the results, assuming cultivation on organic soils. In section 3.3 finally the respective energy-related values referring to the final biofuels are given.

3.1 GHG emissions referring to dry mass of crops – mineral soils

3.1.1 Wheat (grains)

As shown in Figure 4, the GHG emissions range from 228 to 343 g CO_2eq/kg wheat grains (dry matter) with the lowest value calculated for the Braunschweig area and the highest for Saarland. The German average is 275 g CO_2eq/kg wheat grains (dry matter).

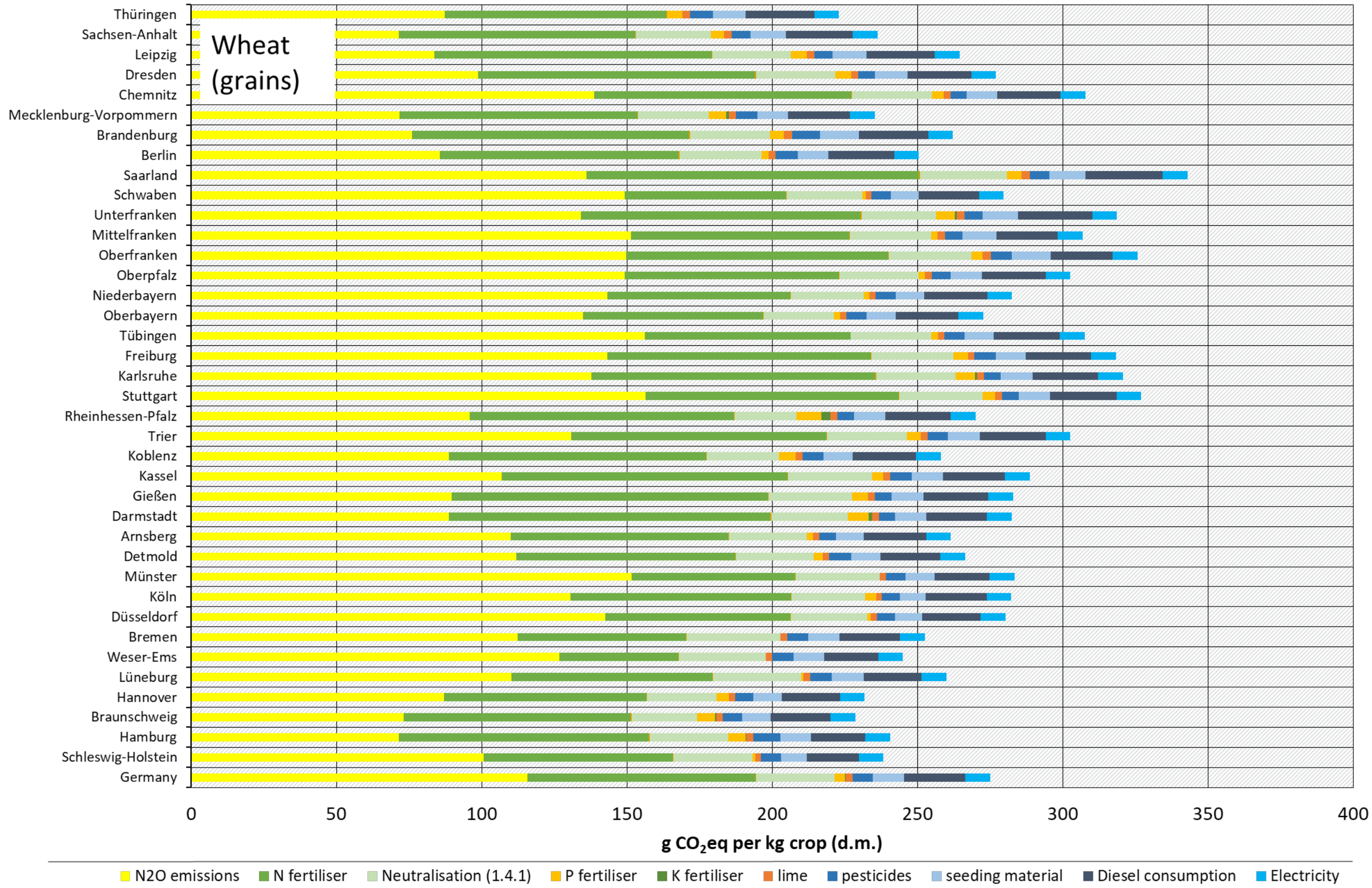
The major reason for the wide range is the emissions of N_2O, which are subject to strong regional differences due to varying N_2O emission factors and N-application rates. On average across Germany, they account for around 42 % of total emissions from wheat cultivation. In Weser-Ems and Münster, their contribution is as high as 53 %, in Brandenburg only 29 %.

Two different parameters determine the level of N_2O emissions for a region: firstly, the respective emission factor for direct N_2O emissions, which varies by a factor of more than two, and secondly, the amount of N fertiliser used in the calculation of these direct emissions. In relation to one dt of harvested wheat, the use of fertiliser varies by a factor of 1.75. Bremen and the regions of Lüneburg and Weser-Ems describe the lower end, while Rheinhessen, Braunschweig and Thüringen produce the highest yields per fertiliser used. These relations also tend to apply to most other crops.

The second most important component of the overall GHG emissions from crop cultivation is emissions from the production of synthetic nitrogen fertilisers. Their contribution to the German average of wheat cultivation emissions is 29 %. In Darmstadt and Gießen, they account for 39 %, which is due to the fact that the proportion of manure is comparatively low here. In Weser-Ems, on the other hand, with a very high use of manure, the contribution of emissions from the production of synthetic nitrogen fertilisers is 17 %.

The case of Weser-Ems also shows that this aspect can dominate the result. The poor yield efficiency in this region in relation to fertiliser use described above is overcompensated for by the high share of manure, which is free from upstream emissions. In Box 1 we discuss why this is to be seen as a systematic weakness of the GHG calculation according to RED II.

Figure 4: GHG emissions from cultivation of wheat (grains) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

The contributions of the other components – at least in absolute figures – do not show such broad ranges. The German averages for these contributions are:

- 9.8 % for neutralisation[31] (in the case of wheat with relatively high input of N fertiliser, these emissions exceed the calculated CO_2 emissions from lime application[32] in all NUTS2 regions, even though using the maximum emission factor of 0.44 kg CO_2/kg $CaCO_3$; for this reason, no contribution from the 'surplus from aglime' component appears in Figure 4).
- 7.7 % for diesel consumption,
- 3.9 % for seeding material,
- 3.1 % for on-farm electricity consumption,
- 2.6 % from pesticides and
- 2.3 % In total from production and provision of other fertilisers including lime.

3.1.2 Rye (grains)

As shown in Figure 5, the results range from 205 to 316 g CO_2eq/kg rye grains (dry matter). The lowest emissions were calculated for Thüringen, the highest for the Stuttgart area. The German average is 264 g CO_2eq/kg rye grains (dry matter).

As for wheat as well as for this and the other crops, the major reason for the wide range is subject to the strong regional differences regarding the emissions of N_2O – contributing to total GHG emissions from rye cultivation with 43 % on German average. NUTS 2 regions where manure takes high shares for N fertilisation the relative contribution by N_2O emissions is higher, whereas for regions with low manure application more synthetic fertiliser is needed, which shifts the balance from the emission contribution from N_2O to synthetic fertilisers. The latter is about 22 % for rye on average in Germany.

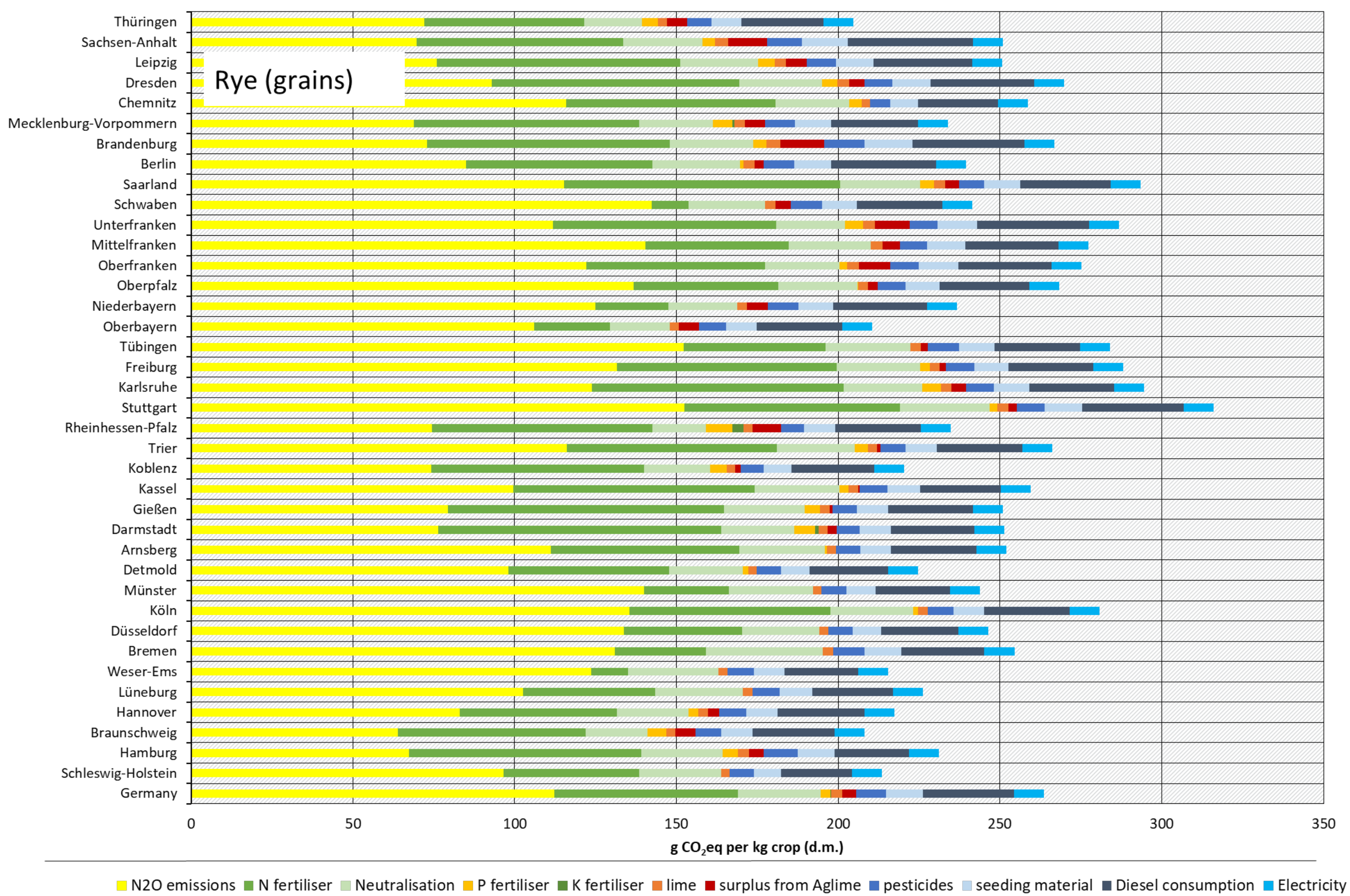
In contrast to wheat, less N fertiliser is applied to rye in relation to the harvest. For this reason, in many NUTS2 regions a surplus of CO_2 emissions from the lime applied is calculated compared to the emissions from acidification and neutralisation of the N fertiliser (shown in dark red for "surplus from aglime" in Figure 5). These additional amounts are to be added to the neutralisation. The highest value for the sum of neutralisation is 39 g CO_2eq/kg rye grains (dry matter) in Brandenburg and the lowest value is 22 g CO_2eq/kg rye grains (dry matter) in Koblenz. At 36 g CO_2eq/kg, the German average accounts for 10% of total emissions.

The contributions of the other components – at least in absolute figures – do not show such broad ranges. The German averages for the other components are 11 % for diesel consumption, 4.3 % for seeding material, 3.5 % for on-farm electricity consumption as well for pesticides and 2.4 % in total from production and provision of other fertilisers including lime.

[31] According to Implementing Regulation (EU) 2022/996, Annex VII No. 1.4.1

[32] According to Implementing Regulation (EU) 2022/996, Annex VII No. 1.4.2

Figure 5: GHG emissions from cultivation of rye (grains) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

3.1.3 Maize (grains)

As shown in Figure 6, the results range from 154 to 232 g CO_2eq/kg maize grains (dry matter). The lowest value refers to Thüringen, the highest to Saarland. The German average is 179 g CO_2eq/kg maize grains (dry matter).

The overall picture corresponds widely to the results for wheat grains, just with lower specific emissions due to lower fertilisation intensity. On German average the emissions of N_2O take 41.3 % of the total emission share. Emissions due to production of synthetic N-fertilisers contribute 25.3 % for maize grains.

The German averages for the other components are 9.5 % from neutralisation (including “surplus from aglime”), 9.9 % for diesel consumption, 8.1 % for on-farm electricity (demand relatively high due to purification requirements), 1.8 % from pesticides, 0,9 % for seeding material and 3.1 % in total from production and provision of other fertilisers including lime.

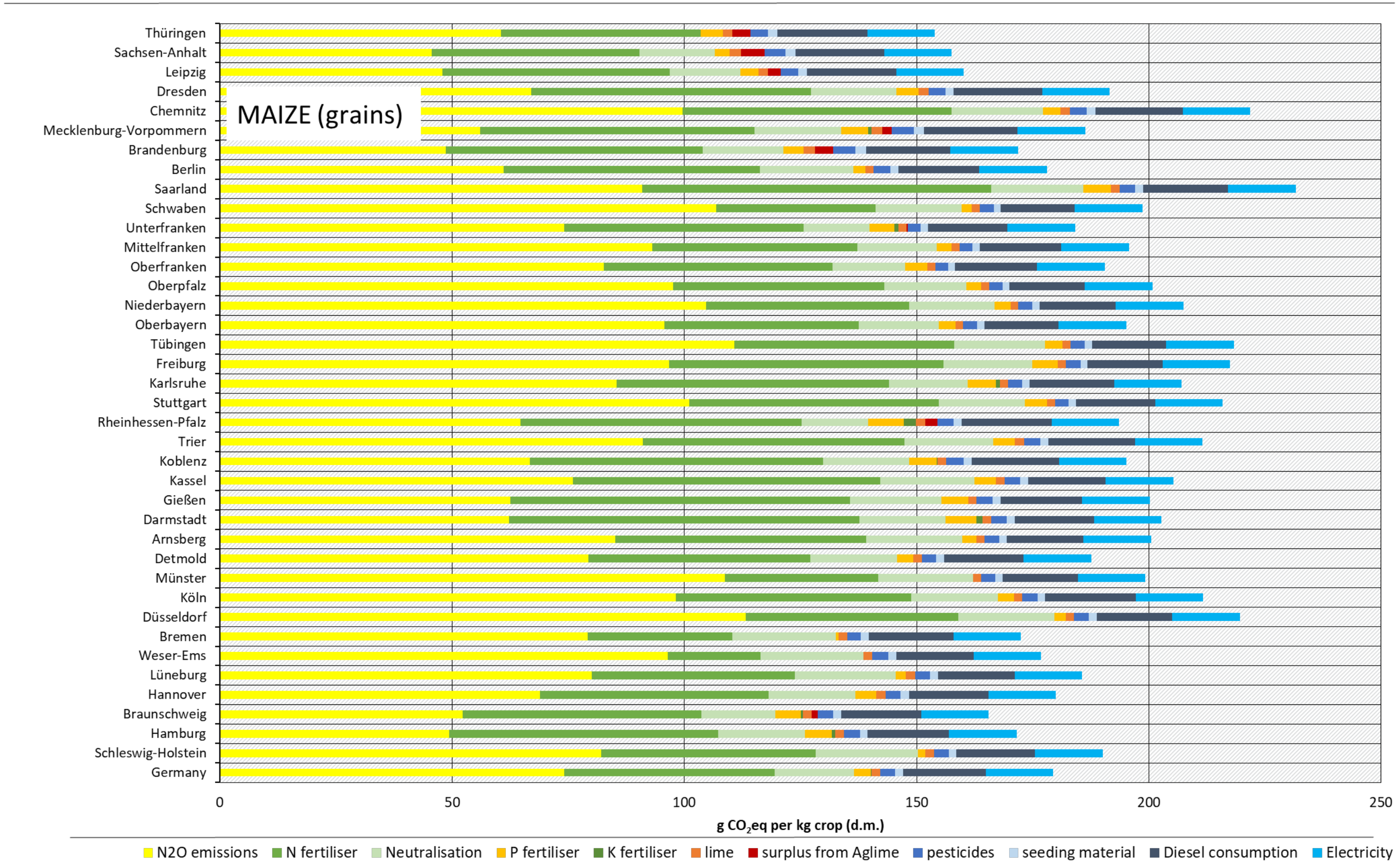
3.1.4 Barley (grains)

As shown in Figure 7, the results range from 188 to 287 g CO_2eq/kg barley grains (dry matter). The lowest value refers to Braunschweig, the highest to Saarland. The German average is 224 g CO_2eq/kg barley grains (dry matter).

The overall picture corresponds widely to the results for wheat grains, just with lower specific emissions due to lower fertilisation intensity. On German average the emissions of N_2O take 41.9 % of the total emission share. Synthetic N-fertilisers contribute 24.2 % for barley grains.

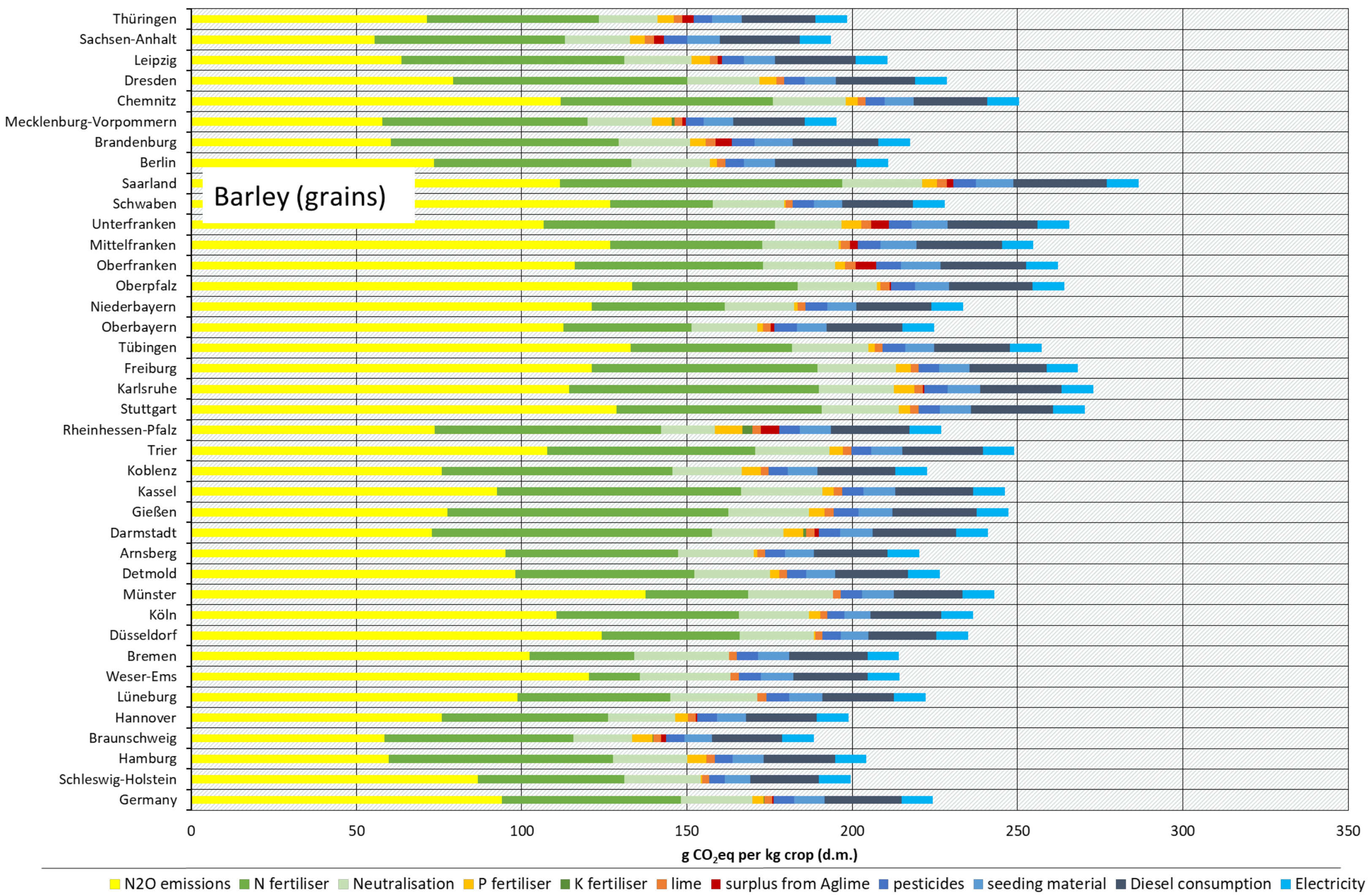
The German averages for the other components are 9.7 % from neutralisation (including “surplus from aglime”), 10.3 % for diesel consumption, 4.3 % for on-farm electricity consumption, 4,3 % for seeding material, 2.8 % from pesticides and 2.7 % in total from production and provision of other fertilisers including lime.

Figure 6: GHG emissions from cultivation of maize (grains) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

Figure 7: GHG emissions from cultivation of barley (grains) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

3.1.5 Triticale (grains)

As shown in Figure 8, the results range from 225 to 311 g CO_2eq/kg triticale grains (dry matter). The lowest value refers to Braunschweig, the highest to Saarland. The German average is 264 g CO_2eq/kg triticale grains (dry matter).

Again, the overall picture corresponds widely to the results for wheat grains, just with lower specific emissions due to lower fertilisation intensity. On German average the emissions of N_2O take 42.7 % of the total emission share. Synthetic N-fertilisers contribute 24.8 % for triticale grains.

The German averages for the other components are 9.8 % from neutralisation (including "surplus from aglime"), 10.3 % for diesel consumption, 3,6 % for seeding material, 3.4 % for on-farm electricity consumption, 3.1 % from pesticides and 2.2 % in total from production and provision of other fertilisers including lime.

3.1.6 Sugar beet

As shown in Figure 9, the results range from 68.4 to 102 g CO_2eq/kg sugar beet grains (dry matter). The lowest value refers to Mecklenburg-Vorpommern, the highest to the Karlsruhe area. The German average is 84.1 g CO_2eq/kg sugar beet (dry matter).

Also, for sugar beet, the overall picture corresponds widely to the results for the cereals. The range is mostly caused by regional differences in N_2O emissions. On German average they take 41,1 % of the total emission. Emissions due to production of synthetic N-fertilisers contribute 24.3 % to overall emissions from sugar beet cultivation. Emissions from neutralisation (including "surplus from aglime") contribute 9.5 %.

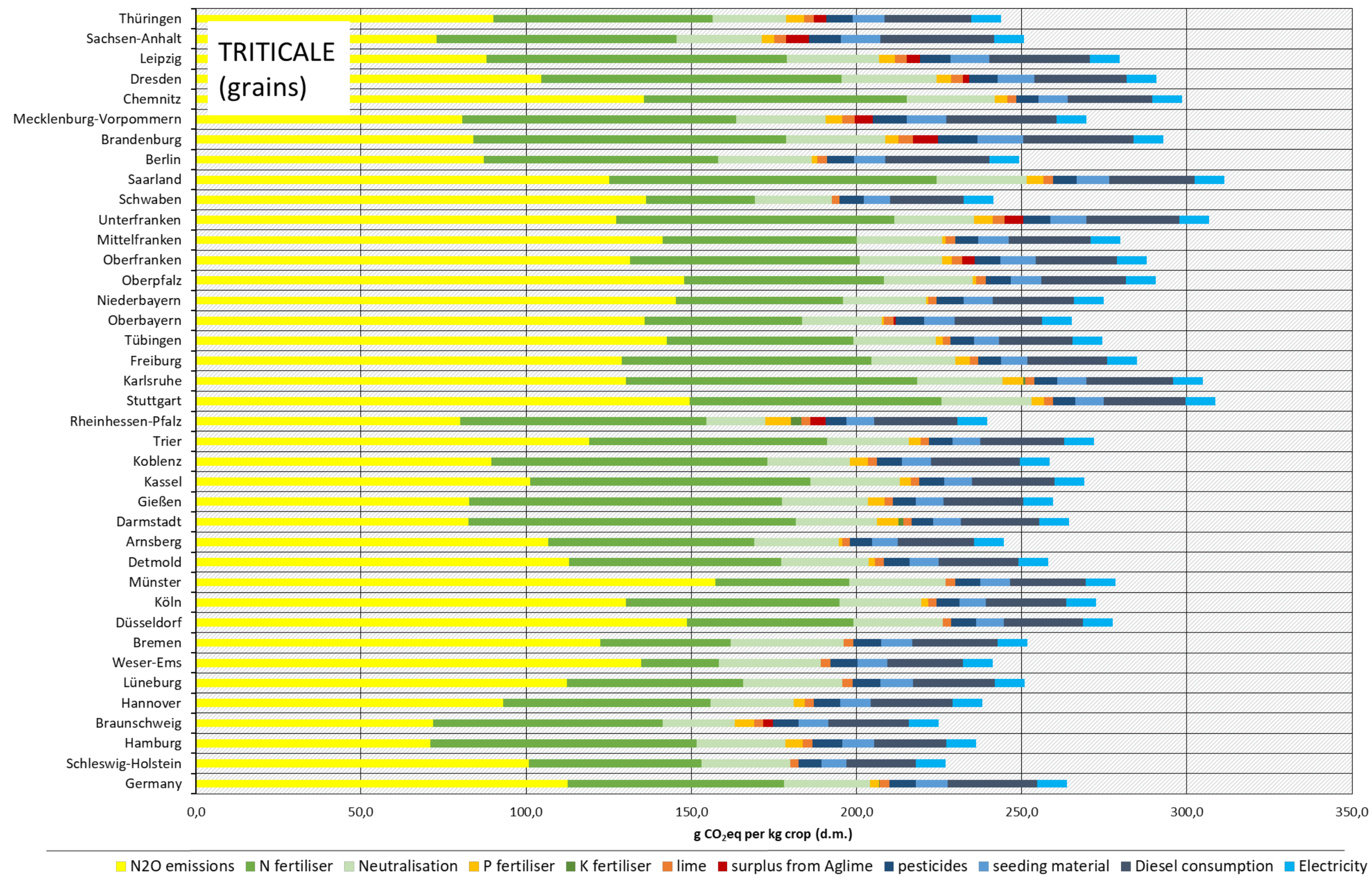
Unlike most of the other crops, sugar beet requires fertilizing with potassium, which contributes 4.5 % to the total emissions. Also, diesel consumption ranges slightly higher than for other crops, contributing 10.8 %. This is also true for pesticides with 4.6 % and P-fertilizer with 2.5 %. On the other side, emissions from seeding material only contribute by 1 % and emissions from electricity consumption is near to negligible.

3.1.7 Rapeseed

As shown in Figure 10, the results range from 362 to 531 g CO_2eq/kg rapeseed (dry matter). The lowest value refers to Sachsen-Anhalt, the highest to Saarland. The German average is 430 g CO_2eq/kg rapeseed (dry matter).

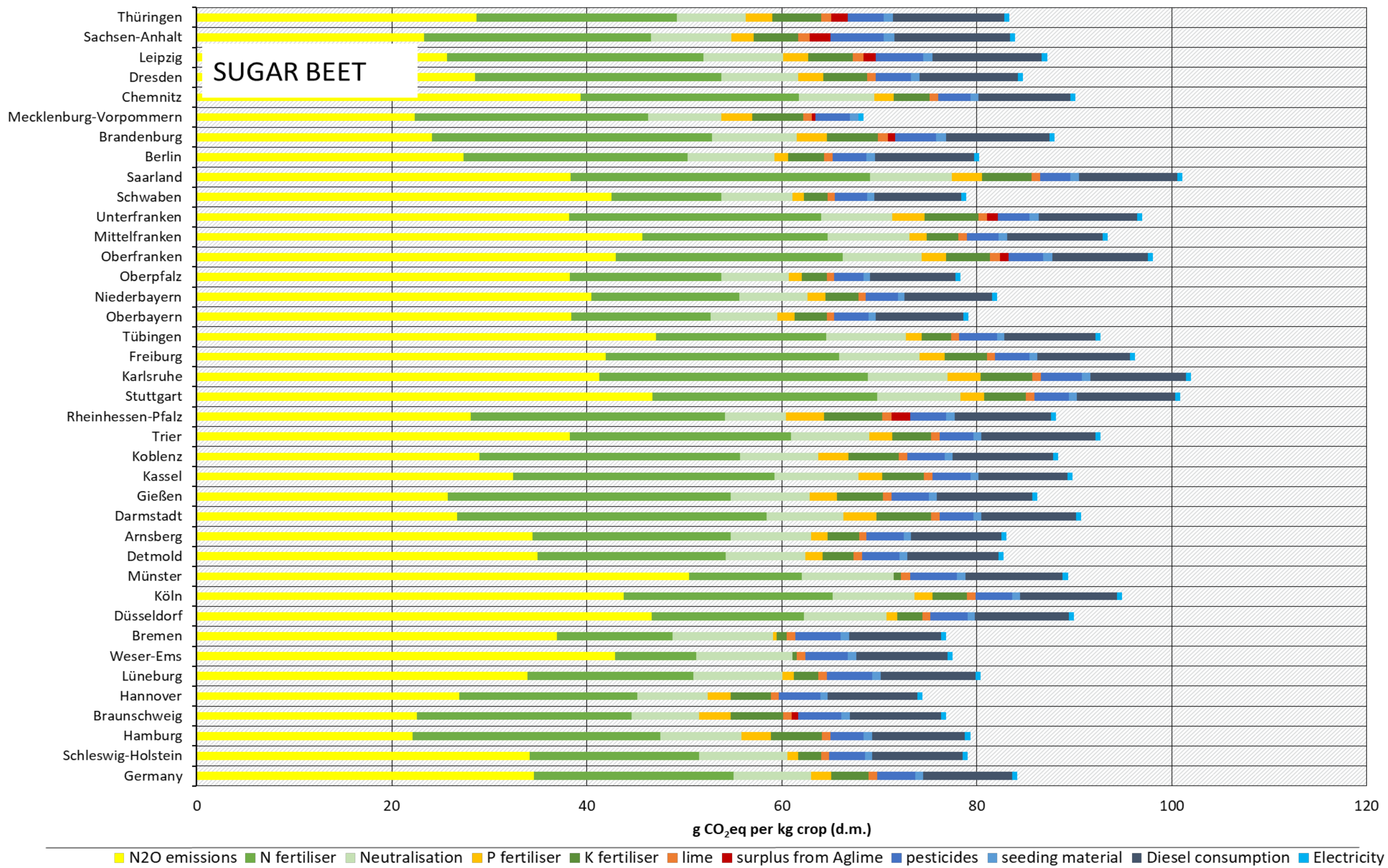
Also, for rapeseed, the overall picture corresponds widely to the results for the cereals. The range is mostly caused by regional differences in N_2O emissions. On German average they take 44 % of the total emission share. Emissions due to production of synthetic N-fertilisers contribute 26.7 % for rapeseed. Emissions from neutralisation (including "surplus from aglime") contribute 10.1 %. Diesel consumption contributes 10.0 %, pesticides with 3.5 %, emissions from electricity consumption 2.1 % and production and provision of other fertilizers including lime and seeding material sum up to 3.5 %.

Figure 8: GHG emissions from cultivation of triticale (grains) on mineral soils, per NUTS2 region and system component



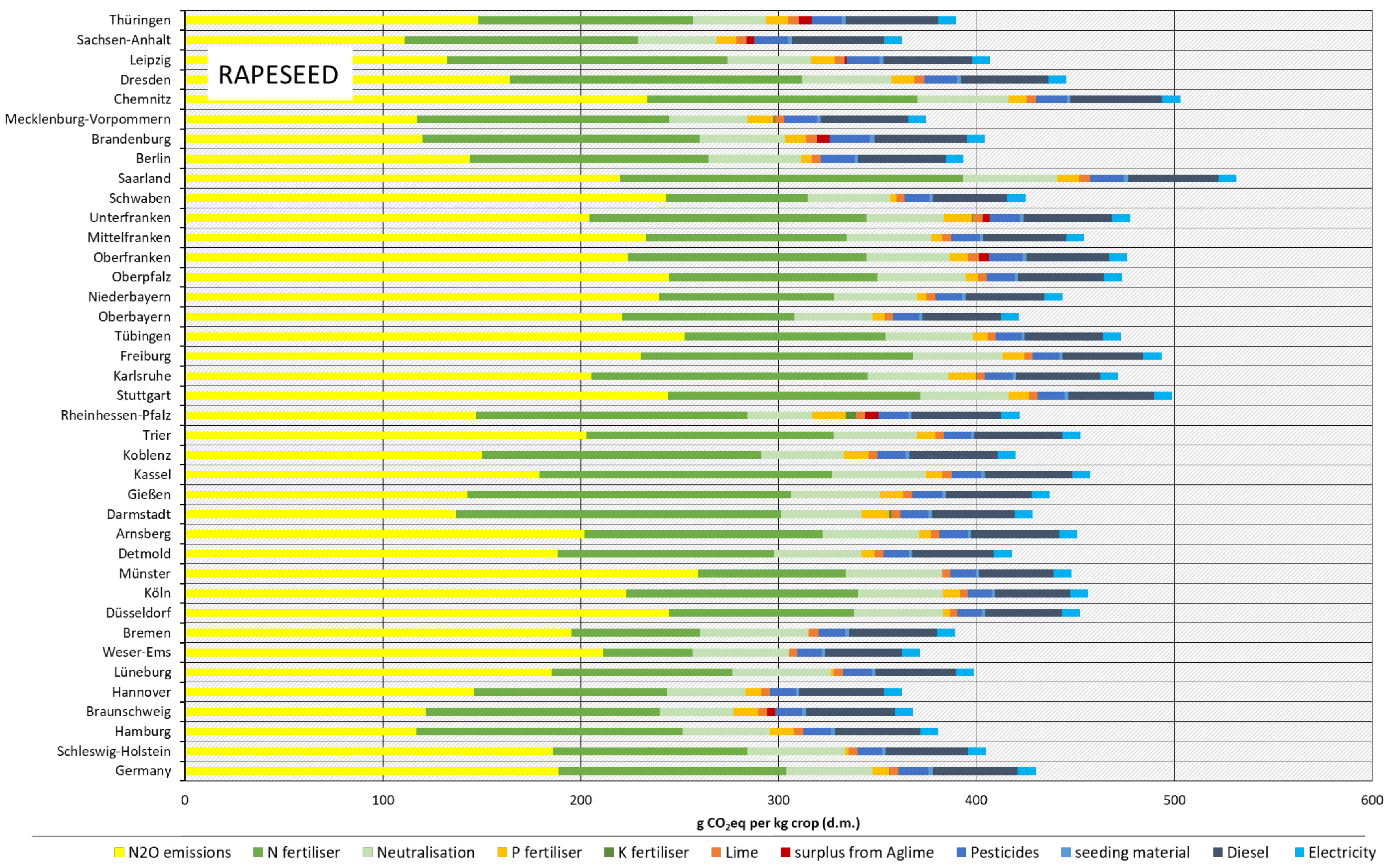
Calculation and illustration by ifeu

Figure 9: GHG emissions from cultivation of sugar beet on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

Figure 10: GHG emissions from cultivation of rapeseed on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

3.1.8 Maize (whole plant)

As shown in Figure 11, the results range from 96.3 to 154.5 g CO_2eq/kg ensiled maize (dry matter). The lowest value refers to Braunschweig, the highest to Saarland. The German average is 112 g CO_2eq/kg ensiled maize (dry matter).

The differences in N_2O emissions – though still being the major aspect for large region al ranges – are a bit less dominant. On German average they take 37.7 % of the total emission share. Synthetic N-fertilisers contribute 26.4 %. Emissions from neutralisation (including "surplus from aglime") contribute 8.9 %. Diesel consumption contributes to a relatively high share of 14.3 %, since processing of the harvested maize plant, chopping and ensiling is included.

Similar to sugar beet, maize whole plant requires an increased amount of potassium fertiliser, contributing 5.7 % to the total emissions. The production and provision of the needed phosphorous and lime adds a further 3.1 % to the emission. Pesticide application results in 1.9 % contribution to the total emission. Emissions from electricity consumption makes 1.0 %, from seeding material 0.9 %.

As for many other crops, the value for Saarland is the highest. However, Figure 11 illustrates the clear distance. One reason for this is the overall high proportion of synthetic N fertiliser and minimal proportion of organic N fertiliser. On the other hand, however, the sales statistics for fertiliser types for Saarland show a high proportion of synthetic N fertiliser types with comparatively high GHG emission factors. For example, almost no urea is used in Saarland, but a high proportion of calcium ammonium nitrate.

3.1.9 Wheat (whole plant)

For wheat whole plant the results range from 153 to 272 g CO_2eq/kg ensiled wheat (dry matter), as shown in Figure 12. The lowest value refers to Braunschweig, the highest to Brandenburg. The German average is 202 g CO_2eq/kg ensiled wheat (dry matter).

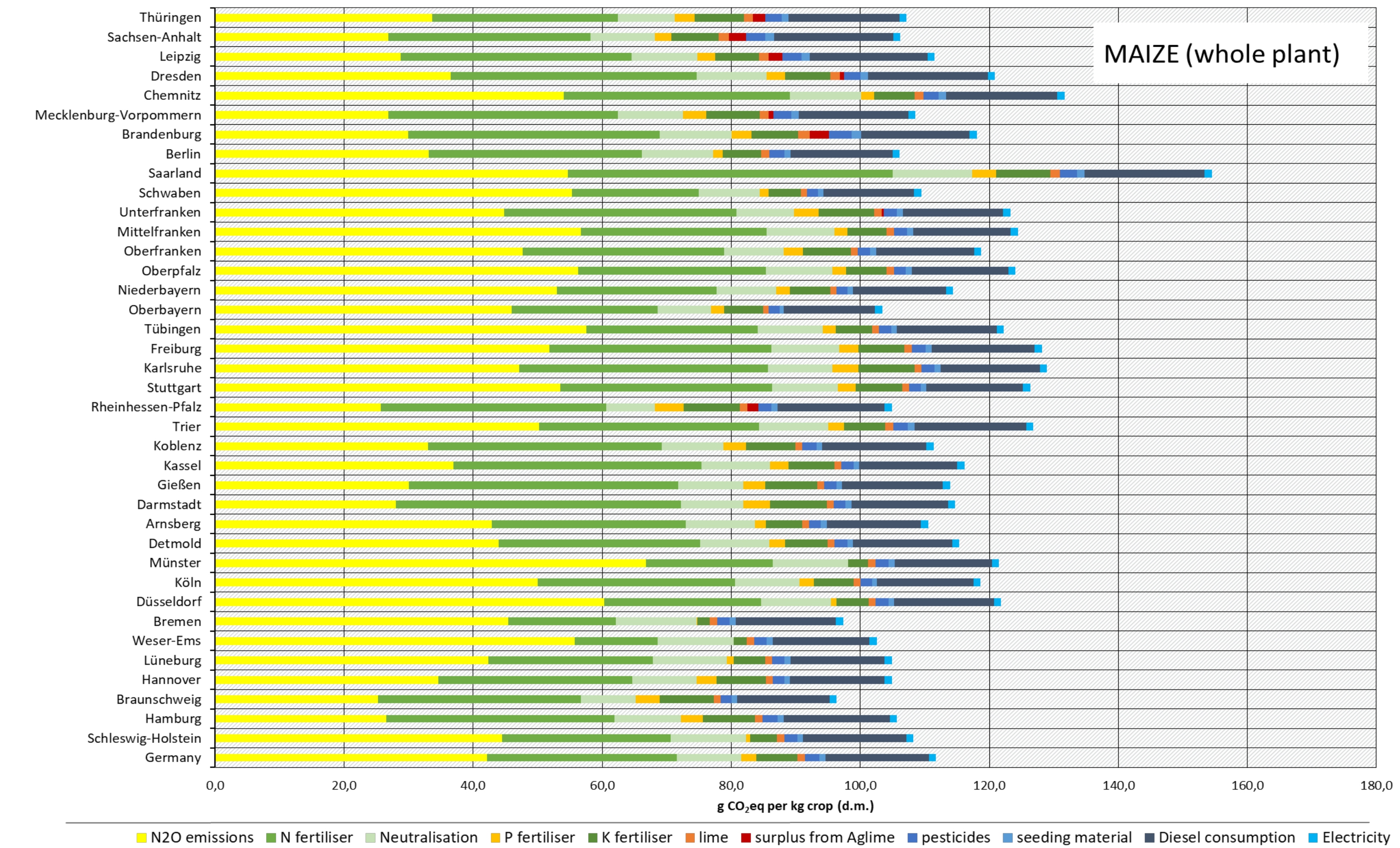
The N_2O emissions take a share of 36.8 % on German average. Synthetic N-fertilisers contribute 29.6 %. Diesel consumption contributes by 9.0 %, since processing of the harvested maize plant, chopping and ensiling is included. Emissions from neutralisation (including "surplus from aglime") contribute 9.0 %.

Similar to maize whole plant, wheat whole plant requires a certain amount of potassium fertiliser, contributing 4.4 % to the total emissions. The production and provision of the needed phosphorous and lime adds a further 4.3 % to the emission, seeding material 3,6 %.

Data for pesticide application specifically for wheat whole plants are not available. We assumed the same application per hectare as for wheat grain cropping. This results in 2.6 % contribution to the total emission.

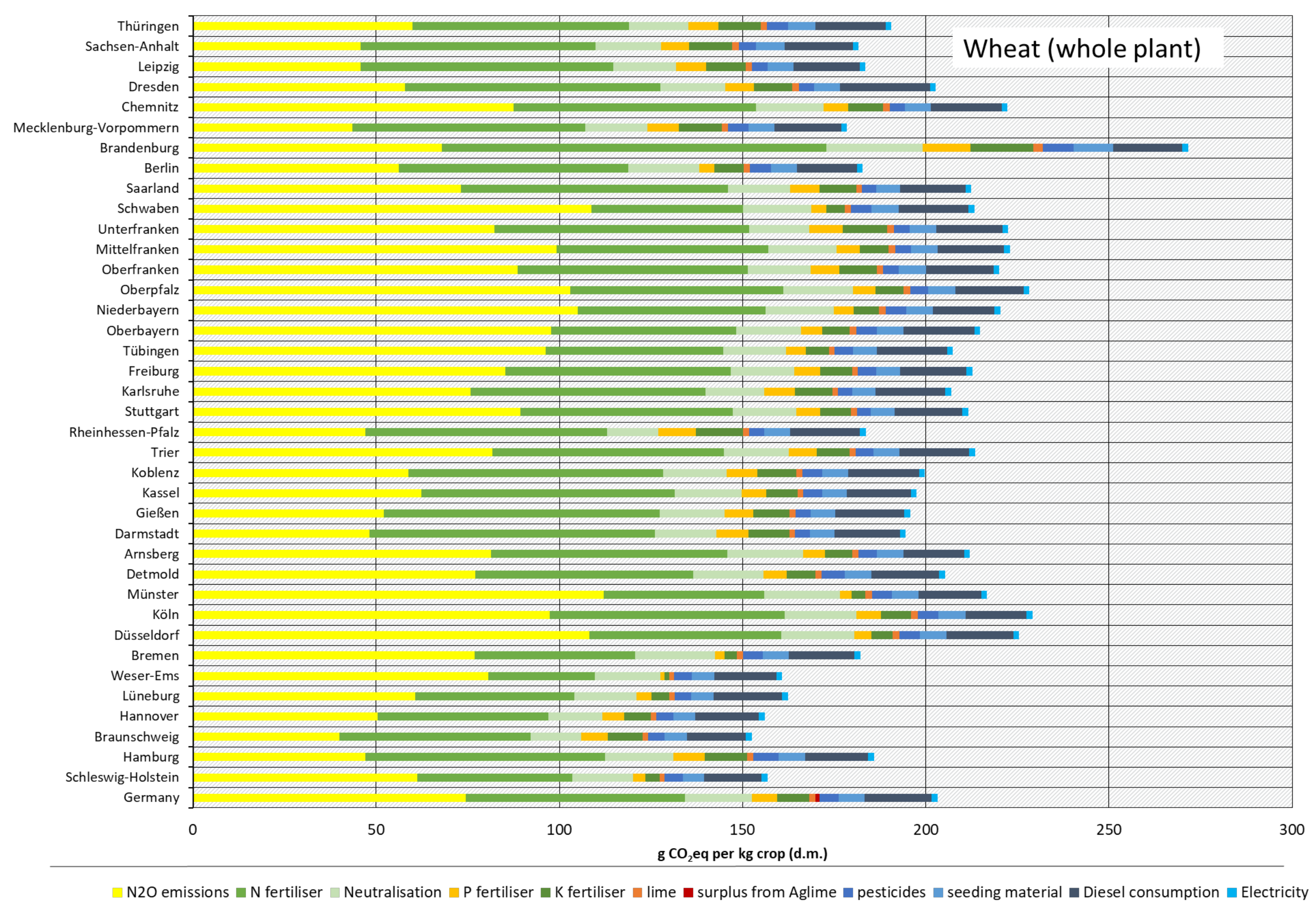
Emissions from electricity consumption makes 0.8 %.

Figure 11: GHG emissions from cultivation of maize (whole plant) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

Figure 12: GHG emissions from cultivation of wheat (whole plant) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

3.1.10 Field grass (whole plant)

The results for field grass show a large range from 168 to 250 g CO_2eq/kg ensiled grass (dry matter), as shown in Figure 13. The lowest value refers to the area of Bremen, the highest to the area of Düsseldorf. The German average is 205 g CO_2eq/kg ensiled grass (dry matter).

The N_2O emissions dominate the result here even more clearly than for most other arable crops, accounting for 43 % of the total on German average.

Synthetic N-fertilisers contribute 31.3 %, potassium 8.0 %. Diesel consumption contributes by 4.1 %, including processing of the harvested grass, chopping and ensiling. Emissions from neutralisation (including "surplus from aglime") contribute 10.4 %, slightly higher than other crops.

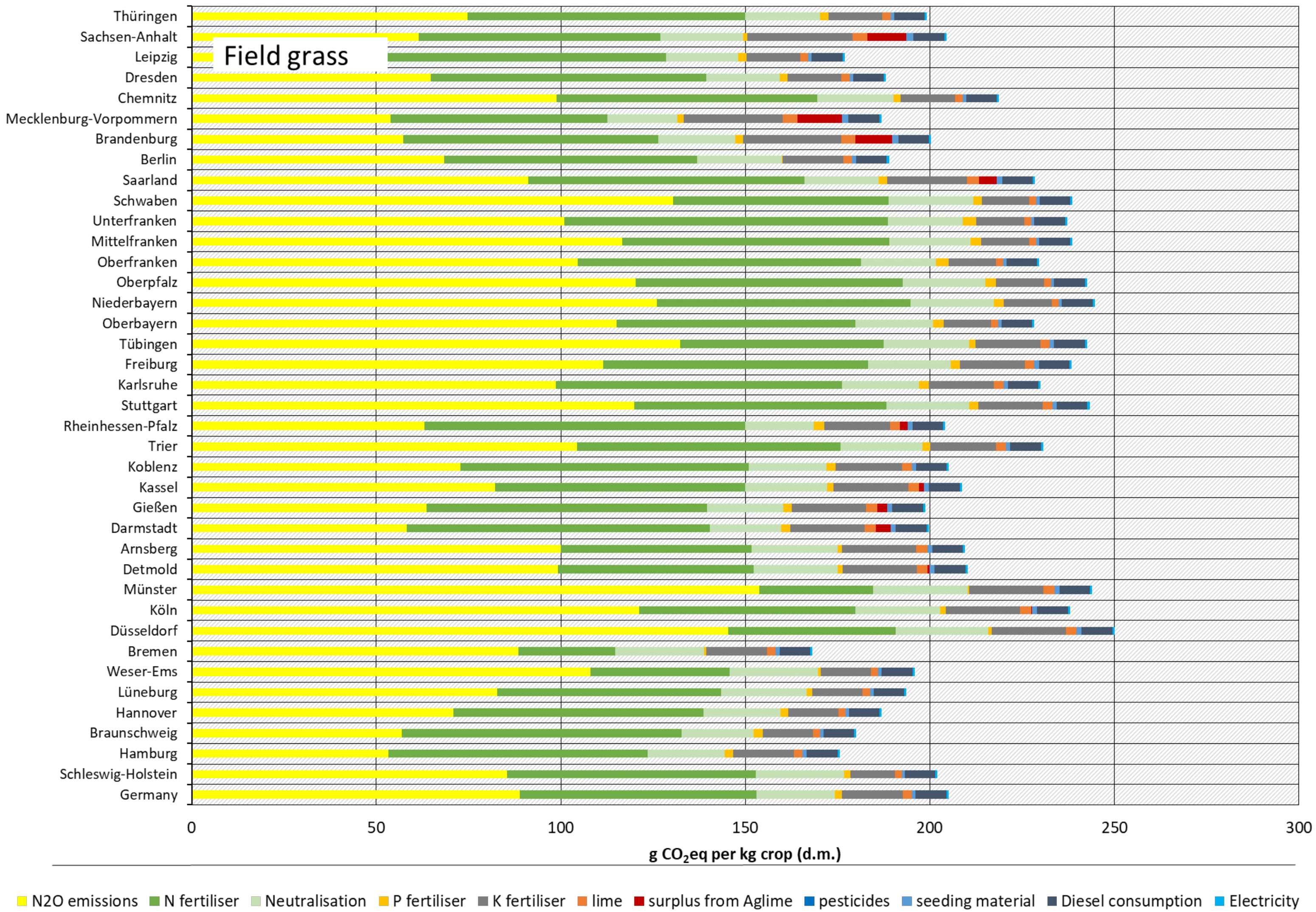
No data is available on the use of pesticides for field grass. It is assumed that the quantities used here are negligible in terms of the contribution to GHG emissions. P fertiliser, lime, seeding material and electricity sum up to 3.0 %.

3.1.11 . Grassland cuttings (whole plant)

The discussion of the results for grassland cuttings should be preceded by some explanations, as grassland differs from arable land in many ways. Firstly, it should be mentioned that very different types of grassland are cultivated in Germany. In the scope of this study (production of substrate for biogas plants), only permanent grassland that is mown, i.e. meadows or mown pastures, is considered. The intensity of cultivation can vary considerably. As a rule, the more intensive the fertilisation, the higher the cut yields. Conversely, extensive grassland usually has a significantly higher value for biodiversity. However, grassland areas are declining in Germany. Especially for the more extensive areas, the utilisation purposes for local animal nutrition are decreasing. The utilisation of grassland cuttings for biogas plants is therefore often associated with the goal of preserving grassland. Due to the diversity of grassland, it is therefore not possible to define actual or typical cultivation conditions specifically tailored to use for biogas production. Irrespective of this, Article 29 paragraph 3 (b) of RED II stipulates that *biofuels, bioliquids and biomass fuels produced from agricultural biomass … shall not be made from raw material obtained from land with a high biodiversity value, … unless evidence is provided that the harvesting of the raw material is necessary to preserve its status as highly biodiverse grassland* (Article 29 paragraph 3 (d)).

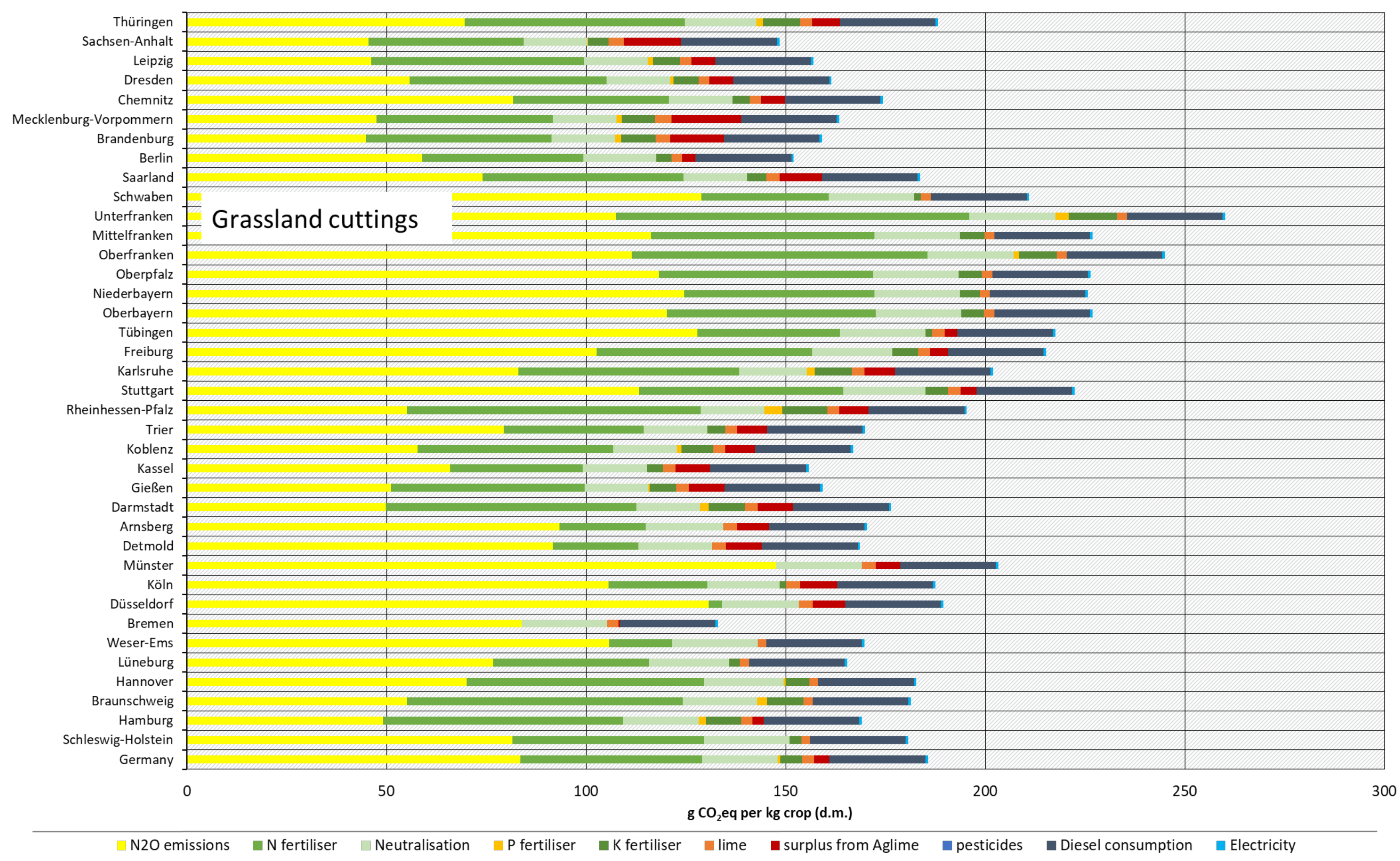
A further difficulty regarding the data basis for grassland has already been explained in chapter 2.2.2, stating that the methodology for estimates of the N fertilisation is less reliable for grassland than for cropland and may lead to a bias: in case of low manure supply in regions with humus-poor soils (e.g. Brandenburg) and thus low rates of additional N delivery from soil, particularly high N fertiliser use is calculated; in case of high manure supply in regions with humus-rich soils (e.g. regions in Bayern) and thus high rates additional N delivery from soil, rather low N fertiliser use is estimated. At the same time, according to the official statistics used, rather small differences in crop yields are used to calculate overall GHG emissions. For this reason, we figured the N-fertiliser/yield ratios out for all NUTS2 regions and narrowed the effective range of ratios by >30percentile and <70percentile. The result resembles the pattern of most other crops because the outliers then are smoothed by the percentiles.

Figure 13: GHG emissions from cultivation of field grass (whole plant) on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

Figure 14: GHG emissions from cultivation of grassland on mineral soils, per NUTS2 region and system component



Calculation and illustration by ifeu

According to the procedures described, the results range from 133 to 260 g CO_2eq/kg ensiled grass (dry matter). The German average value is 186 g CO_2eq/kg ensiled cuttings (dry matter) and, as can be seen from Figure 14, is made up of 45 % N_2O field emissions, 24,5 % N fertiliser production and 12,9 % diesel consumption. Emissions from neutralisation (including "surplus from aglime") contribute 12.3 %, even higher than for field grass.

Potassium contributes 2.9 %, lime production 1.6 %. Phosphorus and electricity are well below 1%. Use of pesticides was not considered which is in line with the common practice of grassland cultivation. Also seeding material has been neglected, as this is only required for permanent grassland for initial sowing (once for long-term use) or in the case of gaps for reseeding (only on a case-by-case basis). The resulting quantities are significantly lower than those of arable grass,[33] which is why neglecting it here seems justified.

3.2 GHG emissions referring to dry mass of crops – organic soils

The calculation of GHG emissions from cultivation on organic soils differs from that on mineral soils due to a different formula for N_2O field emissions (see also section 2.4.8). With the cultivation and the necessary drainage of organic soils, mineralisation proceeds, manifesting in emissions of CO_2, N_2O and CH_4. All three GHGs are climate-relevant. According to the IPCC calculation rule and following the methodology of the Implementing Regulation (EU) 2022/996, Annex VII, however, only N_2O emissions are considered here.

Agricultural land with organic soils is very unevenly distributed in Germany. In some NUTS 2 regions there are no such areas. In others, they even occur to a high degree. A map showing the distribution can be found in Annex A.3 (Tegetmeyer et al. 2020).[34]

In the following, the GHG emissions from cultivation on organic soils are calculated for the NUTS 2 areas in which organic soils account for more than 0.5 % of the agricultural area. The largest area shares are found in the northern regions of Germany, especially in Bremen, Weser-Ems, Lüneburg, Mecklenburg-Vorpommern, Brandenburg and Schleswig-Holstein. However, some southern regions, such as Oberbayern and Schwaben, also have significant shares of agriculture on organic soils. In around half of the NUTS 2 regions, the proportion of organic soils is below 0.5%. These NUTS 2 regions are not considered further here.

As expected, the results show high emission values. Examples are illustrated in Figure 15 for rapeseed and Figure 16 for maize (whole plants). A distinction is made between the sum of all components except N_2O field emissions and N_2O field emissions from cultivation on organic soils. **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.** in Annex **Fehler! Verweisquelle konnte nicht gefunden werden.** give the total results for all crops and NUTS 2 regions considered.

For rapeseed, the total values range from 1605 (Weser-Ems) to 2120 g CO_2eq/kg rapeseed d.m. (Oberfranken), see Figure 15. For maize (whole plant), the total values range from 343 (Oberbayern) to 607 g CO_2eq/kg ensiled maize d. m. (Brandenburg), see Figure 16. In all cases, N_2O field emissions account for around 90 % of total GHG emissions from cultivation on organic soils.

[33] for reseeding, 5 to 10 kg/ha is often sufficient: Source: https://www.agrarheute.com/pflanze/gruenland/checkliste-so-saeen-gruenland-richtig-543374

[34] The GAEC 2 data (good agricultural and environmental conditions) published by the German federal states can be used to check whether the cultivation of raw materials takes place on land classified as organic soil for the 17 NUTS 2 areas concerned.

Figure 15: GHG emissions of rapeseed cultivated on organic soil, differentiated by NUTS2 region and N_2O field emissions (yellow) and the sum of all other emissions (blue)

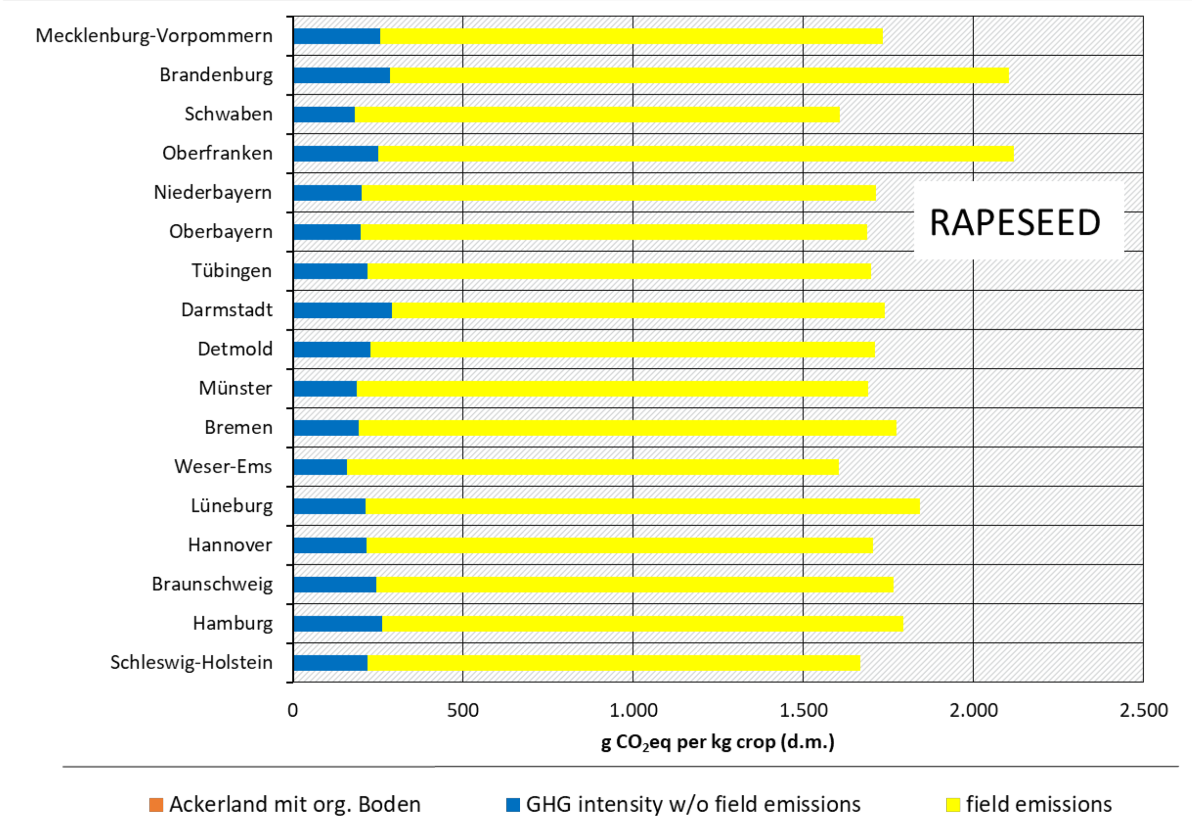
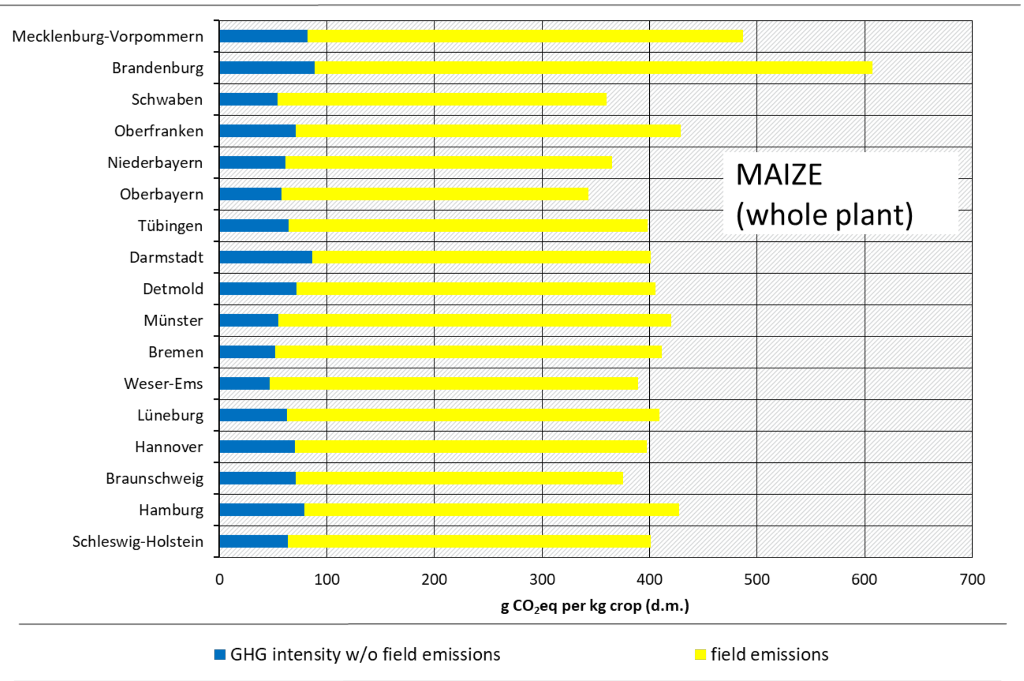


Figure 16: GHG emissions of wheat (whole plant) from cultivation on organic soil, differentiated by NUTS2 region and N_2O field emissions (yellow) and the sum of all other emissions (blue)



Calculation and illustration by ifeu

Since the main factor for determining these emissions is N_2O emissions due to mineralisation which in turn is mostly driven by the factor area, the lower the specific yields per hectare, the higher the results. This results in the comparative advantage of high-yield sites over sites with lower yields. However, this does not take into account the fact that the "average" yields of the NUTS2 areas according to statistics do not differentiate between cultivation on mineral and organic soils. However, the differences between the regions (based on these averages) should therefore be questioned. The analysis of GHG emissions from cultivation on organic soils show an enormous difference to the respective GHG emissions from cultivation on mineral soils. For this purpose, the calculations are considered sufficiently robust.

Looking at the two examples, the ranges for rapeseed are 362 to 531 g CO_2eq/kg for cultivation on mineral soils and 1605 to 2120 g CO_2eq/kg for cultivation on organic soils, as Figure 15 shows. For maize whole plants we see 96 to 155 g CO_2eq/kg for mineral soils and 360 to 607 g CO_2eq/kg for organic soils (Figure 16).

3.3 GHG emissions referring to energy content of derived biofuel

As already mentioned in section 2.1.5, there is no recognised standard model available for the standard values of RED II. The initial calculation of the NUTS 2 values was performed using the formerly recognised voluntary system BioGrace. For this report, the conversion is carried out on an informal basis using the calculation tool from the BioEm project (Fehrenbach et al. 2016). This tool contains a more updated set of process data and emissions factors compared to BioGrace.

Table 3 shows the applied conversion factors taken from this source. These factors consider:

- The material loss via the processing and transport steps;
- The conversion from mass unit to energy unit based on lower heating value;
- The allocation of co-products based on lower heating value.

Table 3: Conversion factors from emission per kg crop (d. m.) to emission per MJ biofuel

Crop	Value	Unit
Wheat (grains)	0.0621	kg crop d.m./MJ ethanol
Rye (grains)	0.0619	kg crop d.m./MJ ethanol
Maize (grains)	0.0632	kg crop d.m./MJ ethanol
Barley (grains) [a)]	0.0620	kg crop d.m./MJ ethanol
Triticale (grains) [a)]	0.0620	kg crop d.m./MJ ethanol
Sugar beet	0.0805	kg crop d.m./MJ ethanol
Rapeseed	0.0365	kg crop d.m./MJ biodiesel
Maize (whole plant)	0.103	kg crop d.m./MJ biomethane
Wheat (whole plant)	0.107	kg crop d.m./MJ biomethane
Field gras (whole plant)	0.125	kg crop d.m./MJ biomethane
Grass land cuttings [b)]	0.125	kg crop d.m./MJ biomethane

a) Barley and triticale are not considered by (Fehrenbach et al. 2016), thus, the average from wheat and rye is taken as an assumption.
b) For grassland cuttings there are no specific conversion factors; due to the substantial comparability with field grass, the same conversion factors can be assumed

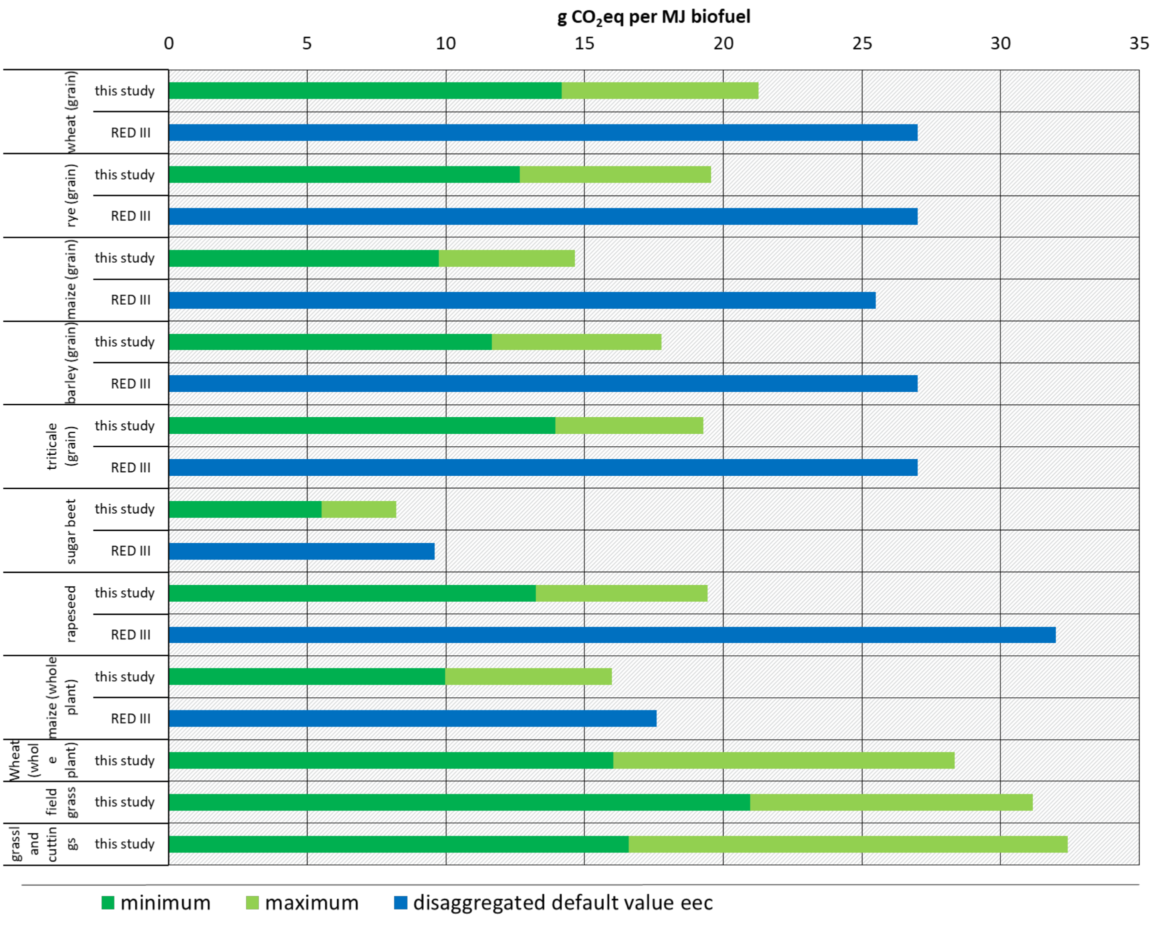
Compilation by ifeu, based on (Fehrenbach et al. 2016)

Figure 17 gives a synopsis of the GHG emissions from cultivation of all crops, showing the resulting range from lowest to highest value. This range is compared with the disaggregated default values (e_{ec}) from RED II:

- Annex V, part D for all liquid biofuels; and
- Annex VI part C for biomethane from maize (whole plant).

The graph shows, that all result values are below the e_{ec} values of the RED II. In some cases, the difference is rather large (e.g. for maize grain nearly a factor 2). In case of sugar beet ethanol and maize (whole plant) biomethane the differences are smaller. For rapeseed the maximum value reached 61 % of the disaggregated default value, the minimum just 41 %.

Figure 17: Synopsis of GHG intensity of all crops per MJ final biofuel, showing the range from minimum to maximum and comparing with the disaggregated default values (e_{ec}) from RED III (Annex V, part D and Annex VI part C)



Calculation and illustration by ifeu

4 Discussion of significant parameters and sensitive aspects

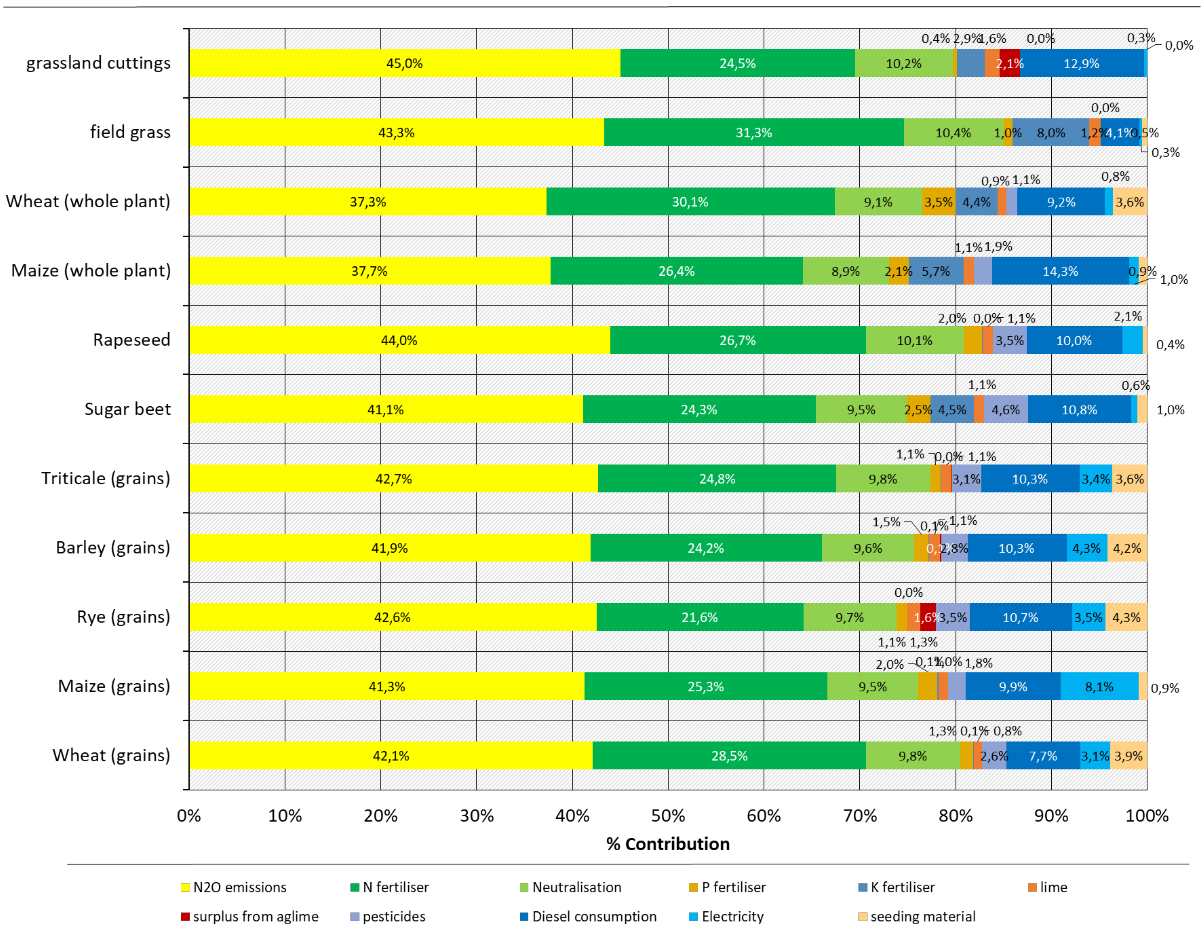
4.1 Discussion of significant parameters

Two components of the calculation of GHG emissions from cultivation (see the overview diagram in Figure 3) mainly determine the results:

1. The field emissions of nitrous oxide (N_2O) – ranging between 38 and 45 % of the overall GHG emissions, in most cases they take more than 40 %.
2. The emissions from the production of synthetic nitrogen fertilisers - mostly ranging between 21.6 and 31.3 % of overall GHG emissions.

These are followed at some distance by the consumption of diesel, neutralisation, electricity, pesticides and seeding material. Emissions from the production of synthetic P fertilisers, lime and, with a few exceptions, potassium fertilisers have little influence. Figure 18 gives an overview on the relative contributions of the components to the sum of GHG emissions for the German averages.

Figure 18: Contributions of the components to the sum of GHG emissions for the German averages, in percent



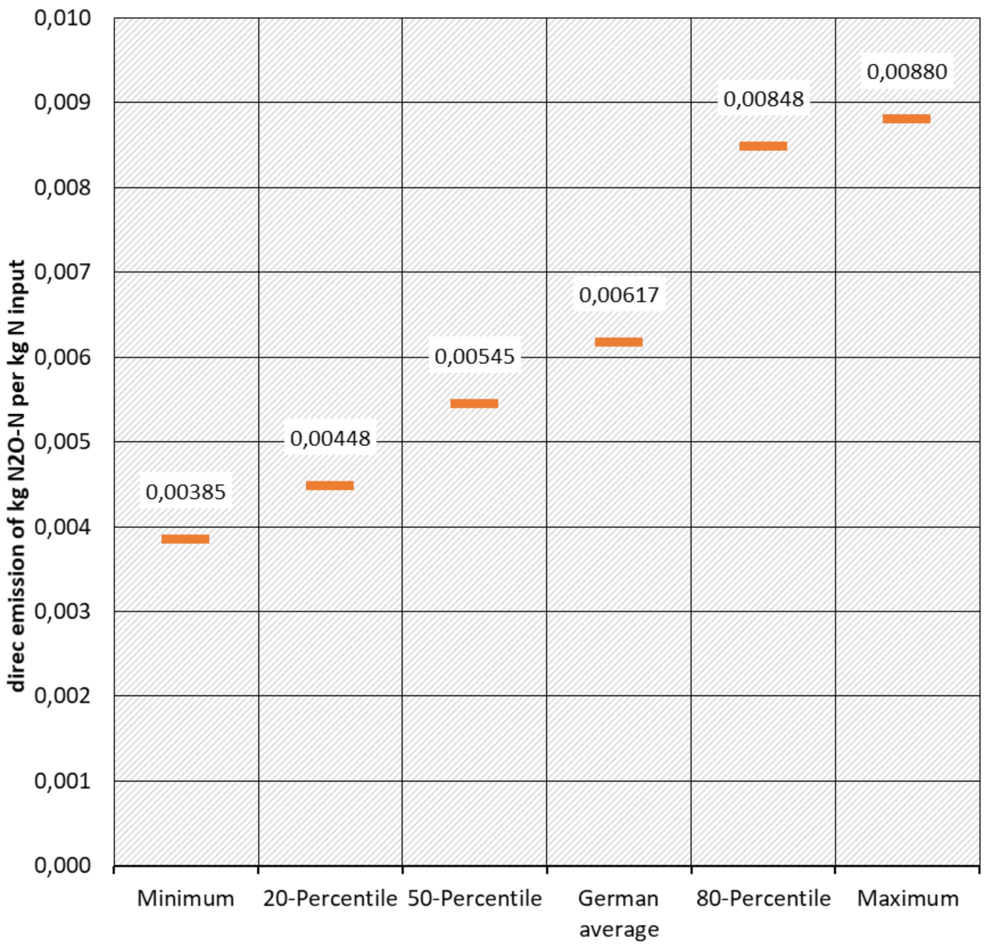
Calculation and illustration by ifeu

4.1.1 Field emissions of nitrous oxide (N_2O)

The **field emissions** of N_2O is also the most significant parameter regarding the regional variability of the results. Foremost, this is due to the wide range within the regional emission factors for direct N_2O emissions. It should be noted that the same emission factors for direct N_2O field emissions was used for all crops and therefore there is no variability between crops in this respect. On the other hand, the regional differences in N fertilisation have a relevant impact on the level of direct N_2O field emissions.

Figure 19 gives an impression for the regional variability of these factors: between minimum and maximum, there is a factor of 2.3 and the middle 60 % (above the 20-percentile and below the 80-percentile) lie within a range of a factor of 1.9. The higher emission factors refer to southern regions, such as all NUTS 2 regions from Bayern and Baden-Württemberg, Saarland, some regions in Nordrhein-Westfalen, the Trier area and the Chemnitz area. Lower factors are connected with more northern regions such as Niedersachsen, Mecklenburg-Vorpommern, Schleswig-Holstein, Brandenburg, but also regions in Mid-Germany, such as Sachsen-Anhalt, Hessen, Leipzig, Dresden.

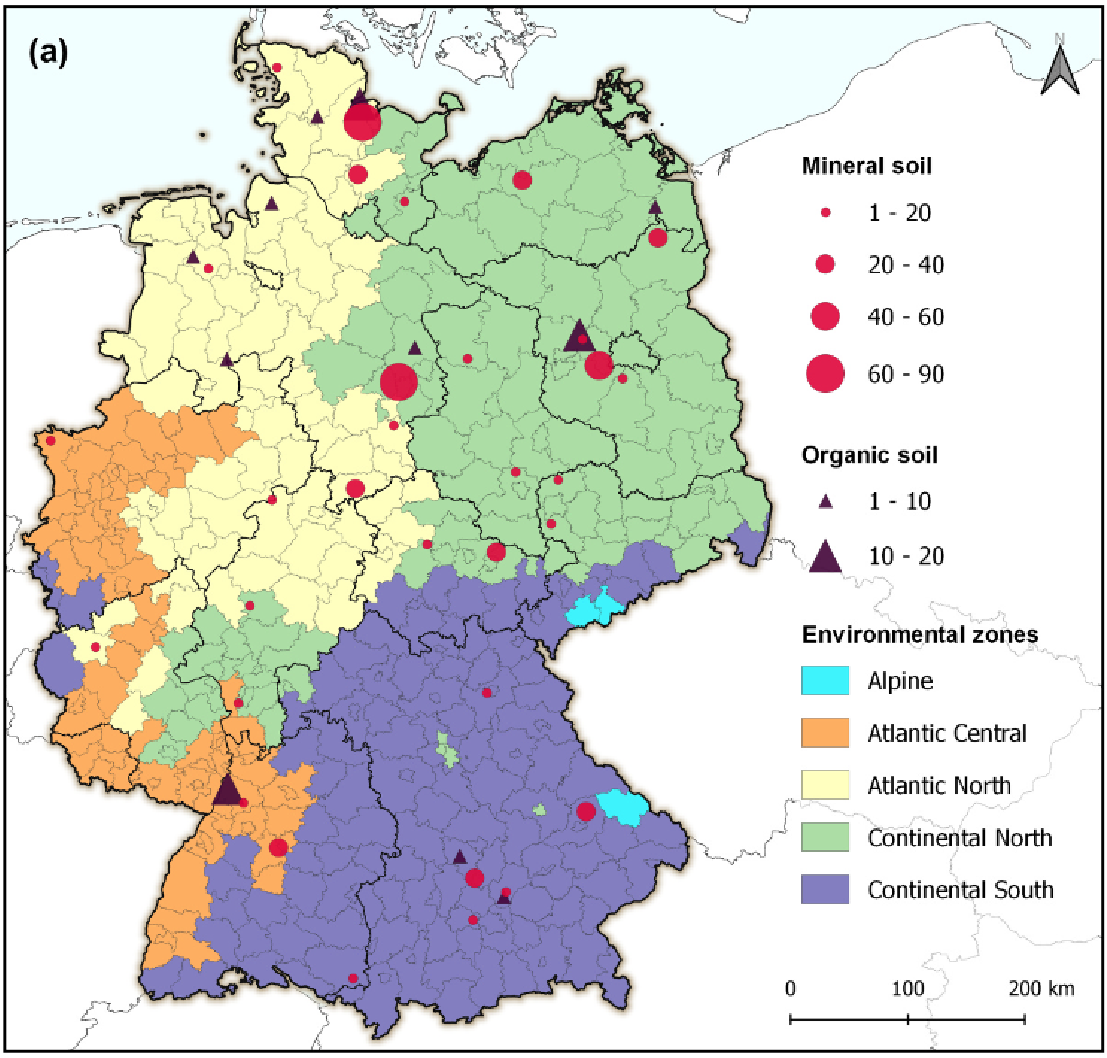
Figure 19: Regional variability of the direct N_2O emission factors



Calculation and illustration by ifeu; source: Thünen-Institute

According to (Mathivanan et al. 2021) the environmental zones have a strong effect on the direct N_2O field emission factor. These were clearly distinguishable from a geographic perspective: Continental South (Bayern, East of Baden-Württemberg) has the highest emission factor, Continental North (Eastern Germany) the lowest (see Figure 20). Thus, a clear divide was seen between the emission factors of the environmental zones in northern and southern Germany due to climatic factors.

Figure 20: Map of Germany showing the five environmental zones and the location clusters of N_2O measurements



Source: (Mathivanan et al. 2021)

Symbol size indicates the number of measurements. Borders of federal states and districts are indicated

4.1.2 Emissions from the production of synthetic nitrogen fertilisers

The second most important component, emissions from the production of applied **synthetic nitrogen fertilisers**, varies also strongly between the NUTS 2 regions. This is driven by two main factors, the quantity and the type of synthetic N fertiliser.

First of all, in regions with a high proportion or density of animal production, large quantities of manure are produced, which leads to a reduced need for synthetic fertiliser. As, according to RED methodology, there are no emission loads for manure before the point of collection, this type of fertiliser is generally associated with lower emission loads than synthetic fertiliser. In consequence, fertiliser production related emissions contribute less to overall GHG emissions in regions with lower animal production. There, more synthetic fertiliser must be added, for which the corresponding emissions from production must be taken into account. For example, regarding rapeseed,

- ► Regions with high proportions of manure for fertilisation (more than 50 % of N input) are the western parts of Niedersachsen, Schleswig-Holstein, Bremen, Münster, Düsseldorf and southern parts of Bayern.
- ► Regions with low proportions of manure (less than 30 % from N input) are Freiburg, Karlsruhe, Rheinhessen-Pfalz, Darmstadt, Gießen, Saarland, Unterfranken, Mecklenburg-Vorpommern, Brandenburg, Dresden, Leipzig, Sachsen-Anhalt, Thüringen.

All other regions (the majority of NUTS 2 regions) range between 30 and 50 % share of N from manure.

The contribution to GHG intensity from synthetic N-fertilisers therefore also varies widely, with the minimum 45 g CO_2eq/kg rapeseed in Weser-Ems and the maximum 160 g CO_2eq/kg rapeseed in Darmstadt and Gießen area. The figures and ratios shown here apply to rapeseed. The findings for other crops are generally similar, although the regions with the highest emission values vary. These are often found in Saarland (for most cereals and whole plants) or in the Stuttgart or Karlsruhe regions (rye, sugar beet).

The question of whether this parameter (high manure/low manure) results in a meaningful steering effect due to the different regional emission values is discussed further below (see Box 1).

Box 1: Brief discussion of the positive effect of high fertiliser input of manure

The consideration of the proportion of organic fertilisers in the calculation of the NUTS 2 values follows the logic of mapping the regional conditions in their typology as representative as possible. In addition, a distinction is also made between synthetic and organic fertilisers when calculating actual values. The regional calculation here also assumes that the regional mix of synthetic and organic fertilisers is the same, regardless of the use of a crop (food, animal feed, biofuel).

As manure is generally categorised as a residual substance (e.g. in the list of Part A in Annex IX of RED II), emissions are only accounted from the point of collection. This means that

- ► the higher the proportion of manure in fertilisation (and therefore the lower the proportion of synthetic fertiliser), the lower the resulting emissions intensity.
- ► regions with high livestock numbers and manure production are favoured, in some cases considerably.

Even if the procedure is formally correct, the possible steering effect associated with it must be viewed critically. This could incentivise the preferential production of crops for biofuels in areas with high livestock numbers. This could entail an indirect promotion of large-scale livestock farming and lead to an adverse competition for land and consequent rising land rents in these regions. However, for reasons of sustainability and climate protection, this should not be incentivised. This is all the more true as other potential negative environmental impacts of livestock farming such as high nitrogen surpluses with eutrophication effects and groundwater pollution are disregarded when calculating GHG emissions of cultivation.

Another parameter is the **type of synthetic fertiliser**, which also varies from region to region according to sales statistics. The emission factors of the fertilisers applied in Germany range from 1.19 kg CO_2eq per kg N for urea to 3.67 kg CO_2eq per kg N for calcium ammonium nitrate (CAN). In some regions CAN is the prevalent type of fertilizer (e.g. Saarland), in others urea is the preferred type (e.g. Mecklenburg-Vorpommern). Most regions show a mix of N fertilisers with approx. 37 % CAN, 16 % urea, 11 % urea ammonium nitrate solutions and 36 % others.

4.2 Discussion of the potential impact from data uncertainties

In section 2.3 a number of identified uncertainties are listed. With regard to the previous section on significant parameters and factors, these uncertainties are assessed in the followings.

4.2.1 Yield data

The yield data are of fundamental importance for the calculations carried out here, as the results relate precisely to the mass of crop produced. Since the applied yield data originates from official source, national and regional statistics, collected from empirical enquiries, an intrinsic high level of reliability can be assumed. Nevertheless, certain residual uncertainties remain even in the statistical surveys.

With regard to the period selected, it should be noted that four of the five years are considered dry with correspondingly reduced yields. On the other hand, possibly this particular situation has to be considered more typical for the coming years.

A fundamental uncertainty in the application of statistical yield data is that the data for all other components are not collected in the same way and thus consistently with the yields. For all other data, models are required that are only partially aligned with the empirical yield data. An overall and complete consistency cannot be assured on this basis.

Another more minor aspect is the conversion to dry matter. The statistical data for cereals, sugar beet and rapeseed are given in fresh matter. The conversion is done via standard factors, which might not represent the actual situation in all cases.

As already mentioned, there is a lack of coherent data on regional yields and N-fertiliser application. Narrowing the N-fertiliser/yield ratios by >30percentile and <70percentile is considered a robust alternative.

4.2.2 Fertiliser application

As mentioned above, the data for fertiliser application constitute a model-based estimate. Actually, there are no crop-specific empirical data available on fertilisation or soil nutrient levels. According to the applied model, the requirement for N fertiliser is determined in accordance with the Fertiliser Application Ordinance[35] (Annex 4), taking into account the respective crop and yield-specific nitrogen requirement value for arable crops and grassland as well as the available N from soil mineralisation processes, previous crops and organic fertilisers. This estimations are done based on the AGRUM DE Project[36] (Ackermann et al. 2015).

Basically, the same restriction applies to the use of fertilisers as to the crop yields: the four dry years influence the result in the direction of comparatively low harvests with the partially fertiliser applications. It should also be noted that the version of the Fertiliser Application Ordinance used for the modelling has only been in force since 2017 and revised in 2020,

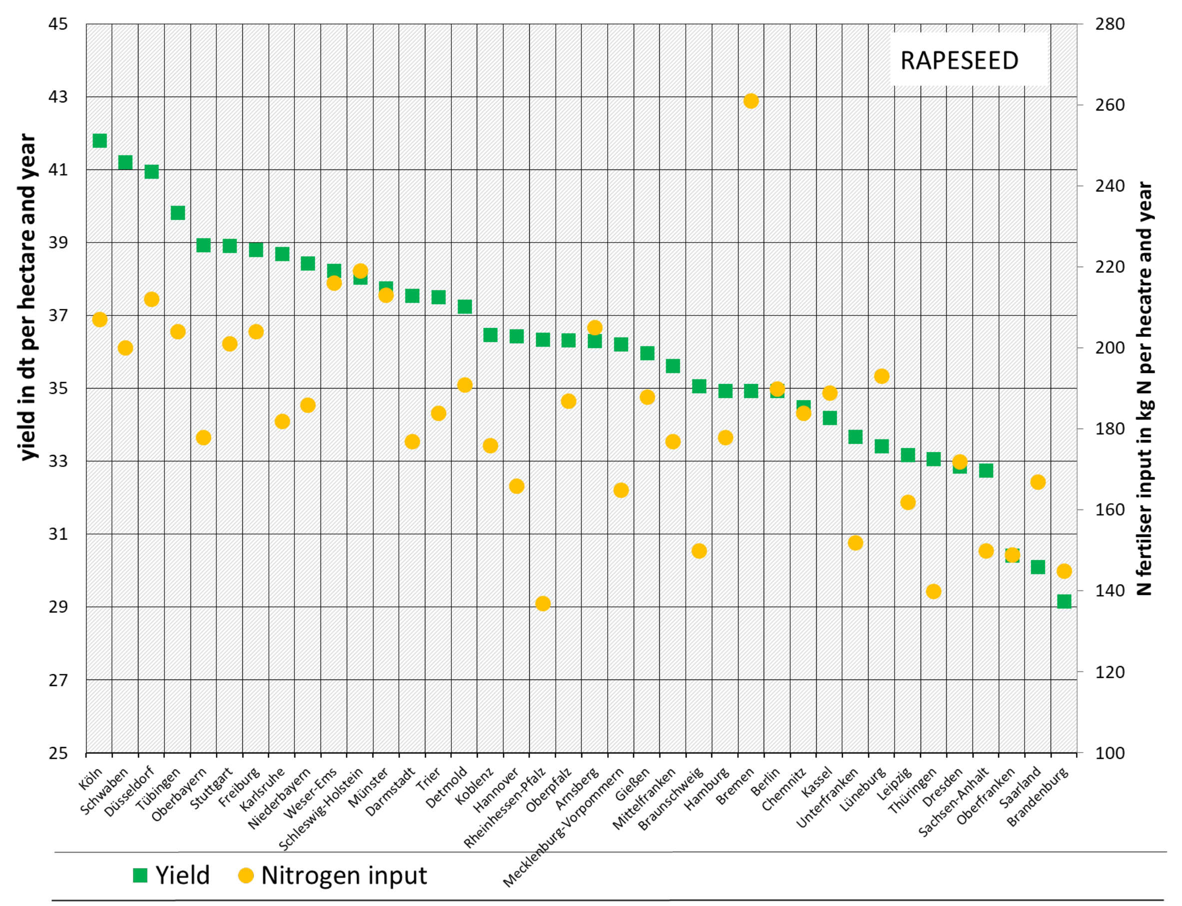
[35] Düngeverordnung (DüV) von 2020 (sowie 2017). https://www.gesetze-im-internet.de/d_v_2017/D%C3%BCV.pdf

[36] https://www.thuenen.de/en/cross-institutional-projects/agrum-germany

followed by the designation of polluted ares with further N fertilization restrictions in 2021. This causes certain uncertainties in the modelling.

Overall, however, there are very large discrepancies in the relationship between total-N-input and yield. In Figure 21, both variables are plotted against each other using oilseed rape as an example. There are considerable differences between the NUTS 2 regions. On average, the fertiliser input is 5.0 kg N per dt of rapeseed. In the most unfavourable case, 7.5 kg N is required. This applies to Bremen and reflects the situation there of very high N surpluses from animal excrement. Bremen must be seen as an outlier here, as Figure 21 also shows. The second-highest value is already significantly lower in Schleswig-Holstein at 5.76 N per dt of rapeseed. The lowest specific fertiliser requirement is 3.8 kg N per dt of rapeseed in Rheinhessen-Pfalz. Synthetic fertilisers are used almost exclusively there.

Figure 21: Combined analysis of yields from data on N fertilisation (total N) for rapeseed



Calculation and illustration by ifeu; source: Destatis; Thünen-Institut

4.2.3 Specification of fertiliser types

The various fertilisers have different emissions in terms of their production. The aim of this study is therefore to take regional differences into account when selecting fertiliser types. This is only partially successful, as the available data is only available in a resolution at NUTS 1 level and ultimately only reflects market data (the data are given in annex C.3). It is not possible to conclude from this information what exactly was used in the individual regions on an annual basis. Furthermore, there is no differentiation between the respective crops. The use of this regionalised market data is therefore more of an approximation.

The question is, if the national Mix of fertiliser types were used instead of the regional data on nitrogen fertiliser types, what influence would this have on the results? For the German average mix we figure out a mean emission factor of 3,411 kg CO_2eq per kg N. In the worst case (which would correspond to the case of Bremen) the e-factor is 3,971 kg CO_2eq per kg N. The lowest emission factor is 2,985 kg CO_2eq per kg N (Hamburg). However, 60 % of all e-factors can be found within an interval from 3,347 kg CO_2eq. and 3,520 kg CO_2eq. which is very close to the German average. Thus, apart from some specific cases the assumption of regional fertiliser mixes has no significant influence on the result for a region. In individual cases, as already described above using the example of Saarland, this assumption in combination with other factors (almost exclusively synthetic fertilisers) can be an important influencing factor. Whereas for Bremen, the region within the highest e-factor for synthetic N fertiliser, the share of organic fertiliser is predominant, lowering the relevance of that e-factor strongly.

4.2.4 Field emissions due to neutralisation of fertiliser acidification and liming application

Unfortunately, the data basis for the use of lime is very rudimentary: data is only available for the total annual use in Germany. There is no basis for mapping a regional distribution. This is particularly important in view of the differentiated consideration of soils of varying acidity (i.e. pH > or <6.4). The Implementation regulation, annex VII section 1.4.2 requires such a differentiated consideration. However, this cannot be used here. Thus, we have to admit an inaccuracy due to the uniform application of lime assumed here. However, the connected uncertainty is limited by the fact that the neutralisation emissions from nitrogen fertilisation already contain high specific contributions from soil CO_2 emissions.

4.2.5 Field emissions of nitrous oxide (N_2O)

These emissions are among the main factors in the respective results for crops by region. An approach at Tier 2 level was chosen to calculate them. The calculation was carried out according to the formula specifications of the IPCC and the Implementation Guideline. The required factors were provided by the Thünen Institut. Despite all the fundamental uncertainties of the underlying models, these calculations can be considered solid. The same factors are also used in the calculation of the national reporting on Germany's emissions inventory.

4.2.6 Application of pesticides

These emissions vary with contributions of around 1 to 4.6 % rather on a less significant level. On the other side, a number of simplifications and assumptions have to be made in order to handle the comprehensive data base provided by Julius-Kühn-Institut. First of all, the geographical distinction of regions is different to the NUTS 2 system. An easy attribution to NUTS 2 was possible for some regions. For many others rough estimation of land shares has been made. Secondly, the data pointed out applied quantities of marketed preparations. For an GHG assessment, it was necessary to figure out the quantity and type of active agent. With regard on the large list of preparations, this could only be done by rough estimations. Finally, there were no data for rye and triticale. The authors assumed an average of data for wheat and barley to fill this gap. Moreover, data for whole-plant cropping of wheat and maize are missing and added by the respective data for grains. For field grass and grassland the application of pesticides is determined to be close to zero.

4.2.7 Consumption of Diesel and on-farm electricity

Date for the **consumption of Diesel** are provided by KTBL and derive from the KTBL farm calculator model,[37] which is regarded as the premium source for such agricultural processes in Germany. Nonetheless, simplifications are necessary also in this case. The modelling focusses on soil type and the need for machine power for soil cultivation. Thus, regional differences refer also to soil types, while the type of machinery and field sizes are set equal for all regions.

However, the data in the calculator tool are considered to be conservative. In reality, lower consumption levels are possible, since modern machines are more efficient.

With contribution from 4 to 14 % by diesel consumption to the overall emission intensities there is only a small potential of deviation. Supposed, there might be an overestimation by 20 %, the overall result would lower by 2 to 3 %.

Data for the **electricity consumption** is also taken from the KTBL calculator. The main influencing factor for electricity consumption probably is moisture content of the harvested crop with moisture content varying with weather. This again might vary between regions but especially between the years. As there is no reliable data nor an available tool or model to estimate regional differences of electricity consumption, regional differences are disregarded here. The results can be considered as robust and similar conclusions can be drawn as for diesel consumption.

4.2.8 Background data

The emission factors for the background system are completely taken from the Implementing Regulation (EU) 2022/996, Annex IX. Some of these data might be somehow dated, however they are compiled from data bases which represent the state of art of LCA calculation.

The emission factors for the background system are considered to be generic and do not offer options for regional distinctions at NUTS 2 level.

Highly relevant are the emission data for the fertilisers. The respective data origin in publications by IFS (Hoxha und Christensen 2019) and Fertilizers Europe as well as calculation by (Prussi et al. 2020), representing the standard source for this product group.

4.2.9 Conclusions on uncertainties

The analyses carried out here integrate various levels and components. For each of them the best available source was used. Whenever applicable, the data used correspond to the official statistical data and the sources for national reporting. Due to the complexity, uncertainties are unavoidable. These have been described and evaluated in detail above. In this sense, the results obtained are considered plausible. They are based on a significantly improved and updated database compared to the first calculations of NUTS 2 values for Germany in 2010. The mostly reduced emission intensities compared to then can also be considered plausible and are based on an improved scientific basis. The significantly larger bandwidths between the regions compared to 2010 are based on improved models that reflect these spatial characteristics.

4.3 Comparison with the previous German NUTS 2 emission factors

Figure 22 shows a comparing synopsis of the results from this study and the former results for NUTS 2 values as presented in the first NUTS 2 report in 2010. The graph shows that for wheat, rye and maize the upper end of the range exceeds the range from 2010. In all other cases the

[37] https://www.ktbl.de/webanwendungen/dieselbedarfsrechner

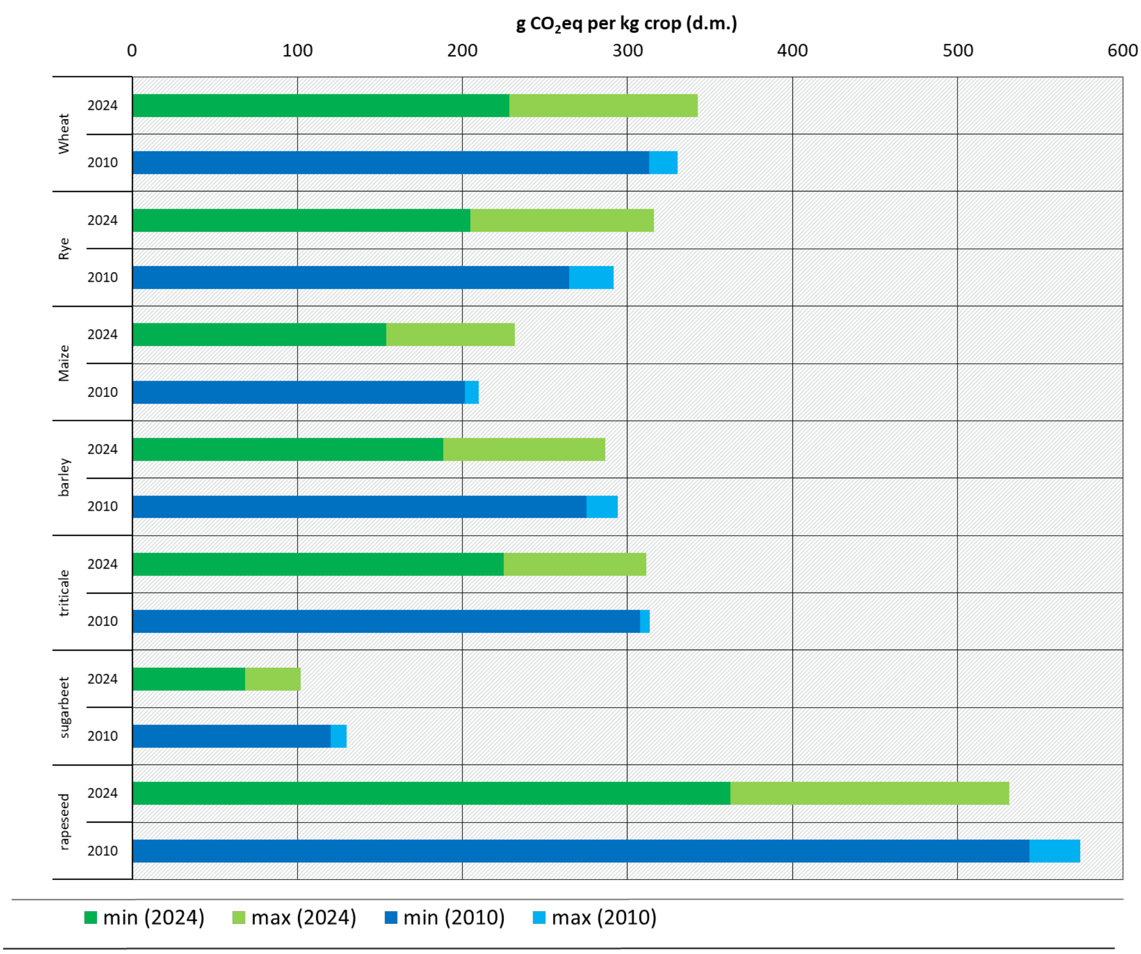
emission values are lower in the study at hand, with a more or less clear difference between the lowest regional value in 2010 and the highest regional value in 2024 in many cases.

Following factors have changed and contribute to changes of the emission intensities compared to 2010:

- First of all, the input of N fertiliser has increased, since in 2010 the approach was to calculate just the withdrawal of nutrient by the crop to the need of fertilisation. Actual applications, considering losses and surpluses, were disregarded. The study at hand considers realistically applied quantities, actually higher quantities than in 2010.
- On the other side, now also the existing organic fertilisers in NUTS 2 regions are considered unlike 2010, when all N input was attributed to synthetic fertiliser.
- Moreover, the emission factors for the production of fertilisers has been updated and the factors applied here are lower than in the data base for the report in 2010.
- Emissions from neutralisation of the acidification due to fertilizer application and from lime application is now included according to the implementing regulation.
- Also according to the implementing, emissions due to seeding material production is now included.
- Finally, the updated calculation of N_2O field emissions based on research by the Thünen-Institut provide significantly lower values.

The second and the third factor clearly already overcompensate the higher fertiliser quantities (first factor) in most of the calculated cases. The same is true for the combination of the first factor with the last factor, where the higher N input is counterbalanced by the lower field N_2O emission factors.

Figure 22: Synopsis of GHG intensity of all crops, showing the range from minimum to maximum and comparing with the results from the first NUTS 2 report (2010)



Calculation and illustration by ifeu

5 Outlook - open questions

The study report at hand constitutes a comprehensive update of the NUTS 2 emissions values in Germany. It takes into account the advanced standard of GHG calculations for biofuels and biomass fuels and is therefore on a much better scientific basis than the data from the first national report from 2010. In addition, the rules and requirements of the pertinent implementation acts published in 2023 were taken into account. The data used is based on information from the leading institutions in Germany in each of the areas of interest and constitute the latest available data.

The NUTS 2 values calculated are considered plausible. Nevertheless, as explained, there are data gaps and uncertainties. In the case of grassland, the data basis was adapted in order to create regional values, that can be considered as plausible.

Uncertainties also arise from the lack of data on the regional application of lime. A uniform application was therefore assumed here. However, the associated inaccuracy is limited by the fact that the neutralisation emissions due to nitrogen fertilisation already include high specific contributions of soil CO_2 emissions.

Another open question is how a controllable use of the values for organic or mineral soils can be ensured in the practice of origin-related application of the NUTS 2 values.

Finally, it would also have to be examined whether the equal treatment of cultivation applied here, irrespective of the use of the product (food, feed, energy), is actually justified or whether a distinction should be made.

6 Literature

Ackermann, A.; Heidecke, C.; Hirt, U. (2015): Der Modellverbund AGRUM als Instrument zum landesweiten Nährstoffmanagement in Niedersachsen. Johann Heinrich von Thünen-Institut, DE. *https://doi.org/10.3220/REP1450256145000* (14.01.2024).

BLE (2010): Leitfaden Nachhaltige Biomasseherstellung. Bundesanstalt für Landwirtschaft und Ernährung. *https://www.ble.de/SharedDocs/Downloads/DE/Klima-Energie/Nachhaltige-Biomasseherstellung/LeitfadenNachhaltigeBiomasseherstellung.pdf?__blob=publicationFile&v=1* (11.11.2021).

Dachbrodt-Saaydeh, S.; Sellmann, J.; Roßberg, D. (2020): Cluster zur regionalen Erhebung und Analyse der Pflanzenschutzintensität (CEPI) im Ackerbau | Journal für Kulturpflanzen. Julius Kühn-Institut (JKI). *https://doi.org/10.5073/JfK.2019.10.02* (03.01.2024).

Destatis (2022): Produzierendes Gewerbe - Düngemittelversorgung. *https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/Publikationen/Downloads-Fachstatistiken/duengemittelversorgung-jahr-2040820217004.pdf?__blob=publicationFile* (10.01.2024).

Destatis (2023a): Land- und Forstwirtschaft, Fischerei Wachstum und Ernte - Feldfrüchte. *https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Feldfruechte-Gruenland/Publikationen/Downloads-Feldfruechte/feldfruechte-jahr-2030321227164.pdf?__blob=publicationFile* (14.01.2024).

Destatis (2023b): Düngemittelversorgung - Fachserie 4 Reihe 8.2. In: *Statistisches Bundesamt*. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/Publikationen/Downloads-Fachstatistiken/duengemittelversorgung-jahr-2040820217004.html. (10.01.2024).

European Environment Agency (2023): EMEP-Guidebook 2023 - chapter 3.D Agricultural soils. *File*, *https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/3-agriculture/3-d-agricultural-soils-2023/view* (11.01.2024).

Eysholdt, M.; Kunkel, R.; Rösemann, C.; Wendland, F.; Wolters, T.; Zinnbauer, M.; Fuß, R. (2022): A model-based estimate of nitrate leaching in Germany for GHG reporting. In: *Journal of Plant Nutrition and Soil Science*. Vol. 185, No. 6, S. 850–863. 10.1002/jpln.202200119

Fehrenbach, H.; Köppen, S.; Markwardt, S.; Vogt, R. (2016): Aktualisierung der Eingangsdaten und Emissionsbilanzen wesentlicher biogener Energienutzungspfade (BioEm). TEXTE Umweltbundesamt, Dessau-Roßlau.

Fröba, N.; Funk, M. (2004): Partial-Time Specific Diesel Fuel Requirement Calculations for Field Tasks. S. 38–39. *https://www.agricultural-engineering.eu/landtechnik/article/view/2004-59-1-038-039* (17.06.2024).

Fuß, R.; Vos, C.; Rösemann, C. (2023): Emissions of greenhouse gases from agriculture. https://www.thuenen.de/en/thuenen-topics/climate-and-air/emission-inventories-accounting-for-climate-protection/greenhouse-gas-emissions-from-agriculture. (29.11.2023).

German Government (2010): Report from the Federal Republic of Germany under Article 19(2) of Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources. *https://energy.ec.europa.eu/system/files/2023-09/19_2_germany_en.pdf* (15.01.2024).

Hoxha, A.; Christensen, B. (2019): The carbon footprint of fertiliser production: regional reference values. Proceedings / International Fertiliser Society International Fertiliser Society, Colchester. https://fertiliser-society.org/store/the-carbon-footprint-of-fertiliser-production-regional-reference-values/

ICAO (2019): CORSIA Methodology for Calculating Actual Life Cycle Emissions Values. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions%20-%20June%202022.pdf

IPCC (2013a): Climate Change 2013: The Physical Science Basis. Intergovernmental Panel on Climate Change. *https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf* (02.05.2023).

IPCC (2013b): 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. *https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_separate_files/WS_Chp1_Introduction.pdf* (18.03.2024).

IPCC (2019): 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Chapter 11 - N2O Emissions from managed soils, and co2 emissions from lime and urea application. *https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf* (05.03.2024).

Mathivanan, G. P.; Eysholdt, M.; Zinnbauer, M.; Rösemann, C.; Fuß, R. (2021): New N2O emission factors for crop residues and fertiliser inputs to agricultural soils in Germany. In: *Agriculture, Ecosystems & Environment*. Vol. 322, S. 107640. https://doi.org/10.1016/j.agee.2021.107640

Prussi, M.; Yugo, M.; de Prada, L.; Padella, M.; Edwards, M. (2020): JEC Well-To-Wheels report v5. European Commission. *https://publications.jrc.ec.europa.eu/repository/handle/JRC121213* (15.09.2022).

Rösemann, C.; Vos, C.; Haenel, H.-D.; Dämmgen, U.; Döring, U.; Wulf, S.; Eurich-Menden, B.; Freibauer, A.; Döhler, H.; Steuer, B.; Fuß, R. (2023): Calculations of gaseous and particulate emissions from German agriculture 1990 – 2021 - Report on methods and data (RMD) Submission 2023. In: *Thünen Gitlab - DMZ*. https://git-dmz.thuenen.de/vos/EmissionsAgriculture2023. (27.02.2024).

Tegetmeyer, C.; Barthelmes, K.-D.; Busse, S.; Barthelmes, A. (2020): Aggregierte Karte der organischen Böden Deutschland. Greifswald Moor Centrum. *https://www.greifswaldmoor.de/files/dokumente/GMC%20Schriften/2020-01_Tegetmeyer%20et%20al.pdf* (22.05.2023).

Tiemeyer, B.; Freibauer, A.; Borraz, E. A.; Augustin, J.; Bechtold, M.; Beetz, S.; Beyer, C.; Ebli, M.; Eickenscheidt, T.; Fiedler, S.; Förster, C.; Gensior, A.; Giebels, M.; Glatzel, S.; Heinichen, J.; Hoffmann, M.; Höper, H.; Jurasinski, G.; Laggner, A.; Leiber-Sauheitl, K.; Peichl-Brak, M.; Drösler, M. (2020): A new methodology for organic soils in national greenhouse gas inventories: Data synthesis, derivation and application. In: *Ecological Indicators*. Vol. 109, S. 105838. https://doi.org/10.1016/j.ecolind.2019.105838

UBA (2023): Germany. 2023 National Inventory Report (NIR). | UNFCCC. *https://unfccc.int/documents/627785* (08.08.2023).

Vos, C.; Rösemann, C.; Haenel, H.-D.; Dämmgen, U.; Döring, U.; Wulf, S.; Eurich-Menden, B.; Freibauer, A.; Döhler, H.; Steuer, B.; Osterburg, B.; Fuß, R. (2024): Calculations of gaseous and particulate emissions from German agriculture 1990 – 2022 - Report on methods and data (RMD) Submission 2024. In: *GitLab*. https://git-dmz.thuenen.de/vos/emissionsagriculture2024/-/wikis/home. (27.02.2024).

Wittnebel, M.; Frank, S.; Tiemeyer, B. (2023): Aktualisierte Kulisse organischer Böden in Deutschland. Johann Heinrich von Thünen-Institut, DE. https://doi.org/10.3220/DATA20230510130443-0

Zinnbauer, M.; Cailleret, M.; Henseler, M.; Herrmann, F.; Kreins, P.; Kunkel, R.; Nguyen, H.; Tetzlaff, B.; Venohr, M.; Wolters, T.; Wendland, F. (2023): Quantifizierung aktueller und zukünftiger Nährstoffeinträge und Handlungsbedarfe für ein deutschlandweites Nährstoffmanagement – AGRUM-DE. Braunschweig. *https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_108.pdf*.

UBA (2024): Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2024 - National Inventory Report for the German Greenhouse Gas Inventory 1990 – 2021 (forthcoming)

A Annex – Regional Clusters

A.1 NUTS 2 regions in Germany

A.1.1 Geographical distribution of NUTS 2 regions in Germany

Figure 23: A.1 NUTS 2 regions in Germany

Source: EUROSTAT
https://ec.europa.eu/eurostat/documents/345175/17780005/2021-NUTS-2-map-DE.pdf/376e820d-6216-aef2-2929-f8017d0777e3?t=1698686342775

A.1.2 Shares of arable land and grassland in NUTS 2 regions in Germany

Table 4: Arable land and grassland in NUTS 2 regions in Germany, in total area (ha) and percentage (%)

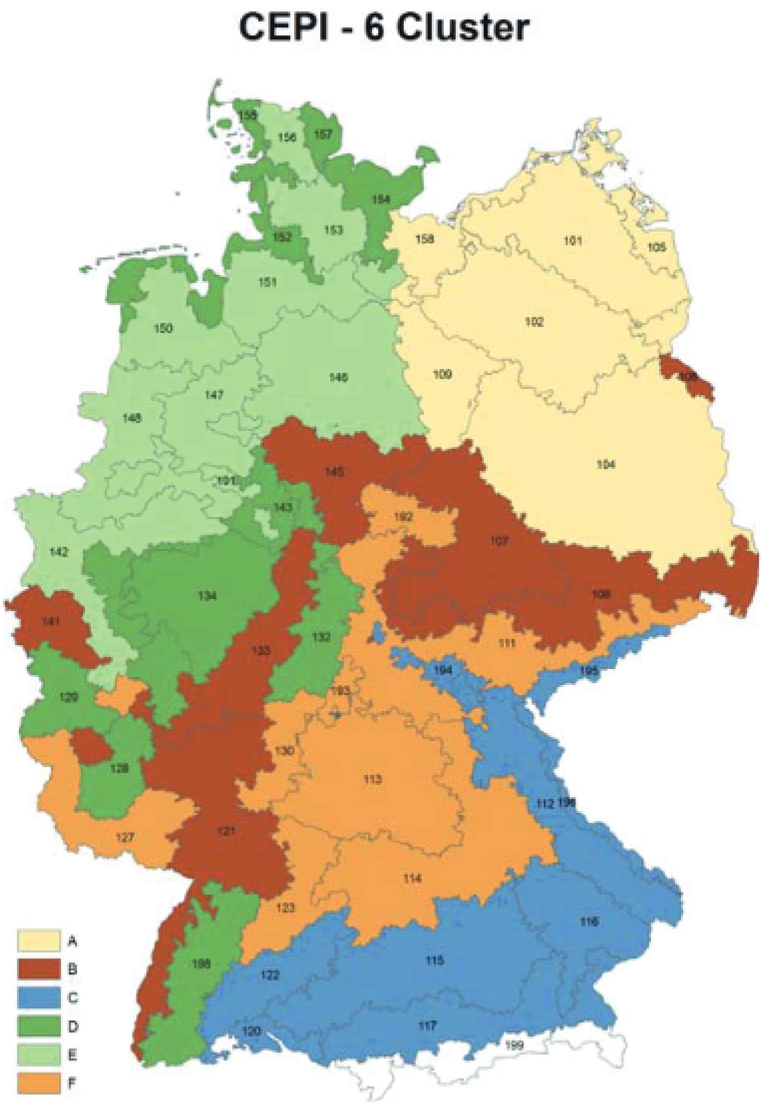
NUTS 2 area	Arable land (ha)	Arable land Share (%)	Grassland (ha)	Grassland Share (%)
Germany	11877013	100%	4874745	100%
Schleswig-Holstein	651470	5.5%	349043	7.2%
Hamburg	5673	0.048%	6424	0.13%
Braunschweig	337974	2.8%	50178	1.0%
Hannover	420795	3.5%	75323	1.5%
Lüneburg	509192	4.3%	286911	5.9%
Weser-Ems	597003	5.0%	322221	6.6%
Bremen	1544	0.0%	6923	0.1%
Düsseldorf	159228	1.3%	60870	1.2%
Köln	180052	1.5%	112112	2.3%
Münster	330192	2.8%	65616	1.3%
Detmold	263377	2.2%	72712	1.5%
Arnsberg	132815	1.1%	112942	2.3%
Darmstadt	157456	1.3%	80344	1.6%
Gießen	116597	1.0%	89946	1.8%
Kassel	212032	1.8%	121556	2.5%
Koblenz	149783	1.3%	103778	2.1%
Trier	73714	0.6%	102143	2.1%
Rheinhessen-Pfalz	172602	1.5%	42988	0.9%
Stuttgart	314753	2.7%	142252	2.9%
Karlsruhe	142087	1.2%	57320	1.2%
Freiburg	144079	1.2%	163299	3.3%
Tübingen	233615	2.0%	188526	3.9%

NUTS 2 area	Arable land (ha)	Arable land Share (%)	Grassland (ha)	Grassland Share (%)
Oberbayern	435107	3.7%	342329	7.0%
Niederbayern	386036	3.3%	140313	2.9%
Oberpfalz	278859	2.3%	122394	2.5%
Oberfranken	213318	1.8%	94141	1.9%
Mittelfranken	237466	2.0%	98856	2.0%
Unterfranken	284978	2.4%	62549	1.3%
Schwaben	243319	2.0%	267097	5.5%
Saarland	37509	0.3%	41172	0.8%
Berlin	1587	0.0%	618	0.0%
Brandenburg	1034886	8.7%	288108	5.9%
Mecklenburg-Vorpommern	1085542	9.1%	267175	5.5%
Chemnitz	281173	2.4%	80445	1.7%
Dresden	236409	2.0%	27091	0.6%
Leipzig	265.827	2.2%	-	-
Sachsen-Anhalt	997529	8.4%	169434	3.5%
Thüringen	613471	5.2%	176872	3.6%

Source: Destatis: https://www.regionalstatistik.de/genesis/online

A.2 CEPI Clusters in Germany for intensity of crop protection in arable farming

Figure 24: Clusters for the regional evaluation and analysis of pesticide use intensity (CEPI) in arable crops



Source: (Dachbrodt-Saaydeh et al. 2020)

Table 5: Assignment of areal proportions (in percent) of CEPI clusters (A – F) within the NUTS 2 areas

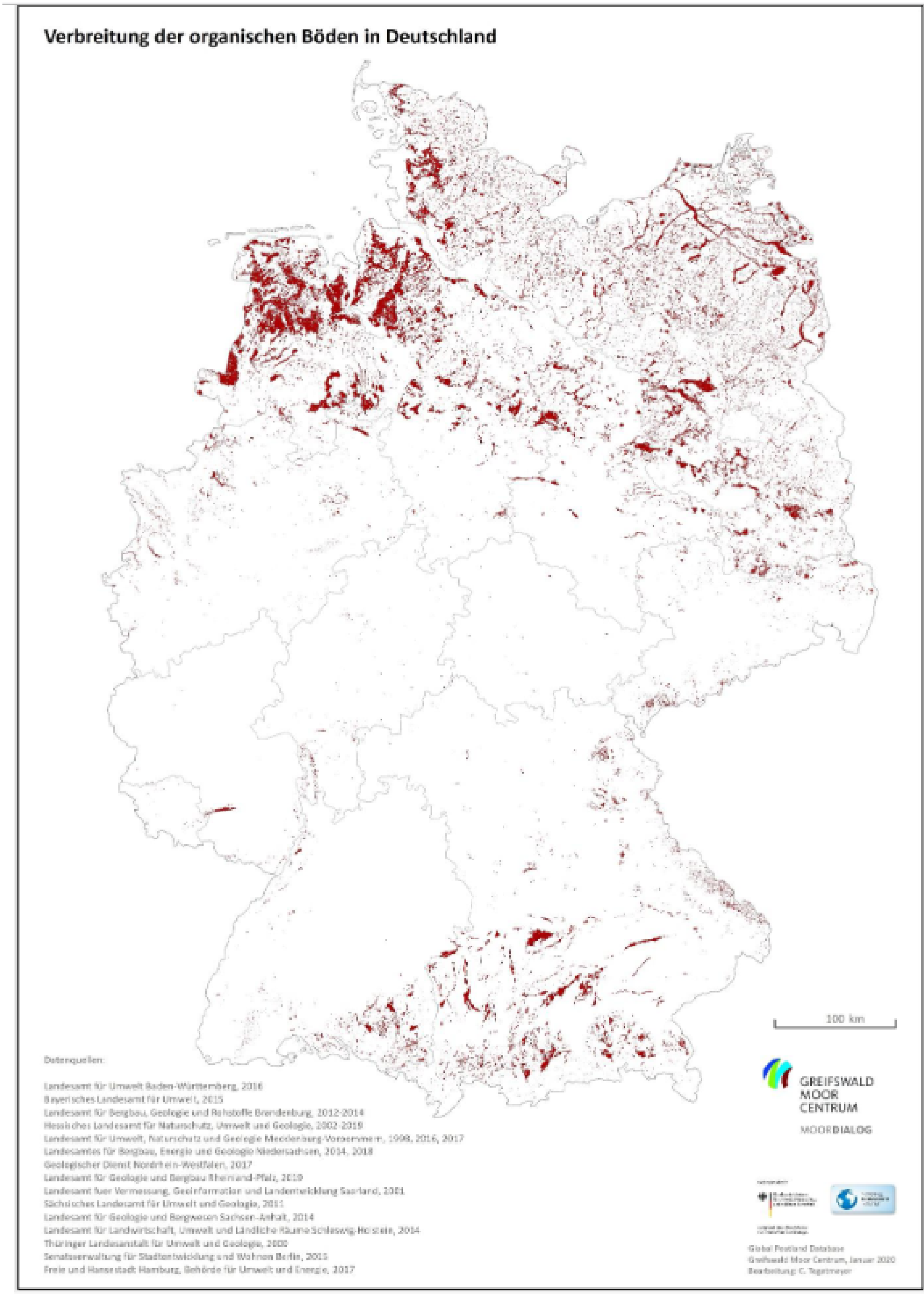
Federal state (NUTS 1)	NUTS 2 area	A	B	C	D	E	F
Schleswig-Holstein	Schleswig-Holstein			50	50		
Hamburg	Hamburg				100		
Niedersachsen	Braunschweig					100	
	Hannover					100	
	Lüneburg					100	
	Weser-Ems				20	80	
Bremen	Bremen					100	
NRW	Düsseldorf		33		33	33	
	Köln		33		33		33
	Münster					100	
	Detmold				50	50	
	Arnsberg		50			50	
Hessen	Darmstadt		50				50
	Gießen		100				
	Kassel		33		33	33	
Rheinland-Pfalz	Koblenz		50		50		
	Trier		33		33		33
	Rheinhessen-Pfalz		50				50
Baden-Württemberg	Stuttgart		50				50
	Karlsruhe		100				
	Freiburg		50		50		
	Tübingen			100			
Bayern	Oberbayern			100			
	Niederbayern			100			
	Oberpfalz			50			50

Federal state (NUTS 1)	NUTS 2 area	A	B	C	D	E	F
	Oberfranken						100
	Mittelfranken						100
	Unterfranken						100
	Schwaben				100		
Saarland	Saarland						100
Berlin	Berlin	100					
Brandenburg	Brandenburg	100					
Mecklenburg-Vorpommern	Mecklenburg-Vorpommern	100					
Sachsen	Chemnitz		50				50
	Dresden		50				50
	Leipzig		100				
Sachsen-Anhalt	Sachsen-Anhalt		100				
Thüringen	Thüringen				50		50

Source: estimation by ifeu, based on the CEPI map (Figure 24)

A.3 Distribution of organic soils (bogs and fens) in Germany.

Figure 25: Distribution of organic soils (bogs and fens) in Germany.



Source: (Tegetmeyer et al. 2020)

B Result tables – GHG emissions from cultivation

B.1 On mineral soils

Table 6: GHG emissions from cultivation of crops (kg d.m.) for wheat (grains)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE F0	Schleswig-Holstein	66.5	34.3	67.8	27.2	6.9	26.3	9.0	**238.0**
DE 60	Hamburg	55.0	16.4	94.6	27.1	9.3	27.1	10.7	**240.2**
DE 91	Braunschweig	51.5	21.6	86.9	22.6	6.6	29.2	9.9	**228.3**
DE 92	Hannover	59.1	28.0	75.8	24.0	6.4	28.7	9.6	**231.6**
DE 93	Lüneburg	73.5	36.7	72.3	30.4	7.4	28.3	11.1	**259.7**
DE 94	Weser-Ems	77.5	49.4	43.2	29.9	7.4	27.2	10.4	**244.9**
DE 50	Bremen	83.9	28.5	60.4	32.3	7.1	29.4	10.7	**252.3**
DE A1	Düsseldorf	98.9	43.5	67.1	26.3	6.4	28.7	9.2	**280.1**
DE A2	Köln	98.4	32.3	81.5	25.3	6.2	29.4	9.0	**282.1**
DE A3	Münster	99.8	51.9	58.5	28.8	6.7	27.4	10.1	**283.2**
DE A4	Detmold	74.4	37.6	80.7	26.7	7.6	29.1	9.9	**266.1**
DE A5	Arnsberg	75.4	34.5	79.1	26.9	5.8	29.9	9.6	**261.2**
DE 71	Darmstadt	62.2	26.5	121.2	26.5	5.6	29.5	10.5	**282.1**
DE 72	Gießen	69.0	20.7	116.8	28.5	5.8	30.9	10.9	**282.6**
DE 73	Kassel	74.7	32.1	104.7	28.8	7.4	29.9	10.7	**288.4**
DE B1	Koblenz	69.8	19.0	96.5	24.8	7.2	30.3	10.2	**257.8**
DE B2	Trier	108.3	22.7	94.7	27.6	7.1	31.1	11.0	**302.4**
DE B3	Rheinhessen-Pfalz	63.0	32.9	104.9	21.3	5.7	31.0	10.8	**269.6**
DE 11	Stuttgart	127.4	29.0	93.7	28.7	5.8	31.5	10.8	**326.9**
DE 12	Karlsruhe	113.4	24.5	107.3	27.4	5.9	31.0	11.0	**320.4**
DE 13	Freiburg	122.2	21.0	97.8	28.4	7.3	31.0	10.4	**318.0**
DE 14	Tübingen	127.2	28.9	75.4	27.5	6.9	31.2	10.1	**307.3**
DE 21	Oberbayern	113.3	21.7	66.1	24.3	7.0	30.1	10.1	**272.4**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE 22	Niederbayern	117.3	26.0	67.0	25.1	6.8	30.2	9.8	**282.3**
DE 23	Oberpfalz	126.8	22.4	78.3	27.3	6.5	30.5	10.7	**302.4**
DE 24	Oberfranken	132.9	16.9	96.7	28.5	7.2	29.7	13.5	**325.4**
DE 25	Mittelfranken	129.0	22.5	79.8	28.0	6.2	29.7	11.6	**306.7**
DE 26	Unterfranken	116.2	18.0	106.0	25.7	6.4	34.1	12.1	**318.4**
DE 27	Schwaben	121.6	27.6	58.8	26.0	6.6	29.3	9.5	**279.5**
DE C0	Saarland	113.2	22.8	122.5	29.8	6.7	35.1	12.6	**342.7**
DE 30	Berlin	58.0	27.6	86.8	28.4	7.6	31.1	10.7	**250.2**
DE 40	Brandenburg	56.1	20.0	102.9	27.5	9.6	32.3	13.4	**261.9**
DE 80	Mecklenb.-Vorp.	49.6	22.3	90.9	24.4	7.5	29.9	10.5	**235.0**
DE D4	Chemnitz	110.3	28.4	94.9	27.5	5.6	30.2	10.6	**307.5**
DE D2	Dresden	71.6	27.1	103.2	27.4	5.9	30.5	11.1	**276.7**
DE D5	Leipzig	54.7	29.1	103.6	26.8	6.3	31.9	11.7	**264.1**
DE E0	Sachsen-Anhalt	52.2	19.2	88.7	25.7	6.5	31.6	12.1	**235.9**
DE G0	Thüringen	71.4	15.8	84.1	23.6	7.9	32.2	11.3	**246.3**

Table 7: GHG emissions from cultivation of crops (kg d.m.) for rye (grains)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE F0	Schleswig-Holstein	62.4	34.2	44.3	25.6	7.4	31.2	8.5	**213.5**
DE 60	Hamburg	51.4	16.0	79.7	29.8	10.5	32.2	11.4	**231.1**
DE 91	Braunschweig	43.9	20.1	66.5	25.3	8.1	34.6	9.7	**208.2**
DE 92	Hannover	54.4	28.6	54.7	25.6	8.2	36.0	9.8	**217.3**
DE 93	Lüneburg	65.7	36.8	43.8	27.1	8.5	34.0	10.1	**226.1**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE 94	Weser-Ems	72.4	51.3	14.3	27.9	8.1	32.0	9.5	**215.4**
DE 50	Bremen	93.7	37.3	31.6	36.0	9.5	34.9	11.4	**254.4**
DE A1	Düsseldorf	90.5	43.3	39.2	24.0	7.5	33.1	8.9	**246.4**
DE A2	Köln	100.2	35.3	66.3	25.7	8.0	35.8	9.5	**280.8**
DE A3	Münster	89.6	50.4	29.0	25.9	7.6	32.2	9.1	**243.8**
DE A4	Detmold	63.6	34.5	53.9	22.8	7.6	33.6	8.7	**224.6**
DE A5	Arnsberg	74.6	36.7	61.5	26.5	7.5	35.7	9.4	**251.9**
DE 71	Darmstadt	52.8	23.5	98.0	25.2	7.1	35.0	9.7	**251.4**
DE 72	Gießen	60.3	19.1	93.1	25.7	7.6	35.3	9.8	**250.9**
DE 73	Kassel	68.0	31.6	80.5	26.6	8.6	34.1	10.2	**259.5**
DE B1	Koblenz	57.4	16.8	73.5	22.1	7.2	35.0	8.5	**220.5**
DE B2	Trier	94.5	21.7	71.9	25.1	7.7	35.6	9.6	**266.1**
DE B3	Rheinhessen-Pfalz	48.7	25.7	82.6	25.3	7.1	35.5	9.7	**234.7**
DE 11	Stuttgart	122.8	29.7	72.6	30.2	8.5	40.7	11.6	**316.0**
DE 12	Karlsruhe	101.0	22.9	86.8	28.9	8.5	35.4	11.1	**294.6**
DE 13	Freiburg	110.9	20.8	74.0	27.6	8.9	35.5	10.5	**288.1**
DE 14	Tübingen	121.8	30.5	46.9	28.4	9.7	35.7	10.9	**284.0**
DE 21	Oberbayern	86.7	19.3	26.1	24.7	8.5	35.8	9.5	**210.6**
DE 22	Niederbayern	99.7	25.3	25.6	27.7	9.5	38.3	10.6	**236.7**
DE 23	Oberpfalz	114.3	22.4	48.0	27.6	8.4	37.1	10.6	**268.4**
DE 24	Oberfranken	106.8	15.3	61.4	32.5	8.8	38.0	12.4	**275.3**
DE 25	Mittelfranken	117.5	22.9	47.8	30.9	8.4	38.0	11.8	**277.3**
DE 26	Unterfranken	95.9	15.9	78.3	32.0	8.6	43.9	12.2	**286.9**
DE 27	Schwaben	110.3	32.0	14.7	28.3	9.7	35.7	10.8	**241.5**
DE C0	Saarland	94.5	20.8	92.8	29.2	7.9	37.2	11.2	**293.5**
DE 30	Berlin	55.4	29.7	62.1	29.8	9.5	41.8	11.4	**239.6**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE 40	Brandenburg	52.5	20.5	83.6	39.1	12.4	43.7	15.0	**266.7**
DE 80	Mecklenburg-Vorpommern	46.5	22.3	79.5	29.1	9.2	36.2	11.1	**234.0**
DE D4	Chemnitz	91.6	24.3	71.2	22.8	6.3	33.9	8.5	**258.6**
DE D2	Dresden	66.7	26.3	84.8	30.4	8.6	41.4	11.6	**269.9**
DE D5	Leipzig	49.1	27.0	83.8	30.5	9.0	39.7	11.7	**250.7**
DE E0	Sachsen-Anhalt	50.0	19.8	71.6	36.6	10.8	48.0	14.0	**250.9**
DE G0	Thüringen	53.6	18.5	57.2	24.1	7.5	34.5	9.2	**204.6**

Table 8: GHG emissions from cultivation of crops (kg d.m.) for maize (grains)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE F0	Schleswig-Holstein	53.7	28.3	49.7	22.0	3.2	31.5	1.6	**190.1**
DE 60	Hamburg	37.9	11.4	66.2	18.7	3.5	32.1	1.7	**171.5**
DE 91	Braunschweig	36.3	15.9	59.2	17.3	3.2	31.8	1.8	**165.5**
DE 92	Hannover	46.2	22.8	55.7	18.7	3.2	31.7	1.8	**180.0**
DE 93	Lüneburg	52.6	27.4	48.0	21.7	3.2	31.0	1.8	**185.7**
DE 94	Weser-Ems	57.6	38.8	21.9	22.2	3.3	31.2	1.8	**176.9**
DE 50	Bremen	58.1	21.1	33.4	22.4	3.0	32.8	1.7	**172.5**
DE A1	Düsseldorf	78.1	35.2	49.9	20.7	3.2	30.9	1.6	**219.7**
DE A2	Köln	73.2	24.9	55.9	18.8	3.2	34.1	1.6	**211.7**
DE A3	Münster	70.8	37.9	34.8	20.4	2.9	30.8	1.6	**199.3**
DE A4	Detmold	52.1	27.2	53.1	18.7	3.2	31.7	1.6	**187.6**
DE A5	Arnsberg	58.0	27.1	58.9	20.7	3.1	31.1	1.6	**200.5**
DE 71	Darmstadt	43.4	18.8	85.4	18.5	3.3	31.7	1.7	**202.7**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE 72	Gießen	47.9	14.6	80.7	19.8	3.4	32.1	1.7	**200.2**
DE 73	Kassel	52.8	23.2	72.6	20.3	3.4	31.2	1.7	**205.3**
DE B1	Koblenz	52.1	14.6	71.2	18.5	3.7	33.4	1.8	**195.2**
DE B2	Trier	74.8	16.3	63.0	19.0	3.5	33.1	1.8	**211.6**
DE B3	Rheinhessen-Pfalz	42.5	22.2	72.8	17.0	3.4	33.9	1.8	**193.6**
DE 11	Stuttgart	82.2	18.9	60.2	18.5	3.0	31.6	1.5	**215.9**
DE 12	Karlsruhe	70.1	15.3	67.4	16.9	3.1	32.7	1.5	**207.1**
DE 13	Freiburg	82.4	14.4	66.2	19.1	3.2	30.7	1.5	**217.6**
DE 14	Tübingen	90.0	20.8	52.9	19.5	3.1	30.6	1.5	**218.3**
DE 21	Oberbayern	80.2	15.6	47.1	17.2	3.1	30.6	1.5	**195.1**
DE 22	Niederbayern	85.5	19.2	48.9	18.3	3.1	31.0	1.5	**207.4**
DE 23	Oberpfalz	82.8	14.9	50.2	17.8	2.9	30.8	1.5	**200.8**
DE 24	Oberfranken	73.3	9.3	55.7	15.7	2.8	32.2	1.5	**190.5**
DE 25	Mittelfranken	79.1	14.0	49.0	17.2	2.8	32.2	1.5	**195.8**
DE 26	Unterfranken	64.0	10.1	59.6	14.5	2.8	31.7	1.5	**184.1**
DE 27	Schwaben	86.3	20.5	38.3	18.5	3.1	30.5	1.5	**198.6**
DE C0	Saarland	75.5	15.4	83.0	19.9	3.3	32.8	1.8	**231.6**
DE 30	Berlin	41.1	20.0	59.6	20.1	3.6	32.1	1.7	**178.1**
DE 40	Brandenburg	35.4	13.2	62.1	21.3	4.8	32.8	2.2	**171.9**
DE 80	Mecklenburg-Vorpommern	38.1	17.8	67.9	20.8	4.7	34.8	2.2	**186.3**
DE D4	Chemnitz	78.9	20.8	63.7	19.6	3.6	33.4	1.9	**221.9**
DE D2	Dresden	48.4	18.6	67.1	18.5	3.6	33.6	1.9	**191.6**
DE D5	Leipzig	31.0	16.9	54.8	17.9	3.8	33.8	1.9	**160.1**
DE E0	Sachsen-Anhalt	32.9	12.8	50.4	21.2	4.5	33.6	2.2	**157.6**
DE G0	Thüringen	45.1	15.4	49.9	3.8	3.9	33.9	1.9	**153.9**

Table 9: GHG emissions from cultivation of crops (kg d.m.) for barlow (grains)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003. as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE F0	Schleswig-Holstein	56.5	30.2	46.8	23.1	4.9	30.2	7.7	**199.4**
DE 60	Hamburg	45.8	14.0	76.0	22.6	5.4	31.1	9.3	**204.3**
DE 91	Braunschweig	40.6	17.8	65.9	19.4	5.6	30.6	8.3	**188.3**
DE 92	Hannover	50.3	25.4	56.6	20.6	6.0	31.0	8.8	**198.8**
DE 93	Lüneburg	64.1	34.7	48.7	26.4	6.9	31.2	10.1	**222.2**
DE 94	Weser-Ems	70.9	49.4	18.2	27.3	6.6	32.0	10.0	**214.3**
DE 50	Bremen	74.2	28.1	34.3	28.5	6.3	33.3	9.3	**214.1**
DE A1	Düsseldorf	84.8	39.4	44.5	22.5	5.5	30.2	8.3	**235.0**
DE A2	Köln	82.3	28.3	60.8	21.1	5.2	31.1	7.8	**236.6**
DE A3	Münster	88.5	49.0	33.6	25.5	6.4	30.4	9.5	**242.9**
DE A4	Detmold	64.0	34.1	59.3	22.9	5.7	31.5	9.0	**226.4**
DE A5	Arnsberg	64.0	31.1	55.7	22.8	6.0	31.9	8.6	**220.2**
DE 71	Darmstadt	50.5	22.3	94.3	22.8	6.5	34.8	9.8	**241.0**
DE 72	Gießen	58.9	18.5	92.6	24.3	7.4	35.2	10.3	**247.2**
DE 73	Kassel	63.6	28.9	79.9	24.5	6.4	33.0	9.7	**246.1**
DE B1	Koblenz	59.0	16.9	77.9	21.0	5.8	33.2	8.9	**222.7**
DE B2	Trier	88.0	19.8	69.5	22.4	6.0	33.9	9.4	**249.0**
DE B3	Rheinhessen-Pfalz	48.4	25.4	82.3	21.8	6.3	33.4	9.4	**226.9**
DE 11	Stuttgart	104.0	24.6	68.0	23.4	6.4	34.3	9.5	**270.3**
DE 12	Karlsruhe	93.7	20.8	84.3	23.0	7.1	34.2	9.9	**272.9**
DE 13	Freiburg	102.6	18.5	75.2	23.8	6.1	32.7	9.4	**268.3**
DE 14	Tübingen	107.2	25.6	53.1	23.2	6.7	32.5	8.9	**257.2**
DE 21	Oberbayern	93.4	19.3	42.6	21.0	6.8	32.5	9.0	**224.7**
DE 22	Niederbayern	98.1	23.0	43.7	21.0	6.6	32.2	8.8	**233.4**
DE 23	Oberpfalz	112.1	21.3	53.9	24.4	7.2	34.7	10.5	**264.1**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003. as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE 24	Oberfranken	101.9	14.2	63.0	28.1	7.4	35.5	12.1	**262.2**
DE 25	Mittelfranken	106.6	20.2	49.5	25.5	6.7	35.5	10.9	**254.8**
DE 26	Unterfranken	91.7	14.8	78.9	25.7	6.8	36.7	11.0	**265.6**
DE 27	Schwaben	101.1	25.7	33.6	21.6	6.4	31.0	8.5	**227.9**
DE C0	Saarland	91.9	19.8	92.8	26.1	6.9	37.9	11.2	**286.6**
DE 30	Berlin	48.8	24.7	64.3	23.8	5.7	34.2	9.3	**210.8**
DE 40	Brandenburg	44.1	16.5	76.5	26.6	6.9	35.5	11.4	**217.4**
DE 80	Mecklenburg-Vorpommern	39.5	18.4	71.2	20.6	5.4	31.3	8.8	**195.2**
DE D4	Chemnitz	88.4	23.3	70.2	22.0	5.9	31.7	8.8	**250.4**
DE D2	Dresden	57.2	22.1	78.4	21.9	6.2	33.7	9.2	**228.6**
DE D5	Leipzig	41.3	22.4	75.4	21.6	6.7	34.1	9.2	**210.7**
DE E0	Sachsen-Anhalt	40.2	15.3	64.7	22.9	7.1	33.7	9.8	**193.6**
DE G0	Thüringen	53.3	18.1	59.5	21.2	5.4	31.8	9.1	**198.4**

Table 10: GHG emissions from cultivation of crops (kg d.m.) for triticale (grains)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE F0	Schleswig-Holstein	65.7	35.1	54.6	26.9	7.0	29.9	7.6	**226.9**
DE 60	Hamburg	54.5	16.6	88.7	26.8	9.1	30.9	9.5	**236.1**
DE 91	Braunschweig	49.8	22.0	78.2	24.6	7.9	33.4	9.1	**224.9**
DE 92	Hannover	61.9	31.2	68.9	25.1	8.0	33.7	9.2	**238.1**
DE 93	Lüneburg	73.0	39.4	56.3	30.1	8.5	33.8	9.8	**250.9**
DE 94	Weser-Ems	80.1	54.6	26.5	30.8	8.1	31.8	9.2	**241.2**
DE 50	Bremen	89.0	33.5	42.4	34.2	8.3	34.7	9.5	**251.6**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE A1	Düsseldorf	101.6	47.1	53.1	26.9	7.4	32.8	8.5	**277.5**
DE A2	Köln	96.8	33.4	69.2	24.9	7.0	33.4	8.0	**272.5**
DE A3	Münster	101.7	55.5	43.2	29.4	7.7	32.0	8.9	**278.5**
DE A4	Detmold	73.9	39.1	68.6	26.5	7.9	33.3	8.7	**258.1**
DE A5	Arnsberg	72.2	34.5	65.8	25.7	6.5	32.2	7.8	**244.7**
DE 71	Darmstadt	57.5	25.1	109.6	24.5	6.5	32.7	8.4	**264.3**
DE 72	Gießen	63.3	19.5	102.2	26.1	6.8	33.0	8.5	**259.4**
DE 73	Kassel	70.0	31.2	90.8	27.0	7.5	33.9	8.5	**268.9**
DE B1	Koblenz	69.8	19.8	91.7	24.8	7.7	35.8	8.8	**258.4**
DE B2	Trier	97.5	21.6	78.2	24.8	7.0	34.4	8.5	**271.9**
DE B3	Rheinhessen-Pfalz	52.5	27.6	88.1	22.5	6.3	34.3	8.3	**239.5**
DE 11	Stuttgart	121.2	28.2	82.7	27.3	6.7	33.7	8.7	**308.5**
DE 12	Karlsruhe	106.8	23.5	97.7	25.8	7.0	35.2	8.8	**304.8**
DE 13	Freiburg	109.5	19.5	82.3	25.4	7.0	33.1	8.0	**284.9**
DE 14	Tübingen	115.4	27.1	61.0	25.0	7.1	31.3	7.6	**274.4**
DE 21	Oberbayern	112.7	23.1	51.1	24.9	8.5	35.6	9.2	**265.2**
DE 22	Niederbayern	117.9	27.5	53.8	25.2	8.1	33.6	8.7	**274.8**
DE 23	Oberpfalz	124.7	23.2	64.4	26.8	7.7	34.6	9.3	**290.7**
DE 24	Oberfranken	115.9	15.6	75.8	28.6	7.7	33.6	10.5	**287.8**
DE 25	Mittelfranken	119.4	21.9	62.8	25.9	6.8	33.6	9.3	**279.8**
DE 26	Unterfranken	109.6	17.7	93.3	30.0	8.1	37.1	11.0	**306.7**
DE 27	Schwaben	108.7	27.7	35.3	23.3	7.3	31.2	7.9	**241.4**
DE C0	Saarland	103.4	21.7	107.2	27.2	7.2	34.7	9.8	**311.3**
DE 30	Berlin	58.0	29.3	75.4	28.3	8.2	40.5	9.5	**249.3**
DE 40	Brandenburg	61.1	22.9	103.1	37.7	11.9	42.4	13.9	**293.0**
DE 80	Mecklenburg-Vorpommern	54.7	26.0	91.8	32.5	10.3	42.4	12.0	**269.6**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE D4	Chemnitz	107.5	28.2	85.8	26.8	6.8	34.7	8.8	**298.6**
DE D2	Dresden	75.4	29.3	98.7	30.6	8.6	36.8	11.3	**290.8**
DE D5	Leipzig	57.0	31.0	99.3	31.8	9.4	39.5	11.7	**279.6**
DE E0	Sachsen-Anhalt	52.6	20.3	80.1	32.7	9.6	43.4	12.0	**250.6**
DE G0	Thüringen	67.3	22.8	74.7	26.0	8.1	35.3	9.6	**243.8**

Table 11: GHG emissions from cultivation of crops (kg d.m.) for sugar beet

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE F0	Schleswig-Holstein	22.2	11.9	21.6	9.1	3.6	9.8	0.8	**79.1**
DE 60	Hamburg	17.0	5.2	34.5	8.4	3.4	10.1	0.9	**79.3**
DE 91	Braunschweig	15.7	6.9	31.6	7.5	4.5	9.9	0.8	**76.9**
DE 92	Hannover	17.9	9.0	25.5	7.3	4.3	9.7	0.8	**74.5**
DE 93	Lüneburg	22.1	11.8	21.6	9.1	4.6	10.3	0.8	**80.4**
DE 94	Weser-Ems	25.6	17.3	9.7	9.9	4.4	9.9	0.8	**77.6**
DE 50	Bremen	26.8	10.1	14.2	10.3	4.6	10.0	0.9	**76.9**
DE A1	Düsseldorf	31.9	14.8	20.1	8.5	3.8	10.1	0.8	**90.0**
DE A2	Köln	32.5	11.2	27.7	8.3	3.8	10.5	0.8	**94.9**
DE A3	Münster	32.5	18.0	13.3	9.4	4.8	10.5	0.9	**89.3**
DE A4	Detmold	22.8	12.1	25.2	8.2	3.8	9.9	0.8	**82.8**
DE A5	Arnsberg	23.3	11.1	25.9	8.3	3.8	9.8	0.7	**83.1**
DE 71	Darmstadt	18.6	8.1	41.6	7.9	3.5	10.3	0.8	**90.7**
DE 72	Gießen	19.6	6.1	37.4	8.1	3.8	10.3	0.8	**86.2**
DE 73	Kassel	22.4	10.0	34.4	8.6	3.9	9.6	0.8	**89.8**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE B1	Koblenz	22.6	6.4	35.9	8.0	3.8	10.8	0.9	**88.3**
DE B2	Trier	31.3	7.0	30.0	8.0	3.4	12.2	0.8	**92.7**
DE B3	Rheinhessen-Pfalz	18.4	9.7	36.9	8.1	3.7	10.4	0.9	**88.1**
DE 11	Stuttgart	37.8	8.9	30.7	8.5	3.5	10.6	0.8	**100.9**
DE 12	Karlsruhe	33.8	7.5	37.1	8.2	4.1	10.4	0.9	**102.0**
DE 13	Freiburg	35.6	6.4	31.7	8.3	3.5	10.0	0.8	**96.2**
DE 14	Tübingen	38.0	9.1	22.9	8.2	3.8	9.8	0.8	**92.7**
DE 21	Oberbayern	31.9	6.5	20.2	6.8	3.5	9.5	0.7	**79.1**
DE 22	Niederbayern	32.9	7.6	21.1	7.0	3.3	9.5	0.7	**82.1**
DE 23	Oberpfalz	32.2	6.0	20.2	6.9	3.0	9.2	0.7	**78.3**
DE 24	Oberfranken	37.9	5.1	31.3	9.0	3.6	10.3	1.0	**98.1**
DE 25	Mittelfranken	38.6	7.1	24.9	8.4	3.2	10.3	0.9	**93.4**
DE 26	Unterfranken	32.9	5.3	35.6	8.3	3.3	10.6	0.9	**97.0**
DE 27	Schwaben	34.0	8.5	15.6	7.3	3.4	9.4	0.7	**78.9**
DE C0	Saarland	31.7	6.6	39.8	8.4	3.1	10.6	0.9	**101.1**
DE 30	Berlin	18.2	9.1	28.9	8.9	3.5	10.7	0.9	**80.3**
DE 40	Brandenburg	17.7	6.5	38.1	9.4	4.2	11.1	1.0	**88.0**
DE 80	Mecklenburg-Vorpommern	15.3	7.1	33.2	7.9	3.5	0.5	0.9	**68.4**
DE D4	Chemnitz	31.1	8.2	28.9	7.8	3.4	9.9	0.8	**90.1**
DE D2	Dresden	20.6	8.0	33.2	7.9	3.6	10.6	0.9	**84.7**
DE D5	Leipzig	16.6	9.0	34.6	9.4	4.9	11.7	1.0	**87.2**
DE E0	Sachsen-Anhalt	16.8	6.5	31.3	10.4	5.4	12.3	1.1	**83.9**
DE G0	Thüringen	21.4	7.3	29.3	8.8	3.7	11.9	1.0	**83.3**

Table 12: GHG emissions from cultivation of crops (kg d.m.) for rapeseed

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE F0	Schleswig-Holstein	121.3	64.6	104.1	49.7	12.7	50.5	1.7	**404.7**
DE 60	Hamburg	89.8	27.3	151.3	44.2	13.9	52.5	1.9	**380.8**
DE 91	Braunschweig	84.4	37.1	135.8	40.9	13.6	54.1	1.9	**367.9**
DE 92	Hannover	97.0	48.9	110.2	39.4	13.1	51.9	1.8	**362.3**
DE 93	Lüneburg	120.8	64.6	97.5	49.8	14.3	49.8	2.0	**398.7**
DE 94	Weser-Ems	126.5	84.8	49.5	48.7	12.5	47.7	1.7	**371.4**
DE 50	Bremen	142.2	53.3	69.9	54.7	13.7	53.6	1.9	**389.2**
DE A1	Düsseldorf	168.3	76.5	101.0	44.7	12.3	47.8	1.6	**452.2**
DE A2	Köln	166.5	56.4	130.0	42.7	12.1	47.1	1.6	**456.4**
DE A3	Münster	168.5	90.7	79.1	48.6	12.7	46.6	1.8	**448.0**
DE A4	Detmold	123.5	65.0	120.2	44.3	13.0	50.2	1.8	**417.9**
DE A5	Arnsberg	136.9	65.1	130.6	48.7	14.2	53.6	1.8	**450.9**
DE 71	Darmstadt	95.5	41.6	183.7	40.7	14.2	50.9	1.8	**428.4**
DE 72	Gießen	109.2	33.7	179.5	45.1	15.3	52.6	1.8	**437.1**
DE 73	Kassel	123.7	55.5	160.7	47.6	14.8	53.3	1.9	**457.5**
DE B1	Koblenz	117.1	33.1	158.1	41.7	14.2	53.8	1.8	**419.8**
DE B2	Trier	166.4	36.5	138.2	42.4	13.8	53.6	1.8	**452.7**
DE B3	Rheinhessen-Pfalz	96.5	50.6	164.1	39.4	14.7	54.6	1.8	**421.7**
DE 11	Stuttgart	198.2	45.9	142.2	44.6	13.7	52.6	1.7	**499.0**
DE 12	Karlsruhe	168.5	36.9	158.0	40.7	14.2	51.6	1.7	**471.7**
DE 13	Freiburg	195.7	34.6	152.7	45.5	13.4	50.0	1.7	**493.5**
DE 14	Tübingen	204.6	47.9	112.9	44.2	13.0	48.7	1.7	**473.0**
DE 21	Oberbayern	184.1	36.7	97.6	39.4	13.3	48.8	1.7	**421.5**
DE 22	Niederbayern	194.9	44.9	97.7	41.7	13.5	49.1	1.7	**443.5**
DE 23	Oberpfalz	206.7	38.0	116.0	44.4	14.2	52.4	1.8	**473.5**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE 24	Oberfranken	197.2	26.4	135.5	47.1	17.0	50.7	2.2	**476.1**
DE 25	Mittelfranken	197.4	35.8	111.2	42.9	14.5	50.7	1.9	**454.3**
DE 26	Unterfranken	176.4	28.0	159.6	42.6	15.3	53.8	2.0	**477.6**
DE 27	Schwaben	195.5	47.6	78.6	41.8	12.6	46.9	1.6	**424.7**
DE C0	Saarland	181.5	38.3	189.7	47.8	17.1	54.8	2.2	**531.4**
DE 30	Berlin	95.8	47.9	130.7	46.8	17.1	53.4	1.9	**393.6**
DE 40	Brandenburg	87.6	32.3	156.5	49.2	20.5	55.8	2.3	**404.2**
DE 80	Mecklenburg-Vorpommern	80.3	37.0	146.1	39.6	16.5	53.3	1.8	**374.5**
DE D4	Chemnitz	185.1	48.6	150.4	46.1	15.5	55.4	1.9	**502.9**
DE D2	Dresden	118.5	45.6	164.3	45.2	16.2	53.5	2.0	**445.4**
DE D5	Leipzig	86.0	46.4	158.7	43.2	16.6	54.1	2.0	**407.0**
DE E0	Sachsen-Anhalt	80.7	30.5	132.9	43.8	16.8	55.7	2.0	**362.3**
DE G0	Thüringen	110.8	37.7	124.9	43.4	15.2	55.7	2.0	**389.7**

Table 13: GHG emissions from cultivation of crops (kg d.m.) for maize (whole plant)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE F0	Schleswig-Holstein	28.5	16.0	32.0	11.7	2.0	17.1	0.9	**108.2**
DE 60	Hamburg	21.1	5.5	47.9	10.4	2.3	17.5	1.0	**105.7**
DE 91	Braunschweig	19.3	5.9	44.7	8.5	1.7	15.4	0.8	**96.3**
DE 92	Hannover	24.4	10.2	41.9	9.9	1.8	15.8	0.9	**104.9**
DE 93	Lüneburg	27.6	14.7	32.6	11.4	1.9	15.7	0.9	**104.9**
DE 94	Weser-Ems	30.4	25.3	16.1	11.7	1.9	16.1	0.9	**102.5**
DE 50	Bremen	32.4	13.0	19.9	12.5	1.9	16.6	1.0	**97.3**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE A1	Düsseldorf	40.7	19.6	31.3	10.8	2.0	16.6	0.9	**121.8**
DE A2	Köln	38.7	11.3	40.0	9.9	1.8	16.1	0.8	**118.7**
DE A3	Münster	40.6	26.1	23.9	11.7	1.9	16.2	1.0	**121.5**
DE A4	Detmold	29.9	14.0	41.4	10.7	2.0	16.5	0.9	**115.4**
DE A5	Arnsberg	29.8	13.0	38.6	10.6	1.8	15.8	0.9	**110.5**
DE 71	Darmstadt	22.7	5.3	58.2	9.7	1.9	16.1	0.9	**114.7**
DE 72	Gießen	24.5	5.5	54.3	10.1	1.9	16.7	0.9	**113.9**
DE 73	Kassel	27.4	9.5	49.5	10.6	1.9	16.3	0.9	**116.2**
DE B1	Koblenz	27.0	6.0	48.4	9.6	2.2	17.3	0.9	**111.4**
DE B2	Trier	41.9	8.3	44.2	10.7	2.3	18.4	1.0	**126.8**
DE B3	Rheinhessen-Pfalz	22.2	3.5	49.4	9.2	2.1	17.6	1.0	**104.9**
DE 11	Stuttgart	45.2	8.3	43.9	10.2	1.8	16.1	0.8	**126.4**
DE 12	Karlsruhe	41.3	5.8	52.4	10.0	2.0	16.5	0.9	**129.0**
DE 13	Freiburg	45.0	6.7	45.8	10.5	2.1	17.1	0.9	**128.1**
DE 14	Tübingen	47.1	10.4	35.2	10.2	1.9	16.6	0.8	**122.2**
DE 21	Oberbayern	38.8	7.2	31.5	8.3	1.6	15.2	0.7	**103.4**
DE 22	Niederbayern	43.5	9.4	34.1	9.3	1.7	15.6	0.8	**114.4**
DE 23	Oberpfalz	48.1	8.2	38.6	10.3	1.9	16.1	0.9	**124.0**
DE 24	Oberfranken	42.8	4.9	42.8	9.2	1.9	16.3	0.9	**118.7**
DE 25	Mittelfranken	48.4	8.3	38.1	10.5	2.0	16.3	1.0	**124.4**
DE 26	Unterfranken	40.3	4.5	49.6	9.2	2.0	16.7	1.0	**123.2**
DE 27	Schwaben	44.2	11.0	27.0	9.5	1.7	15.2	0.8	**109.4**
DE C0	Saarland	46.9	7.7	63.9	12.4	2.6	19.7	1.2	**154.5**
DE 30	Berlin	22.8	10.4	41.6	11.1	2.3	17.0	1.0	**106.1**
DE 40	Brandenburg	22.7	7.2	51.1	14.1	3.5	17.9	1.5	**118.1**
DE 80	Mecklenburg-Vorpommern	20.5	6.3	48.8	10.9	2.7	18.1	1.1	**108.6**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE D4	Chemnitz	44.4	9.6	44.7	11.0	2.4	18.4	1.1	**131.6**
DE D2	Dresden	28.4	8.1	49.5	11.5	2.6	19.6	1.2	**120.9**
DE D5	Leipzig	20.7	8.1	46.9	12.3	2.9	19.4	1.3	**111.5**
DE E0	Sachsen-Anhalt	20.4	6.5	42.8	12.6	3.0	19.6	1.3	**106.2**
DE G0	Thüringen	26.7	7.0	40.9	10.8	2.5	18.3	1.1	**107.2**

Table 14: GHG emissions from cultivation of crops (kg d.m.) for wheat (whole plant)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE F0	Schleswig-Holstein	40.6	20.6	50.9	16.6	4.9	17.4	5.7	**156.8**
DE 60	Hamburg	37.6	9.4	87.4	18.5	7.0	18.8	7.2	**185.8**
DE 91	Braunschweig	31.1	8.9	70.5	13.7	4.5	17.6	6.1	**152.5**
DE 92	Hannover	36.2	14.2	61.3	14.7	4.5	18.9	6.1	**156.0**
DE 93	Lüneburg	41.0	19.6	53.9	16.9	4.5	20.3	6.1	**162.3**
DE 94	Weser-Ems	46.6	34.1	32.8	18.0	4.8	18.5	6.1	**160.8**
DE 50	Bremen	56.8	20.1	51.5	21.8	5.3	19.4	7.2	**182.1**
DE A1	Düsseldorf	75.6	32.6	64.5	20.1	5.6	19.7	7.3	**225.4**
DE A2	Köln	76.5	20.9	80.8	19.7	5.6	18.2	7.3	**229.1**
DE A3	Münster	71.5	40.6	52.5	20.7	5.5	18.6	7.3	**216.7**
DE A4	Detmold	53.6	23.4	75.4	19.2	6.3	20.0	7.3	**205.3**
DE A5	Arnsberg	58.3	23.0	79.6	20.8	4.9	18.1	7.3	**212.1**
DE 71	Darmstadt	39.4	8.8	99.4	16.8	4.0	19.5	6.7	**194.5**
DE 72	Gießen	42.9	9.1	94.8	17.7	4.0	20.5	6.7	**195.7**
DE 73	Kassel	47.2	15.2	86.1	18.2	5.2	19.0	6.7	**197.5**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutrali-sation	Pesti-cide			
DE B1	Koblenz	49.0	9.8	90.2	17.4	5.4	20.9	7.0	**199.7**
DE B2	Trier	69.7	12.1	81.3	17.7	5.0	20.7	7.0	**213.5**
DE B3	Rheinhessen-Pfalz	41.2	5.9	90.8	13.9	4.1	20.6	7.0	**183.6**
DE 11	Stuttgart	76.3	13.1	74.5	17.2	3.8	20.1	6.5	**211.6**
DE 12	Karlsruhe	66.9	8.9	84.0	16.2	3.9	20.6	6.5	**206.9**
DE 13	Freiburg	75.0	10.2	78.8	17.4	5.1	19.8	6.5	**212.7**
DE 14	Tübingen	79.8	16.5	61.6	17.3	5.0	20.8	6.5	**207.3**
DE 21	Oberbayern	82.8	14.9	65.6	17.7	5.6	20.8	7.3	**214.8**
DE 22	Niederbayern	86.8	18.2	65.5	18.6	5.6	18.3	7.3	**220.3**
DE 23	Oberpfalz	88.9	14.1	73.6	19.1	5.0	20.2	7.3	**228.3**
DE 24	Oberfranken	80.1	8.6	82.5	17.2	4.3	20.0	7.3	**220.0**
DE 25	Mittelfranken	86.0	13.3	73.7	18.7	4.3	19.6	7.3	**222.9**
DE 26	Unterfranken	74.7	7.6	92.5	16.5	4.3	19.5	7.3	**222.4**
DE 27	Schwaben	87.6	21.2	52.1	18.7	5.6	20.7	7.3	**213.3**
DE C0	Saarland	63.8	9.3	92.7	16.8	3.8	19.5	6.5	**212.4**
DE 30	Berlin	39.6	16.5	76.5	19.4	5.7	17.9	7.2	**182.8**
DE 40	Brandenburg	53.7	14.2	137.7	26.3	8.5	20.4	10.8	**271.6**
DE 80	Mecklenburg-Vorpommern	34.5	9.1	85.5	17.0	5.6	19.8	7.0	**178.4**
DE D4	Chemnitz	74.0	13.5	84.2	18.4	4.2	20.9	7.1	**222.3**
DE D2	Dresden	46.8	11.0	89.7	17.9	4.2	26.2	7.1	**202.8**
DE D5	Leipzig	35.1	10.6	89.6	17.2	4.2	19.6	7.1	**183.5**
DE E0	Sachsen-Anhalt	36.3	9.4	85.5	17.8	4.6	20.2	7.7	**181.7**
DE G0	Thüringen	49.2	10.7	80.6	16.3	5.8	20.6	7.4	**190.6**

Table 15: GHG emissions from cultivation of crops (kg d.m.) for field grass (whole plant)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE F0	Schleswig-Holstein	58.4	27.0	83.0	23.9	0.0	8.3	0.6	**201.3**
DE 60	Hamburg	42.2	11.0	91.6	20.8	0.0	8.3	0.6	**174.4**
DE 91	Braunschweig	44.6	12.3	93.7	19.6	0.0	8.3	0.6	**179.1**
DE 92	Hannover	51.4	19.5	85.3	20.9	0.0	8.3	0.6	**186.1**
DE 93	Lüneburg	56.2	26.5	77.8	23.2	0.0	8.3	0.6	**192.7**
DE 94	Weser-Ems	62.1	45.9	54.1	24.0	0.0	8.3	0.6	**194.9**
DE 50	Bremen	62.5	26.1	45.7	24.0	0.0	8.3	0.6	**167.1**
DE A1	Düsseldorf	94.0	51.4	69.4	24.9	0.0	8.3	0.6	**248.7**
DE A2	Köln	89.6	31.6	83.3	23.3	0.0	8.3	0.6	**236.6**
DE A3	Münster	89.2	64.6	54.1	25.8	0.0	8.3	0.6	**242.6**
DE A4	Detmold	63.4	35.9	77.4	23.3	0.0	8.3	0.6	**208.9**
DE A5	Arnsberg	65.4	34.6	76.0	23.3	0.0	8.3	0.6	**208.2**
DE 71	Darmstadt	45.3	12.9	107.7	23.4	0.0	8.3	0.6	**198.3**
DE 72	Gießen	50.2	13.4	101.4	23.4	0.0	8.3	0.6	**197.3**
DE 73	Kassel	57.4	24.7	92.9	23.4	0.0	8.3	0.6	**207.3**
DE B1	Koblenz	59.3	13.5	101.2	21.1	0.0	8.3	0.6	**203.9**
DE B2	Trier	87.2	17.2	93.9	22.2	0.0	8.3	0.6	**229.5**
DE B3	Rheinhessen-Pfalz	54.7	8.4	110.3	20.7	0.0	8.3	0.6	**202.9**
DE 11	Stuttgart	100.1	19.7	90.8	22.5	0.0	8.3	0.6	**242.1**
DE 12	Karlsruhe	85.8	12.8	100.6	20.7	0.0	8.3	0.6	**228.8**
DE 13	Freiburg	96.5	14.9	94.4	22.4	0.0	8.3	0.6	**237.2**
DE 14	Tübingen	107.0	25.4	77.0	23.1	0.0	8.3	0.6	**241.4**
DE 21	Oberbayern	98.6	16.5	82.4	21.1	0.0	8.3	0.6	**227.4**
DE 22	Niederbayern	105.7	20.2	86.3	22.7	0.0	8.3	0.6	**243.8**
DE 23	Oberpfalz	104.5	15.7	90.1	22.5	0.0	8.3	0.6	**241.7**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE 24	Oberfranken	94.8	9.7	95.0	20.3	0.0	8.3	0.6	**228.8**
DE 25	Mittelfranken	101.8	14.8	90.0	22.1	0.0	8.3	0.6	**237.7**
DE 26	Unterfranken	92.0	8.9	106.2	20.3	0.0	8.3	0.6	**236.3**
DE 27	Schwaben	107.0	23.5	75.5	22.9	0.0	8.3	0.6	**237.8**
DE C0	Saarland	76.6	14.6	101.9	25.0	0.0	8.3	0.6	**227.0**
DE 30	Berlin	47.1	21.2	87.6	23.0	0.0	8.3	0.6	**187.8**
DE 40	Brandenburg	42.7	14.5	101.7	30.8	0.0	8.3	0.6	**198.6**
DE 80	Mecklenburg-Vorpommern	38.6	15.2	91.3	31.1	0.0	8.3	0.6	**185.1**
DE D4	Chemnitz	82.7	16.1	89.4	20.6	0.0	8.3	0.6	**217.8**
DE D2	Dresden	51.8	13.0	93.6	19.8	0.0	8.3	0.6	**187.1**
DE D5	Leipzig	39.7	12.7	95.1	19.5	0.0	8.3	0.6	**175.9**
DE E0	Sachsen-Anhalt	45.7	15.7	99.2	32.9	0.0	8.3	0.6	**202.5**
DE G0	Thüringen	61.7	13.0	94.3	20.4	0.0	8.3	0.6	**198.2**

Table 16: GHG emissions from cultivation of crops (kg d.m.) for grassland cuttings

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE F0	Schleswig-Holstein	52.4	29.3	53.0	21.4	0.0	24.6	0.0	**180.7**
DE 60	Hamburg	38.5	10.6	73.6	21.7	0.0	24.6	0.0	**169.0**
DE 91	Braunschweig	42.4	12.8	82.9	18.6	0.0	24.6	0.0	**181.3**
DE 92	Hannover	49.2	21.0	68.1	20.0	0.0	24.6	0.0	**182.8**
DE 93	Lüneburg	48.5	28.1	44.1	20.0	0.0	24.6	0.0	**165.4**
DE 94	Weser-Ems	55.6	50.1	18.0	21.4	0.0	24.6	0.0	**169.8**
DE 50	Bremen	55.6	28.3	2.8	21.7	0.0	24.6	0.0	**133.0**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE A1	Düsseldorf	73.0	57.7	6.8	27.5	0.0	24.6	0.0	**189.5**
DE A2	Köln	71.0	34.6	29.8	27.5	0.0	24.6	0.0	**187.5**
DE A3	Münster	74.2	73.6	3.5	27.5	0.0	24.6	0.0	**203.3**
DE A4	Detmold	51.8	39.8	24.9	27.5	0.0	24.6	0.0	**168.6**
DE A5	Arnsberg	54.9	38.5	24.9	27.5	0.0	24.6	0.0	**170.4**
DE 71	Darmstadt	37.3	12.5	77.3	24.8	0.0	24.6	0.0	**176.4**
DE 72	Gießen	38.5	12.6	58.7	24.8	0.0	24.6	0.0	**159.2**
DE 73	Kassel	41.8	24.2	40.3	24.8	0.0	24.6	0.0	**155.7**
DE B1	Koblenz	44.7	13.0	61.2	23.4	0.0	24.6	0.0	**166.9**
DE B2	Trier	62.5	16.8	42.6	23.4	0.0	24.6	0.0	**169.9**
DE B3	Rheinhessen-Pfalz	47.2	8.0	92.2	23.4	0.0	24.6	0.0	**195.4**
DE 11	Stuttgart	91.4	21.8	60.0	24.6	0.0	24.6	0.0	**222.4**
DE 12	Karlsruhe	70.0	13.0	69.9	24.6	0.0	24.6	0.0	**202.0**
DE 13	Freiburg	86.7	15.9	63.4	24.6	0.0	24.6	0.0	**215.3**
DE 14	Tübingen	99.2	28.8	40.5	24.6	0.0	24.6	0.0	**217.6**
DE 21	Oberbayern	100.0	20.1	60.7	21.4	0.0	24.6	0.0	**226.8**
DE 22	Niederbayern	100.0	24.6	55.1	21.4	0.0	24.6	0.0	**225.7**
DE 23	Oberpfalz	99.7	18.5	62.1	21.4	0.0	24.6	0.0	**226.3**
DE 24	Oberfranken	100.0	11.4	87.5	21.4	0.0	24.6	0.0	**245.0**
DE 25	Mittelfranken	98.7	17.5	64.7	21.4	0.0	24.6	0.0	**226.9**
DE 26	Unterfranken	97.1	10.3	106.7	21.5	0.0	24.6	0.0	**260.1**
DE 27	Schwaben	100.0	28.8	36.2	21.4	0.0	24.6	0.0	**211.0**
DE C0	Saarland	60.3	13.8	58.5	26.5	0.0	24.6	0.0	**183.7**
DE 30	Berlin	37.7	21.2	46.8	21.7	0.0	24.6	0.0	**152.1**
DE 40	Brandenburg	32.5	12.4	60.4	29.3	0.0	24.6	0.0	**159.1**
DE 80	Mecklenburg-Vorpommern	32.5	15.1	57.9	33.3	0.0	24.6	0.0	**163.4**

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Soil N_2O		Embedded			Fuel use	Seed	Total
		Direct	Indirect	Fertiliser	Neutralisation	Pesticide			
DE D4	Chemnitz	64.0	17.8	46.1	21.9	0.0	24.6	0.0	**174.4**
DE D2	Dresden	41.7	14.0	59.2	21.9	0.0	24.6	0.0	**161.5**
DE D5	Leipzig	32.5	13.7	64.2	21.9	0.0	24.6	0.0	**156.9**
DE E0	Sachsen-Anhalt	32.5	13.1	48.0	30.3	0.0	24.6	0.0	**148.4**
DE G0	Thüringen	54.3	15.3	69.2	24.8	0.0	24.6	0.0	**188.1**

B.2 On organic soils

Table 17: Total Greenhouse gas emissions arising from the cultivation of Wheat (grains), Rye (grains), Maize (grains), Barley (grains), Triticale (grains) and sugar beet in Germany on organic soils (kg CO_2-eq/tonne harvested good on dry matter basis)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Wheat (grains)	Rye (grains)	Maize (grains)	Barley (grains)	Triticale (grains)	Sugar beet
DE F0	Schleswig-Holstein	811	960	720	802	922	318
DE 60	Hamburg	942	1264	720	957	1130	349
DE 91	Braunschweig	870	1077	755	851	1066	335
DE 92	Hannover	855	1094	768	903	1090	319
DE 93	Lüneburg	971	1122	766	1019	1148	343
DE 94	Weser-Ems	896	1036	745	984	1063	333
DE 50	Bremen	940	1263	709	950	1126	341
DE A3	Münster	910	1029	707	972	1073	356
DE A4	Detmold	899	990	708	931	1050	334
DE 71	Darmstadt	971	1122	760	1025	1050	352
DE 14	Tübingen	961	1260	720	965	978	342
DE 21	Oberbayern	934	1065	692	950	1124	311
DE 22	Niederbayern	919	1189	699	930	1083	294

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Wheat (grains)	Rye (grains)	Maize (grains)	Barley (grains)	Triticale (grains)	Sugar beet
DE 24	Oberfranken	1225	1412	695	1245	1287	412
DE 27	Schwaben	898	1208	690	901	969	297
DE 40	Brandenburg	1146	1625	910	1136	1597	413
DE 80	Mecklenburg-Vorpommern	920	1238	902	904	1389	340

Table 18: Total Greenhouse gas emissions arising from the cultivation of Rapeseed, Maize (whole plant), Wheat (whole plant), Field grass and grassland cuttings in Germany on organic soils (kg CO_2-eq/tonne harvested good on dry matter basis)

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		Rapeseed	Maize (whole plant)	Wheat (whole plant)	Field grass	Grassland cuttings
DE F0	Schleswig-Holstein	1669	401	524	669	651
DE 60	Hamburg	1796	428	661	831	829
DE 91	Braunschweig	1765	375	553	720	723
DE 92	Hannover	1705	398	554	724	721
DE 93	Lüneburg	1844	409	553	721	699
DE 94	Weser-Ems	1605	389	537	703	679
DE 50	Bremen	1774	411	645	807	776
DE A3	Münster	1692	420	670	998	963
DE A4	Detmold	1711	405	678	996	963
DE 71	Darmstadt	1740	401	641	1017	1002
DE 14	Tübingen	1701	398	630	937	917
DE 21	Oberbayern	1688	343	697	743	736
DE 22	Niederbayern	1713	365	697	753	735
DE 24	Oberfranken	2120	429	709	751	760
DE 27	Schwaben	1607	360	689	745	719
DE 40	Brandenburg	2104	607	983	1270	1241

NUTS 2 region in accordance with Regulation (EC) No 1059/2003, as last amended by Delegated Regulation (EU) 2023/674		**Rapeseed**	**Maize (whole plant)**	**Wheat (whole plant)**	**Field grass**	**Grassland cuttings**
DE 80	Mecklenburg-Vorpommern	1733	487	645	1267	1249

C Detailed data

C.1 Data for yields, fertiliser, pesticide, seeding material, Diesel and electricity consumption per crop

Table 19: Wheat (grains) - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	74.2	147	72	25	2	166	2.27	240	9.84	5.11
Schleswig-Holstein	88.2	142	121	7	0.0	166	2.65	240	8.26	5.11
Hamburg	74.2	184	35	39	4	166	3.00	240	8.61	5.11
Braunschweig	80.2	161	37	45	5	166	2.30	240	9.57	5.11
Hannover	82.3	147	69	31	0	166	2.30	240	9.35	5.11
Lüneburg	71.4	127	110	4	0	166	2.30	240	9.17	5.11
Weser-Ems	76.1	80	169	0	0	166	2.44	240	8.68	5.11
Bremen	74.2	93	170	1	0	166	2.30	240	9.69	5.11
Düsseldorf	85.9	134	113	9	0	166	2.38	240	9.37	5.11
Köln	87.9	163	80	28	0	166	2.38	240	9.69	5.11
Münster	78.5	108	140	0	0	166	2.30	240	8.75	5.11
Detmold	79.8	147	86	22	0	166	2.65	240	9.55	5.11
Arnsberg	83.0	152	92	15	0	166	2.07	240	9.94	5.11
Darmstadt	75.1	191	27	47	14	166	1.84	240	9.72	5.11
Gießen	72.7	182	45	36	0	166	1.85	240	10.37	5.11
Kassel	73.8	167	66	26	0	166	2.38	240	9.93	5.11
Koblenz	77.3	167	43	39	0	166	2.42	240	10.08	5.11
Trier	71.9	154	63	29	0	166	2.22	240	10.48	5.11
Rheinhessen-Pfalz	73.5	163	8	54	33	166	1.84	240	10.44	5.11
Stuttgart	73.3	164	66	27	0	166	1.84	240	10.65	5.11
Karlsruhe	72.2	181	35	42	6	166	1.85	240	10.41	5.11
Freiburg	76.4	178	59	32	0	166	2.42	240	10.42	5.11

NUTS2 region	**Yield**	**Fertiliser**					**Pesti-cides**	**Seeds**	**Diesel**	**Electri-city**
		Nitrogen		**Phos-phorous**	**Potas-sium**	**Lime**				
	dt/ (ha•a)	**synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Tübingen	78.7	143	94	17	0	166	2.38	240	10.52	5.11
Oberbayern	78.6	119	90	14	0	166	2.38	240	9.99	5.11
Niederbayern	80.6	124	98	14	0	166	2.38	240	10.06	5.11
Oberpfalz	74.4	134	88	15	0	166	2.10	240	10.19	5.11
Oberfranken	58.7	129	54	20	0	166	1.82	240	9.82	5.11
Mittelfranken	68.1	125	84	13	0	166	1.82	240	9.82	5.11
Unterfranken	65.5	154	30	38	6	166	1.82	240	11.85	5.11
Schwaben	83.1	113	124	8	0	166	2.38	240	9.65	5.11
Saarland	63.0	166	40	28	0	166	1.82	240	12.34	5.11
Berlin	74.2	154	77	26	0	166	2.46	240	10.48	5.11
Brandenburg	59.1	143	35	26	0	166	2.46	240	11.04	5.11
Mecklenb.-Vorp.	75.6	172	29	42	10	166	2.46	240	9.92	5.11
Chemnitz	74.9	165	60	29	0	166	1.84	240	10.07	5.11
Dresden	71.6	170	44	37	0	166	1.84	240	10.20	5.11
Leipzig	67.8	161	38	37	0	166	1.85	240	10.86	5.11
Sachsen-Anhalt	65.7	144	40	33	0	166	1.85	240	10.71	5.11
Thüringen	70.2	141	40	36	0	166	2.41	240	10.98	5.11

Table 20: Rye (grains) - fertiliser. pesticide. seeds. Diesel and electricity consumption

NUTS2 region	**Yield**	**Fertiliser**					**Pesti-cides**	**Seeds**	**Diesel**	**Electri-city**
		Nitrogen		**Phos-phorous**	**Potas-sium**	**Lime**				
	dt/ (ha•a)	**synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	50.8	73	69	14	1	166	2.06	160	13.1	5.55
Schleswig-Holstein	68.6	71	121	0	0	166	2.22	160	10.2	5.55
Hamburg	50.8	105	35	21	0	166	2.32	160	10.6	5.55
Braunschweig	59.9	89	37	31	0	166	2.11	160	11.8	5.55

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser** **Nitrogen** **synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)	**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
Hannover	59.3	74	69	17	0	166	2.11	160	12.4	5.55
Lüneburg	57.2	60	110	0	0	166	2.11	160	11.5	5.55
Weser-Ems	61.2	18	169	0	0	166	2.15	160	10.6	5.55
Bremen	50.8	31	170	0	0	166	2.11	160	11.9	5.55
Düsseldorf	65.0	58	113	0	0	166	2.13	160	11.0	5.55
Köln	61.4	93	80	8	0	166	2.13	160	12.3	5.55
Münster	63.8	41	140	0	0	166	2.11	160	10.7	5.55
Detmold	66.9	81	86	10	0	166	2.22	160	11.3	5.55
Arnsberg	61.9	88	92	3	0	166	2.03	160	12.2	5.55
Darmstadt	60.1	121	27	35	8	166	1.86	160	11.9	5.55
Gießen	59.1	116	45	25	0	166	1.94	160	12.1	5.55
Kassel	57.1	98	66	14	0	166	2.13	160	11.5	5.55
Koblenz	68.5	110	43	31	0	166	2.13	160	11.9	5.55
Trier	60.4	96	63	21	0	166	2.02	160	12.2	5.55
Rheinhessen-Pfalz	60.0	100	8	42	29	166	1.86	160	12.2	5.55
Stuttgart	50.3	86	66	11	0	166	1.86	160	14.6	5.55
Karlsruhe	52.5	105	35	26	0	166	1.94	160	12.1	5.55
Freiburg	55.0	96	59	14	0	166	2.13	160	12.2	5.55
Tübingen	53.4	60	94	0	0	166	2.26	160	12.3	5.55
Oberbayern	61.4	35	90	0	0	166	2.26	160	12.3	5.55
Niederbayern	54.7	30	98	0	0	166	2.26	160	13.5	5.55
Oberpfalz	55.0	60	88	1	0	166	2.02	160	12.9	5.55
Oberfranken	46.7	63	54	10	0	166	1.78	160	13.4	5.55
Mittelfranken	49.0	53	84	0	0	166	1.78	160	13.4	5.55
Unterfranken	47.4	80	30	24	0	166	1.78	160	16.1	5.55
Schwaben	53.7	15	124	0	0	166	2.26	160	12.3	5.55
Saarland	52.0	102	40	19	0	166	1.78	160	12.9	5.55

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser**					**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
		Nitrogen		**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)				
		synth. kg N/ (ha•a)	**organ.** kg N/ (ha•a)							
Berlin	50.8	74	77	8	0	166	2.09	160	15.1	5.55
Brandenburg	38.7	74	35	14	0	166	2.09	160	16.0	5.55
Mecklenb.-Vorp.	52.1	101	29	29	4	166	2.09	160	12.5	5.55
Chemnitz	68.2	110	60	25	0	166	1.86	160	11.4	5.55
Dresden	49.9	95	44	23	0	166	1.86	160	14.9	5.55
Leipzig	49.8	93	38	25	0	166	1.94	160	14.1	5.55
Sachsen-Anhalt	41.4	71	40	17	0	166	1.94	160	18.0	5.55
Thüringen	63.0	82	40	30	0	166	2.05	160	11.7	5.55

Table 21: Maize (grains) - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser**					**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
		Nitrogen		**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)				
		synth. kg N/ (ha•a)	**organ.** kg N/ (ha•a)							
Germany (area weighted average)	95	109	69	31	2	166	1.36	43.8	8.25	8.74
Schleswig-Holstein	96	110	121	14	0	166	1.34	43.8	7.85	8.74
Hamburg	95	159	35	50	9	166	1.45	43.8	8.13	8.74
Braunschweig	88	116	37	44	4	166	1.24	43.8	7.97	8.74
Hannover	88	111	69	36	0	166	1.24	43.8	7.94	8.74
Lüneburg	88	99	110	17	0	166	1.24	43.8	7.62	8.74
Weser-Ems	88	45	169	0	0	166	1.28	43.8	7.72	8.74
Bremen	95	64	170	5	0	166	1.24	43.8	8.44	8.74
Düsseldorf	98	109	113	21	0	166	1.36	43.8	7.58	8.74
Köln	98	121	80	29	0	166	1.36	43.8	9.06	8.74
Münster	98	79	140	0	0	166	1.24	43.8	7.53	8.74
Detmold	98	114	86	30	0	166	1.34	43.8	7.96	8.74
Arnsberg	98	129	92	26	0	166	1.32	43.8	7.68	8.74

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Darmstadt	93	162	27	55	18	166	1.34	43.8	7.93	8.74
Gießen	93	157	45	47	0	166	1.40	43.8	8.15	8.74
Kassel	93	142	66	38	0	166	1.36	43.8	7.74	8.74
Koblenz	89	138	43	46	1	166	1.43	43.8	8.72	8.74
Trier	89	123	63	36	0	166	1.38	43.8	8.62	8.74
Rheinhessen-Pfalz	89	132	8	59	34	166	1.34	43.8	8.99	8.74
Stuttgart	103	142	66	42	0	166	1.34	43.8	7.89	8.74
Karlsruhe	103	155	35	54	13	166	1.40	43.8	8.43	8.74
Freiburg	103	156	59	48	0	166	1.43	43.8	7.51	8.74
Tübingen	103	125	94	34	0	166	1.39	43.8	7.42	8.74
Oberbayern	105	107	90	34	0	166	1.39	43.8	7.43	8.74
Niederbayern	105	112	98	33	0	166	1.39	43.8	7.61	8.74
Oberpfalz	105	116	88	30	0	166	1.33	43.8	7.52	8.74
Oberfranken	105	126	54	45	0	166	1.28	43.8	8.18	8.74
Mittelfranken	105	113	84	30	0	166	1.28	43.8	8.18	8.74
Unterfranken	105	132	30	51	13	166	1.28	43.8	7.95	8.74
Schwaben	105	88	124	21	0	166	1.39	43.8	7.41	8.74
Saarland	89	154	40	45	0	166	1.28	43.8	8.45	8.74
Berlin	95	133	77	37	0	166	1.49	43.8	8.11	8.74
Brandenburg	71	100	35	28	0	166	1.49	43.8	8.45	8.74
Mecklenb.-Vorp.	73	120	29	39	7	166	1.49	43.8	9.37	8.74
Chemnitz	85	122	60	31	0	166	1.34	43.8	8.71	8.74
Dresden	85	127	44	39	0	166	1.34	43.8	8.82	8.74
Leipzig	85	103	38	32	0	166	1.40	43.8	8.91	8.74
Sachsen-Anhalt	71	86	40	25	0	166	1.40	43.8	8.81	8.74
Thüringen	81	92	40	36	0	166	1.36	43.8	8.99	8.74

Table 22: Barley (grains) - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	69.6	95	69	21	1	166	1.88	180	10.7	5.74
Schleswig-Holstein	84.5	93	121	3	0	166	1.78	180	9.6	5.74
Hamburg	69.6	136	35	35	1	166	1.65	180	10.0	5.74
Braunschweig	78.2	115	37	43	3	166	1.91	180	9.8	5.74
Hannover	73.5	95	69	26	0	166	1.91	180	9.9	5.74
Lüneburg	64.2	76	110	0	0	166	1.91	180	10.0	5.74
Weser-Ems	65.1	26	169	0	0	166	1.86	180	10.4	5.74
Bremen	69.6	48	170	0	0	166	1.91	180	11.0	5.74
Düsseldorf	78.3	80	113	3	0	166	1.87	180	9.6	5.74
Köln	83.0	112	80	25	0	166	1.87	180	10.0	5.74
Münster	68.5	52	140	0	0	166	1.91	180	9.7	5.74
Detmold	72.5	96	86	17	0	166	1.78	180	10.2	5.74
Arnsberg	75.3	96	92	8	0	166	1.98	180	10.4	5.74
Darmstadt	66.6	130	27	36	7	166	1.89	180	11.7	5.74
Gießen	63.4	124	45	27	0	166	2.04	180	11.9	5.74
Kassel	67.0	114	66	20	0	166	1.87	180	10.9	5.74
Koblenz	72.7	124	43	36	0	166	1.85	180	11.0	5.74
Trier	68.9	106	63	24	0	166	1.81	180	11.3	5.74
Rheinhessen-Pfalz	69.4	116	8	50	30	166	1.89	180	11.0	5.74
Stuttgart	68.3	109	66	20	0	166	1.89	180	11.5	5.74
Karlsruhe	66.0	128	35	35	0	166	2.04	180	11.4	5.74
Freiburg	69.5	122	59	26	0	166	1.85	180	10.7	5.74
Tübingen	73.3	92	94	12	0	166	2.14	180	10.6	5.74
Oberbayern	72.1	68	90	10	0	166	2.14	180	10.6	5.74
Niederbayern	74.3	73	98	8	0	166	2.14	180	10.5	5.74
Oberpfalz	62.1	76	88	6	0	166	1.94	180	11.7	5.74

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser** **Nitrogen** **synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)	**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
Oberfranken	53.9	75	54	14	0	166	1.74	180	12.0	5.74
Mittelfranken	59.6	67	84	3	0	166	1.74	180	12.0	5.74
Unterfranken	59.1	101	30	31	1	166	1.74	180	12.6	5.74
Schwaben	76.7	58	124	3	0	166	2.14	180	9.9	5.74
Saarland	58.0	114	40	22	0	166	1.74	180	13.1	5.74
Berlin	69.6	105	77	22	0	166	1.72	180	11.4	5.74
Brandenburg	57.1	100	35	24	0	166	1.72	180	12.0	5.74
Mecklenb.-Vorp.	73.6	127	29	41	9	166	1.72	180	10.1	5.74
Chemnitz	73.9	118	60	26	0	166	1.89	180	10.3	5.74
Dresden	70.3	124	44	34	0	166	1.89	180	11.2	5.74
Leipzig	70.3	118	38	37	0	166	2.04	180	11.4	5.74
Sachsen-Anhalt	66.3	103	40	32	0	166	2.04	180	11.2	5.74
Thüringen	71.7	98	40	35	0	166	1.69	180	10.3	5.74

Table 23: Triticale (grains) - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser** **Nitrogen** **synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)	**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
Germany (area weighted average)	58.5	97	69	15	1	166	2.06	160	12.6	5.41
Schleswig-Holstein	73.3	95	121	0	0	166	2.22	160	9.7	5.41
Hamburg	58.5	136	35	27	0	166	2.32	160	10.1	5.41
Braunschweig	61.6	110	37	33	0	166	2.11	160	11.3	5.41
Hannover	60.8	98	69	18	0	166	2.11	160	11.5	5.41
Lüneburg	57.0	78	110	0	0	166	2.11	160	11.5	5.41
Weser-Ems	60.9	37	169	0	0	166	2.15	160	10.6	5.41
Bremen	58.5	50	170	0	0	166	2.11	160	11.9	5.41

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Düsseldorf	65.7	81	113	0	0	166	2.13	160	11.0	5.41
Köln	70.2	111	80	12	0	166	2.13	160	11.3	5.41
Münster	62.7	62	140	0	0	166	2.11	160	10.7	5.41
Detmold	64.4	101	86	10	0	166	2.22	160	11.3	5.41
Arnsberg	71.5	109	92	6	0	166	2.03	160	10.8	5.41
Darmstadt	66.3	151	27	39	12	166	1.86	160	11.0	5.41
Gießen	65.7	143	45	29	0	166	1.94	160	11.1	5.41
Kassel	65.6	128	66	19	0	166	2.13	160	11.5	5.41
Koblenz	63.7	130	43	30	0	166	2.13	160	12.4	5.41
Trier	65.9	116	63	20	0	166	2.02	160	11.7	5.41
Rheinhessen-Pfalz	67.5	123	8	46	30	166	1.86	160	11.7	5.41
Stuttgart	64.3	126	66	21	0	166	1.86	160	11.4	5.41
Karlsruhe	63.6	144	35	35	4	166	1.94	160	12.1	5.41
Freiburg	70.1	136	59	26	0	166	2.13	160	11.2	5.41
Tübingen	73.6	107	94	13	0	166	2.26	160	10.3	5.41
Oberbayern	60.9	71	90	3	0	166	2.26	160	12.3	5.41
Niederbayern	64.0	79	98	3	0	166	2.26	160	11.4	5.41
Oberpfalz	60.3	89	88	6	0	166	2.02	160	11.9	5.41
Oberfranken	53.0	90	54	14	0	166	1.78	160	11.4	5.41
Mittelfranken	59.9	86	84	6	0	166	1.78	160	11.4	5.41
Unterfranken	50.6	104	30	26	0	166	1.78	160	13.0	5.41
Schwaben	71.0	57	124	0	0	166	2.26	160	10.3	5.41
Saarland	56.9	130	40	24	0	166	1.78	160	11.9	5.41
Berlin	58.5	105	77	13	0	166	2.09	160	14.6	5.41
Brandenburg	40.3	97	35	15	0	166	2.09	160	15.5	5.41
Mecklenb.-Vorp.	46.7	108	29	22	0	166	2.09	160	15.5	5.41
Chemnitz	63.2	125	60	22	0	166	1.86	160	11.9	5.41

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Dresden	49.6	112	44	21	0	166	1.86	160	12.9	5.41
Leipzig	47.7	108	38	22	0	166	1.94	160	14.1	5.41
Sachsen-Anhalt	46.4	91	40	18	0	166	1.94	160	15.9	5.41
Thüringen	58.4	102	40	30	0	166	2.05	160	12.2	5.41

Table 24: Sugar beet - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	726.2	100	69	37	104	166	3.28	3.90	1.13	0.084
Schleswig-Holstein	798.9	92	121	21	71	166	3.39	3.90	1.15	0.084
Hamburg	726.2	142	35	52	143	166	2.87	3.90	1.19	0.084
Braunschweig	752.0	114	37	59	152	166	3.91	3.90	1.16	0.084
Hannover	790.0	99	69	45	121	166	3.91	3.90	1.14	0.084
Lüneburg	728.5	85	110	21	69	166	3.91	3.90	1.21	0.084
Weser-Ems	730.1	42	169	0	12	166	3.70	3.90	1.16	0.084
Bremen	726.2	50	170	6	28	166	3.91	3.90	1.18	0.084
Düsseldorf	774.5	79	113	19	76	166	3.40	3.90	1.19	0.084
Köln	768.9	108	80	33	103	166	3.40	3.90	1.23	0.084
Münster	700.6	53	140	0	20	166	3.91	3.90	1.24	0.084
Detmold	760.7	96	86	32	91	166	3.39	3.90	1.16	0.084
Arnsberg	830.4	110	92	32	101	166	3.66	3.90	1.15	0.084
Darmstadt	747.0	146	27	60	157	166	3.01	3.90	1.21	0.084
Gießen	766.3	137	45	50	137	166	3.41	3.90	1.22	0.084
Kassel	751.3	124	66	43	121	166	3.40	3.90	1.13	0.084
Koblenz	715.4	125	43	51	139	166	3.14	3.90	1.27	0.084

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Trier	741.8	110	63	41	112	166	2.96	3.90	1.45	0.084
Rheinhessen-Pfalz	698.1	119	8	63	158	166	3.01	3.90	1.23	0.084
Stuttgart	730.5	116	66	41	117	166	3.01	3.90	1.24	0.084
Karlsruhe	708.0	134	35	55	141	166	3.41	3.90	1.22	0.084
Freiburg	766.0	126	59	45	125	166	3.14	3.90	1.18	0.084
Tübingen	777.0	93	94	29	88	166	3.48	3.90	1.16	0.084
Oberbayern	843.4	79	90	35	106	166	3.48	3.90	1.11	0.084
Niederbayern	910.0	90	98	39	118	166	3.48	3.90	1.12	0.084
Oberpfalz	867.0	88	88	28	83	166	3.04	3.90	1.08	0.084
Oberfranken	630.5	96	54	38	106	166	2.60	3.90	1.21	0.084
Mittelfranken	691.8	86	84	29	84	166	2.60	3.90	1.21	0.084
Unterfranken	680.6	115	30	54	141	166	2.60	3.90	1.26	0.084
Schwaben	884.5	65	124	26	79	166	3.48	3.90	1.11	0.084
Saarland	718	136	40	51	137	166	2.60	3.90	1.25	0.084
Berlin	726.2	113	77	40	100	166	2.93	3.90	1.26	0.084
Brandenburg	603.5	118	35	45	119	166	2.93	3.90	1.32	0.084
Mecklenb.-Vorp.	717.0	128	29	55	142	166	2.93	3.90	0.00	0.084
Chemnitz	771.7	115	60	39	108	166	3.01	3.90	1.16	0.084
Dresden	718.1	121	44	47	121	166	3.01	3.90	1.25	0.084
Leipzig	604.3	106	38	40	104	166	3.41	3.90	1.39	0.084
Sachsen-Anhalt	543.0	91	40	36	93	166	3.41	3.90	1.46	0.084
Thüringen	643.6	93	40	45	121	166	2.74	3.90	1.41	0.084

Table 25: Rapeseed - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	34.9	107	69	28	1	166	2.42	8.00	21.1	5.79
Schleswig-Holstein	38.0	98	121	6	0	166	2.22	8.00	20.3	5.79
Hamburg	34.9	143	35	41	0	166	2.24	8.00	21.3	5.79
Braunschweig	35.1	113	37	42	0	166	2.20	8.00	22.1	5.79
Hannover	36.4	97	69	27	0	166	2.20	8.00	21.0	5.79
Lüneburg	33.4	83	110	4	0	166	2.20	8.00	20.0	5.79
Weser-Ems	38.2	47	169	0	0	166	2.21	8.00	18.9	5.79
Bremen	34.9	52	170	1	0	166	2.20	8.00	21.8	5.79
Düsseldorf	40.9	99	113	13	0	166	2.32	8.00	19.0	5.79
Köln	41.8	127	80	33	0	166	2.32	8.00	18.6	5.79
Münster	37.7	73	140	0	0	166	2.20	8.00	18.4	5.79
Detmold	37.2	105	86	23	0	166	2.22	8.00	20.2	5.79
Arnsberg	36.3	113	92	19	0	166	2.36	8.00	21.8	5.79
Darmstadt	37.5	150	27	48	8	166	2.45	8.00	20.5	5.79
Gießen	36.0	143	45	39	0	166	2.53	8.00	21.3	5.79
Kassel	34.2	123	66	26	0	166	2.32	8.00	21.7	5.79
Koblenz	36.5	133	43	42	0	166	2.39	8.00	21.9	5.79
Trier	37.5	121	63	31	0	166	2.38	8.00	21.8	5.79
Rheinhessen-Pfalz	36.3	129	8	57	28	166	2.45	8.00	22.3	5.79
Stuttgart	38.9	135	66	37	0	166	2.45	8.00	21.4	5.79
Karlsruhe	38.7	147	35	49	1	166	2.53	8.00	20.9	5.79
Freiburg	38.8	145	59	39	0	166	2.39	8.00	20.1	5.79
Tübingen	39.8	110	94	26	0	166	2.38	8.00	19.4	5.79
Oberbayern	38.9	88	90	22	0	166	2.38	8.00	19.5	5.79
Niederbayern	38.4	88	98	18	0	166	2.38	8.00	19.6	5.79
Oberpfalz	36.3	99	88	21	0	166	2.38	8.00	21.2	5.79

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser** **Nitrogen** **synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)	**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
Oberfranken	30.4	95	54	27	0	166	2.37	8.00	20.4	5.79
Mittelfranken	35.6	93	84	19	0	166	2.37	8.00	20.4	5.79
Unterfranken	33.7	122	30	45	3	166	2.37	8.00	21.9	5.79
Schwaben	41.2	76	124	13	0	166	2.38	8.00	18.6	5.79
Saarland	30.1	127	40	30	0	166	2.37	8.00	22.4	5.79
Berlin	34.9	113	77	28	0	166	2.75	8.00	21.7	5.79
Brandenburg	29.2	110	35	30	0	166	2.75	8.00	22.9	5.79
Mecklenb.-Vorp.	36.2	136	29	47	5	166	2.75	8.00	21.7	5.79
Chemnitz	34.5	124	60	32	0	166	2.45	8.00	22.7	5.79
Dresden	32.9	128	44	38	0	166	2.45	8.00	21.8	5.79
Leipzig	33.2	124	38	40	0	166	2.53	8.00	22.1	5.79
Sachsen-Anhalt	32.8	110	40	38	0	166	2.53	8.00	22.8	5.79
Thüringen	33.1	100	40	38	0	166	2.31	8.00	22.9	5.79

Table 26: Maize (whole plant) - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser** **Nitrogen** **synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)	**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
Germany (area weighted average)	400.0	109	69	31	131	166	1.36	43.75	2.72	0.27
Schleswig-Holstein	426.1	101	121	9	92	166	1.34	43.75	2.72	0.27
Hamburg	400.0	149	35	45	166	166	1.45	43.75	2.79	0.27
Braunschweig	459.0	136	37	57	198	166	1.24	43.75	2.43	0.27
Hannover	435.0	123	69	45	171	166	1.24	43.75	2.49	0.27
Lüneburg	411.3	99	110	15	102	166	1.24	43.75	2.47	0.27
Weser-Ems	420.4	51	169	0	45	166	1.28	43.75	2.55	0.27
Bremen	400.0	53	170	2	39	166	1.24	43.75	2.63	0.27

NUTS2 region	**Yield**	**Fertiliser**					**Pesti-cides**	**Seeds**	**Diesel**	**Electri-city**
		Nitrogen		**Phos-phorous**	**Potas-sium**	**Lime**				
	dt/ (ha•a)	**synth.** kg N/ (ha•a)	**organ.** kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Düsseldorf	430.1	94	113	12	109	166	1.36	43.75	2.63	0.27
Köln	474.3	130	80	33	152	166	1.36	43.75	2.54	0.27
Münster	403.0	71	140	0	64	166	1.24	43.75	2.56	0.27
Detmold	432.7	121	86	33	148	166	1.34	43.75	2.61	0.27
Arnsberg	451.9	122	92	25	132	166	1.32	43.75	2.49	0.27
Darmstadt	452.1	168	27	61	206	166	1.34	43.75	2.55	0.27
Gießen	454.4	160	45	50	189	166	1.40	43.75	2.65	0.27
Kassel	447.5	145	66	41	165	166	1.36	43.75	2.59	0.27
Koblenz	416.1	135	43	45	164	166	1.43	43.75	2.75	0.27
Trier	372.7	114	63	29	122	166	1.38	43.75	2.93	0.27
Rheinhessen-Pfalz	405.5	127	8	57	183	166	1.34	43.75	2.81	0.27
Stuttgart	456.8	141	66	41	169	166	1.34	43.75	2.55	0.27
Karlsruhe	432.6	157	35	55	194	166	1.40	43.75	2.62	0.27
Freiburg	418.9	136	59	39	155	166	1.43	43.75	2.71	0.27
Tübingen	460.7	115	94	28	135	166	1.39	43.75	2.64	0.27
Oberbayern	534.6	108	90	36	165	166	1.39	43.75	2.40	0.27
Niederbayern	505.5	112	98	35	164	166	1.39	43.75	2.46	0.27
Oberpfalz	438.4	114	88	31	142	166	1.33	43.75	2.54	0.27
Oberfranken	418.7	117	54	41	161	166	1.28	43.75	2.57	0.27
Mittelfranken	399.3	103	84	26	125	166	1.28	43.75	2.57	0.27
Unterfranken	403.1	130	30	51	178	166	1.28	43.75	2.64	0.27
Schwaben	504.4	89	124	22	131	166	1.39	43.75	2.39	0.27
Saarland	313.6	133	40	36	137	166	1.28	43.75	3.16	0.27
Berlin	400.0	122	77	32	123	166	1.49	43.75	2.69	0.27
Brandenburg	264.4	96	35	27	99	166	1.49	43.75	2.86	0.27
Mecklenb.-Vorp.	341.8	124	29	42	146	166	1.49	43.75	2.89	0.27
Chemnitz	347.6	111	60	25	112	166	1.34	43.75	2.93	0.27

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Dresden	325.0	113	44	32	119	166	1.34	43.75	3.15	0.27
Leipzig	303.1	99	38	29	106	166	1.40	43.75	3.10	0.27
Sachsen-Anhalt	294.7	91	40	30	112	166	1.40	43.75	3.14	0.27
Thüringen	346.2	96	40	37	137	166	1.36	43.75	2.92	0.27

Table 27: Wheat (whole plant) - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	270.5	150	69	62	124	166	2.25	240	3.10	0.38
Schleswig-Holstein	338.8	130	121	37	69	166	2.65	240	2.68	0.38
Hamburg	270.5	187	35	77	160	166	3.00	240	2.93	0.38
Braunschweig	319.6	157	37	78	156	166	2.30	240	2.73	0.38
Hannover	319.6	140	69	63	121	166	2.30	240	2.94	0.38
Lüneburg	319.6	131	110	43	79	166	2.30	240	3.18	0.38
Weser-Ems	319.6	87	169	12	20	166	2.44	240	2.88	0.38
Bremen	270.5	94	170	22	46	166	2.30	240	3.04	0.38
Düsseldorf	264.9	124	113	38	80	166	2.38	240	3.08	0.38
Köln	264.9	152	80	55	114	166	2.38	240	2.83	0.38
Münster	264.9	104	140	26	52	166	2.30	240	2.90	0.38
Detmold	264.9	141	86	54	105	166	2.65	240	3.14	0.38
Arnsberg	264.9	153	92	49	102	166	2.07	240	2.82	0.38
Darmstadt	289.9	190	27	82	167	166	1.84	240	3.04	0.38
Gießen	289.9	184	45	73	150	166	1.85	240	3.22	0.38
Kassel	289.9	169	66	63	127	166	2.38	240	2.96	0.38
Koblenz	279.7	174	43	74	153	166	2.42	240	3.29	0.38

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser**					**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
		Nitrogen		**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)				
		synth. kg N/ (ha•a)	**organ.** kg N/ (ha•a)							
Trier	279.7	158	63	67	129	166	2.22	240	3.25	0.38
Rheinhessen-Pfalz	279.7	165	8	91	187	166	1.84	240	3.24	0.38
Stuttgart	300.6	164	66	63	129	166	1.84	240	3.15	0.38
Karlsruhe	300.6	181	35	78	159	166	1.85	240	3.23	0.38
Freiburg	300.6	174	59	66	135	166	2.42	240	3.09	0.38
Tübingen	300.6	137	94	51	97	166	2.38	240	3.26	0.38
Oberbayern	265.4	120	90	51	102	166	2.38	240	3.26	0.38
Niederbayern	265.4	122	98	47	95	166	2.38	240	2.85	0.38
Oberpfalz	265.4	138	88	53	105	166	2.10	240	3.17	0.38
Oberfranken	265.4	149	54	68	140	166	1.82	240	3.13	0.38
Mittelfranken	265.4	137	84	55	108	166	1.82	240	3.07	0.38
Unterfranken	265.4	165	30	80	165	166	1.82	240	3.05	0.38
Schwaben	265.4	98	124	36	67	166	2.38	240	3.25	0.38
Saarland	298.8	184	40	75	155	166	1.82	240	3.04	0.38
Berlin	270.5	157	77	62	110	166	2.46	240	2.77	0.38
Brandenburg	180.9	177	35	78	159	166	2.46	240	3.21	0.38
Mecklenb.-Vorp.	276.4	179	29	81	166	166	2.46	240	3.09	0.38
Chemnitz	275.4	166	60	66	135	166	1.84	240	3.29	0.38
Dresden	275.4	175	44	75	149	166	1.84	240	4.18	0.38
Leipzig	275.4	173	38	79	154	166	1.85	240	3.06	0.38
Sachsen-Anhalt	251.2	159	40	77	152	166	1.85	240	3.17	0.38
Thüringen	261.5	149	40	75	155	166	2.41	240	3.24	0.38

Table 28: Field grass - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	68.8	117	69	19	130	166	0	25.0	4.0	0.40
Schleswig-Holstein	93.2	163	121	12	163	166	0	25.0	4.04	0.40
Hamburg	68.8	146	35	33	173	166	0	25.0	4.04	0.40
Braunschweig	82.9	169	37	44	203	166	0	25.0	4.04	0.40
Hannover	82.9	151	69	29	174	166	0	25.0	4.04	0.40
Lüneburg	82.9	135	110	12	141	166	0	25.0	4.04	0.40
Weser-Ems	82.9	84	169	0	68	166	0	25.0	4.04	0.40
Bremen	68.8	41	170	0	39	166	0	25.0	4.04	0.40
Düsseldorf	56.0	65	113	0	54	166	0	25.0	4.04	0.40
Köln	56.0	84	80	0	85	166	0	25.0	4.04	0.40
Münster	56.0	44	140	0	18	166	0	25.0	4.04	0.40
Detmold	56.0	76	86	0	71	166	0	25.0	4.04	0.40
Arnsberg	56.0	74	92	0	69	166	0	25.0	4.04	0.40
Darmstadt	55.7	110	27	27	135	166	0	25.0	4.04	0.40
Gießen	55.7	102	45	17	116	166	0	25.0	4.04	0.40
Kassel	55.7	91	66	9	98	166	0	25.0	4.04	0.40
Koblenz	63.0	126	43	28	149	166	0	25.0	4.04	0.40
Trier	63.0	115	63	18	124	166	0	25.0	4.04	0.40
Rheinhessen-Pfalz	63.0	140	8	41	172	166	0	25.0	4.04	0.40
Stuttgart	64.2	118	66	17	134	166	0	25.0	4.04	0.40
Karlsruhe	64.2	134	35	32	162	166	0	25.0	4.04	0.40
Freiburg	64.2	124	59	20	141	166	0	25.0	4.04	0.40
Tübingen	64.2	95	94	5	103	166	0	25.0	4.04	0.40
Oberbayern	87.0	144	90	23	179	166	0	25.0	4.04	0.40
Niederbayern	87.0	153	98	19	173	166	0	25.0	4.04	0.40
Oberpfalz	87.0	161	88	25	183	166	0	25.0	4.04	0.40

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth. kg N/ (ha•a)	organ. kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Oberfranken	87.0	171	54	39	213	166	0	25.0	4.04	0.40
Mittelfranken	87.0	161	84	26	181	166	0	25.0	4.04	0.40
Unterfranken	87.0	195	30	51	238	166	0	25.0	4.04	0.40
Schwaben	87.0	130	124	8	144	166	0	25.0	4.04	0.40
Saarland	52.1	94	40	14	103	166	0	25.0	4.04	0.40
Berlin	68.8	125	77	19	128	166	0	25.0	4.04	0.40
Brandenburg	42.4	78	35	15	88	166	0	25.0	4.04	0.40
Mecklenb.-Vorp.	42.0	72	29	15	84	166	0	25.0	4.04	0.40
Chemnitz	77.1	142	60	27	164	166	0	25.0	4.04	0.40
Dresden	77.1	150	44	36	180	166	0	25.0	4.04	0.40
Leipzig	77.1	153	38	38	183	166	0	25.0	4.04	0.40
Sachsen-Anhalt	39.6	73	40	12	81	166	0	25.0	4.04	0.40
Thüringen	77.2	160	40	38	184	166	0	25.0	4.04	0.40

Table 29: Grassland cuttings - fertiliser, pesticide, seeds, Diesel and electricity consumption

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth kg N/ (ha•a)	organ kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Germany (area weighted average)	57.0	68	69	4	46	166	0	0	11.62	0.45
Schleswig-Holstein	81.4	101	121	0	37	166	0	0	11.62	0.45
Hamburg	60.0	109	35	10	78	166	0	0	11.62	0.45
Braunschweig	73.3	136	37	18	98	166	0	0	11.62	0.45
Hannover	73.3	117	69	3	65	166	0	0	11.62	0.45
Lüneburg	73.3	77	110	0	30	166	0	0	11.62	0.45
Weser-Ems	73.3	31	169	0	0	166	0	0	11.62	0.45

NUTS2 region	Yield	Fertiliser					Pesti-cides	Seeds	Diesel	Electri-city
		Nitrogen		Phos-phorous	Potas-sium	Lime				
	dt/ (ha•a)	synth kg N/ (ha•a)	organ kg N/ (ha•a)	kg P_2O_5/ (ha•a)	kg K_2O/ (ha•a)	kg CaO /(ha•a)	kg / (ha•a)	kg / (ha•a)	liter/ (ha•a)	kWh/ (ha•a)
Bremen	60.0	0	170	0	0	166	0	0	11.62	0.45
Düsseldorf	47.4	4	113	0	0	166	0	0	11.62	0.45
Köln	47.4	30	80	0	11	166	0	0	11.62	0.45
Münster	47.4	0	140	0	0	166	0	0	11.62	0.45
Detmold	47.4	26	86	0	0	166	0	0	11.62	0.45
Arnsberg	47.4	26	92	0	0	166	0	0	11.62	0.45
Darmstadt	52.6	80	27	11	70	166	0	0	11.62	0.45
Gießen	52.6	62	45	2	51	166	0	0	11.62	0.45
Kassel	52.6	42	66	0	31	166	0	0	11.62	0.45
Koblenz	55.8	70	43	6	66	166	0	0	11.62	0.45
Trier	55.8	50	63	0	38	166	0	0	11.62	0.45
Rheinhessen-Pfalz	55.8	105	8	22	93	166	0	0	11.62	0.45
Stuttgart	53.1	73	66	0	45	166	0	0	11.62	0.45
Karlsruhe	53.1	79	35	10	73	166	0	0	11.62	0.45
Freiburg	53.1	77	59	0	50	166	0	0	11.62	0.45
Tübingen	53.1	51	94	0	13	166	0	0	11.62	0.45
Oberbayern	64.8	87	90	0	54	166	0	0	11.62	0.45
Niederbayern	64.8	79	98	0	47	166	0	0	11.62	0.45
Oberpfalz	64.8	89	88	0	56	166	0	0	11.62	0.45
Oberfranken	64.8	123	54	9	89	166	0	0	11.62	0.45
Mittelfranken	64.8	93	84	0	58	166	0	0	11.62	0.45
Unterfranken	64.8	147	30	21	115	166	0	0	11.62	0.45
Schwaben	64.8	53	124	0	16	166	0	0	11.62	0.45
Saarland	49.2	60	40	0	35	166	0	0	11.62	0.45
Berlin	60.0	64	77	0	33	166	0	0	11.62	0.45
Brandenburg	44.5	55	35	6	57	166	0	0	11.62	0.45

NUTS2 region	**Yield** dt/ (ha•a)	**Fertiliser** **Nitrogen** synth kg N/ (ha•a)	organ kg N/ (ha•a)	**Phos-phorous** kg P_2O_5/ (ha•a)	**Potas-sium** kg K_2O/ (ha•a)	**Lime** kg CaO /(ha•a)	**Pesti-cides** kg / (ha•a)	**Seeds** kg / (ha•a)	**Diesel** liter/ (ha•a)	**Electri-city** kWh/ (ha•a)
Mecklenb.-Vorp.	39.2	50	29	5	48	166	0	0	11.62	0.45
Chemnitz	59.5	61	60	0	38	166	0	0	11.62	0.45
Dresden	59.5	77	44	5	55	166	0	0	11.62	0.45
Leipzig	59.5	83	38	8	60	166	0	0	11.62	0.45
Sachsen-Anhalt	43.0	47	40	1	32	166	0	0	11.62	0.45
Thüringen	52.6	80	40	8	72	166	0	0	11.62	0.45

C.2 Data for N_2O field emission

Table 30: Regionalised emission factors and parameters for the calculation of N_2O field emissions on mineral soils

NUTS 2 area	Direct emission [a] [kg N2O-N / kg N]	Indirect emission [b] [kg N / kg N] FRACGASF	Indirect emission [b] [kg N / kg N] FRACGASM	Indirect emission [a] [kg N / kg N] FRACLEACH
Schleswig-Holstein	0.00460	0.0529	0.1410	0.1307
Hamburg	0.00385	0.0782	0.1410	0.0240
Braunschweig	0.00431	0.0574	0.2102	0.0860
Hannover	0.00465	0.0574	0.2102	0.1035
Lüneburg	0.00457	0.0574	0.2102	0.0908
Weser-Ems	0.00489	0.0574	0.2102	0.1371
Bremen	0.00489	0.0476	0.1924	0.0225
Düsseldorf	0.00710	0.0578	0.1924	0.1756
Köln	0.00735	0.0578	0.1924	0.1264
Münster	0.00652	0.0578	0.1924	0.1864
Detmold	0.00526	0.0578	0.1924	0.1443
Arnsberg	0.00530	0.0578	0.1924	0.1216
Darmstadt	0.00443	0.0510	0.1924	0.1093
Gießen	0.00457	0.0510	0.1512	0.0598
Kassel	0.00489	0.0510	0.1934	0.1078
Koblenz	0.00530	0.0538	0.1934	0.0564
Trier	0.00741	0.0538	0.1934	0.0554
Rheinhessen-Pfalz	0.00559	0.0538	0.1740	0.2112
Stuttgart	0.00839	0.0574	0.1382	0.1001
Karlsruhe	0.00783	0.0574	0.1512	0.0875
Freiburg	0.00813	0.0574	0.1512	0.0537
Tübingen	0.00873	0.0574	0.1512	0.0944

NUTS 2 area	Direct emission [a] [kg N2O-N / kg N]	Indirect emission [b] [kg N / kg N] FRACGASF	Indirect emission [b] [kg N / kg N] FRACGASM	Indirect emission [a] [kg N / kg N] FRACLEACH
Oberbayern	0.00880	0.0543	0.1512	0.0657
Niederbayern	0.00880	0.0543	0.1392	0.0942
Oberpfalz	0.00877	0.0543	0.1392	0.0608
Oberfranken	0.00880	0.0543	0.1392	0.0295
Mittelfranken	0.00868	0.0543	0.1392	0.0571
Unterfranken	0.00854	0.0543	0.1392	0.0586
Schwaben	0.00880	0.0543	0.2050	0.0606
Saarland	0.00715	0.0567	0.2050	0.0532
Berlin	0.00385	0.0733	0.2050	0.0598
Brandenburg	0.00385	0.0681	0.1740	0.0438
Mecklenburg-Vorpommern	0.00385	0.0536	0.2012	0.0891
Chemnitz	0.00758	0.0546	0.1254	0.1104
Dresden	0.00495	0.0546	0.1254	0.1070
Leipzig	0.00385	0.0546	0.1254	0.1240
Sachsen-Anhalt	0.00385	0.0572	0.1344	0.0615
Thüringen	0.00572	0.0598	0.1386	0.1018

a) UBA (2024)

b) Data calculated by ifeu based on data by Thünen-Institut.

Table 31: Regionalised emission factors and parameters for the calculation of N_2O field emissions on organic soils (all values in kg N_2O-N per hectare and year)

NUTS 2 area	Mineralisation organic soil, arable land a) [kg N_2O-N / (ha x a)]	Mineralisation organic soil, grassland a) [kg N_2O-N / (ha x a)]
Schleswig-Holstein	11.05	4.561
Hamburg	11.01	4.549
Braunschweig	10.99	4.546
Hannover	11.08	4.575
Lüneburg	11.03	4.543
Weser-Ems	11.01	4.546
Bremen	10.98	4.509
Düsseldorf	11.06	4.498
Köln	11.10	4.463
Münster	11.01	4.544
Detmold	11.06	4.564
Arnsberg	11.10	4.173
Darmstadt	11.10	4.582
Gießen	-	4.600
Kassel	11.10	4.600
Koblenz	-	-
Trier	-	1.196
Rheinhessen-Pfalz	11.10	4.488
Stuttgart	11.10	4.570
Karlsruhe	11.08	4.407
Freiburg	11.10	4.411
Tübingen	11.10	4.451
Oberbayern	11.09	4.524
Niederbayern	11.04	4.514

NUTS 2 area	Mineralisation organic soil, arable land a) [kg N_2O-N / (ha x a)]	Mineralisation organic soil, grassland a) [kg N_2O-N / (ha x a)]
Oberpfalz	11.10	4.413
Oberfranken	11.10	4.422
Mittelfranken	11.10	4.575
Unterfranken	11.10	4.600
Schwaben	11.08	4.557
Saarland	11.10	4.589
Berlin	11.10	4.590
Brandenburg	11.03	4.568
Mecklenburg-Vorpommern	11.04	4.420
Chemnitz	11.10	4.410
Dresden	11.10	4.568
Leipzig	11.10	4.600
Sachsen-Anhalt	11.09	4.566
Thüringen	11.08	4.578

a) Data provided by Thünen-Institut

Table 32: N-input by of agricultural residues (F_{CR}) per crop

Crop	Wheat	Maize	Rye	Barley	Triticale	Sugar beet	Rapeseed
N-input (kg N/(ha*a)	5.40	5.34	7.37	6.98	8.14	23.51	2.00

Source: calculation based on IPCC 2006 Vol.4 chapter 11 table 11.6 and performed by the BioGrace tool

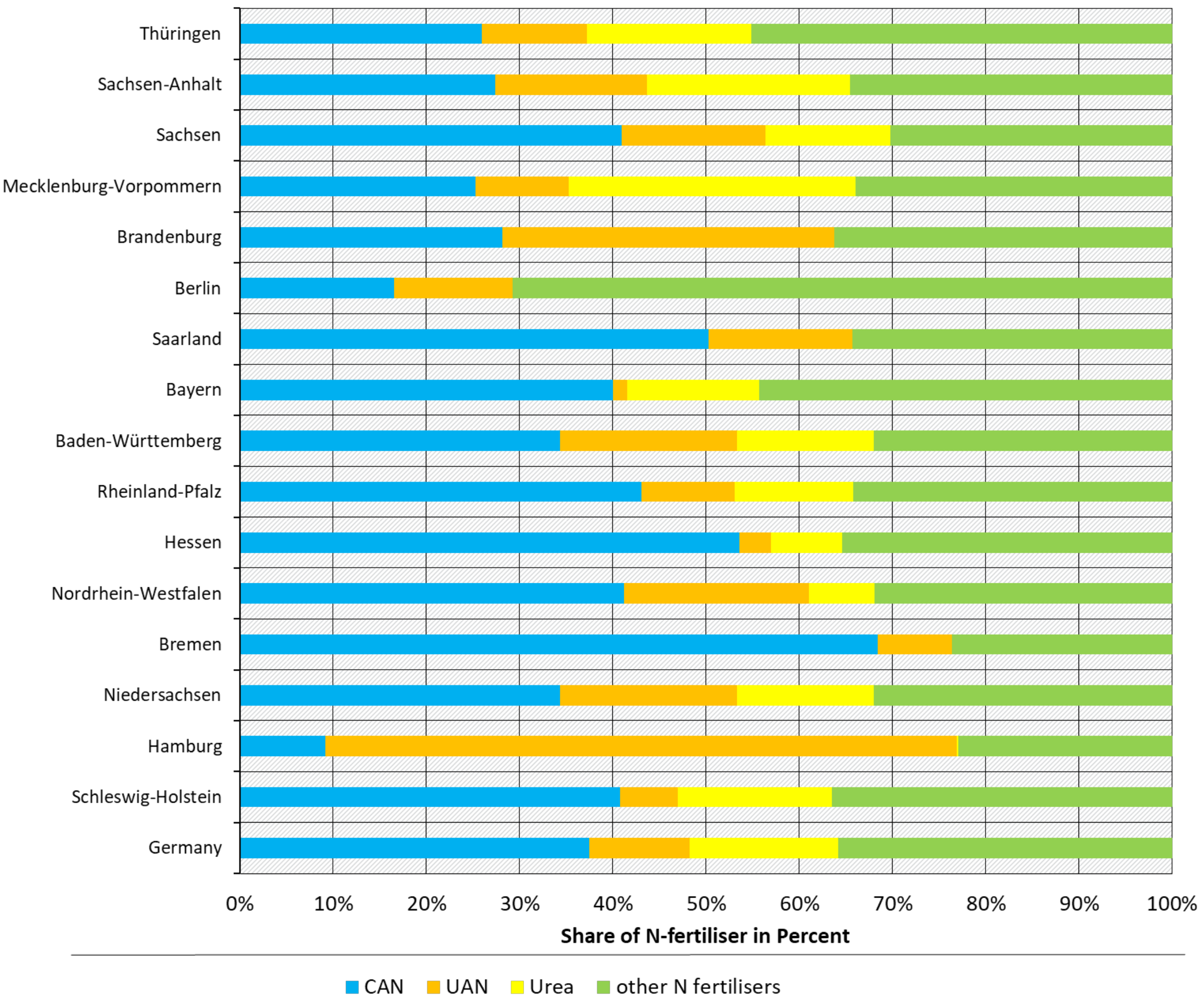
C.3 Data for fertiliser type application

Table 33: Statistical data for sold N fertilisers by NUTS 1 region (shares from total N fertilisers in percent)

	CAN	UAN	Urea	other N-fertiliser [a)]
Germany	37%	11%	16%	36%
Schleswig-Holstein	41%	6%	17%	37%
Hamburg	9%	68%	0%	23%
Niedersachsen	34%	19%	15%	32%
Bremen	68%	8%	0%	24%
Nordrhein-Westfalen	41%	20%	7%	32%
Hessen	54%	3%	8%	35%
Rheinland-Pfalz	43%	10%	13%	34%
Baden-Württemberg	34%	19%	15%	32%
Bayern	40%	1%	14%	44%
Saarland	50%	15%	0%	34%
Berlin	17%	13%	0%	71%
Brandenburg	28%	36%	0%	36%
Mecklenburg-Vorpommern	25%	10%	31%	34%
Sachsen	41%	15%	13%	30%
Sachsen-Anhalt	27%	16%	22%	35%
Thüringen	26%	11%	18%	45%

Source: https://www.regionalstatistik.de/genesis/online

Figure 26: Statistical data for sold N fertilisers by NUTS 1 region (shares from total N fertilisers in percent)



Source: https://www.regionalstatistik.de/genesis/online; illustration : ifeu

Table 34: Statistical data for sold P fertilisers by NUTS 1 region (shares from total P fertilisers in percent)

	Superphosphate	Phosphorite	NP-fertiliser
Germany	12%	2%	86%
Schleswig-Holstein	11%	1%	88%
Hamburg	13%	1%	86%
Niedersachsen	13%	1%	86%
Bremen	0%	1%	99%
Nordrhein-Westfalen	5%	1%	94%
Hessen	9%	1%	90%
Rheinland-Pfalz	5%	1%	94%
Baden-Württemberg	2%	2%	96%
Bayern	2%	7%	92%
Saarland	1%	2%	97%
Berlin	93%	0%	7%
Brandenburg	13%	2%	85%
Mecklenburg-Vorpommern	19%	1%	80%
Sachsen	23%	2%	75%
Sachsen-Anhalt	47%	0%	52%
Thüringen	21%	3%	76%

Source: https://www.regionalstatistik.de/genesis/online

C.4 Data for pesticide type application

Table 35: Application of pesticides by crop and CEPI cluster (kg active agent per hectare and year)

CEPI cluster	Wheat	Maize	Barley	Sugar beet	Rapeseed
Germany (NUTS 0)	2335	1374	1948	3437	2449
A	2459	1489	1720	2933	2746
B	1847	1399	2043	3414	2531
C	2377	1393	2139	3477	2382
D	2996	1452	1648	2869	2242
E	2301	1237	1915	3909	2197
F	1824	1275	1739	2604	2373

Table 36: list of traded pesticide preparations by crop

Wheat	Maize	Barley	Sugar beet	Rapeseed
ACTIVUS SC	Adengo	Abran	AGIL-S	AGIL-S
Acucel	Amega	ADDITION	Amega	AMBARAC
ADDITION	AMEGA 360	Adexar	AMEGA 360	Amega
Adexar	ARIGO	Agolin	Amega 360	AMEGA 360
Agolin	Arrat	Alliance	Amistar Gold	AMISTAR GOLD
Alliance	Aspect	Alonty	AMISTAR GOLD	Ampera
Alonty	B 235	AMEGA 360	Barbarian Biograde 360	Angelus
Amega	Bandera	AMISTAR	BARCLAY GALLUP BIOGRADE 360	Astro 400
AMEGA 360	BARCLAY GALLUP BIOGRADE 360	AMISTAR MAX	BARILOCHE	AVAUNT
AMISTAR	Barracuda	AMISTAR Opti	Belvedere Duo	Azbany
Ampera	BASILICO	ARIANE C	Betanal Tandem	Aziza
ARIANE C	Berghoff Glyphosate ULTRA	ARNOLD	Betasana SC	AZOXYSTAR SC

Wheat	Maize	Barley	Sugar beet	Rapeseed
ARNOLD	Border	Ascra Xpro	Bulldock	Ballet
ARTUS	Bromotril 225 EC	AURELIA	CLAP	Ballet
Ascra Xpro	Bromoxynil 235	Aviator Xpro	Clinic TF	Belkar
Atlantis Flex	Buctril	AXIAL 50	Cliophar 600 SL	Biscaya
Atlantis OD	Calaris	Azbany	Coprantol Duo	Bulldock
ATLANTIS WG	Callisto	BAKATA	COPRANTOL DUO	Bulldock Top
Attribut	CALUMA	Balaya	Cyperkill Max	Butisan
AURELIA	CATO	Ballet	Debut	Butisan Gold
Aurora	Certrol B	BARCLAY GALLUP BIOGRADE 450	DEBUT	Butisan Kombi
Aviator Xpro	CORAGEN	BATTLE DELTA	Debut DuoActive	Butisan Top
AVOXA	DANEVA	BeFlex	Devoid	Cantus
AXIAL 50	Dominator 480 TF	Biscaya	Dinagam	Cantus Gold
Axial Komplett	Dual Gold	BOGOTA Ge	DOMARK 10 EC	CARAMBA
Azbany	Durano	BONTIMA	Duett Ultra	Carax
AZOXYSTAR SC	DURANO TF	Boxer	Durano	Carax
BAKATA	Durano TF	Broadcast	Durano TF	Centium 36 CS
Balaya	EFFIGO	Bulldock	Focus Ultra	Cercobin FL
Ballet	Elumis	Cadou SC	Funguran progress	Chamane
BARCLAY GALLUP BIOGRADE 450	Gardo Gold	CALMA	Fusilade MAX	CIRCUIT SYNC TEC
BATTLE DELTA	Glyfos Dakar	Camposan Top	Gallant super	CLAYTON SPARTA
BeFlex	Glyfos SUPREME	Camposan-Extra	GALLANT SUPER	Clearfield-Clentiga
Biathlon 4D	Glyfos TF Classic	Carmina 640	Glyfos	CLEMATIS
Biscaya	Glyfosate 360 TF	CARPATUS SC	Glyfos Dakar	Clomazone 360 CS
BOGOTA Ge	HARMONY SX	CCC720	Glyfosate 360 TF	Cohort

Wheat	Maize	Barley	Sugar beet	Rapeseed
Bolt	Ikanos	Ceriax	Glyphogan	Colzor Trio
BOUDHA	Innoprotect Elumis	Cerone 660	Goltix Gold	Colzor Uno
Boxer	KELVIN ULTRA	CLEANSHOT	Goltix Super	Colzor Uno flex
Broadcast	Landmaster Supreme 480 TF	Comet	Goltix Titan	Cooper
BROADWAY	Laudis	CONCERT SX	GOLTIX TITAN	Corail
Bulldock	Lodin	Cooper	GRAMFIX	Corail
Cadou SC	LOGANO 100 SC	Corail	GRAMIN	CRANE
CALMA	Lotus Dicamba	Countdown	Grasser 100 EC	CRANE
Cameo SX	Lotus Nicosulfuron	Countdown NT	Helosate 450 TF	Credence
Camposan-Extra	Mais-Banvel WG	Croupier OD	Jaguar	Custodia
Capalo	MaisTer power	CTU 700	Juwel	Cyperkill
CARAMBA	MARAN	Curbatur	Karate Zeon	Cyperkill Max
Carmina 640	MILAGRO forte	Cyperkill	Kezuro	Cythrin 250 EC
CARPATUS SC	Motivell Forte	Cyperkill Max	Lambda WG	Danjiri
CCC720	Nagano	Cythrin 250 EC	Lamdex Forte	Decis forte
Ceriax	NICOGAN	Decis forte	Landmaster Classic 360 TF	Dinagam
Cerone 660	NICOSH 4% OD	Dicopur M	Landmaster Supreme 480 TF	Durano
Champion	NISSHIN	DIFLANIL 500 SC	Leopard	Durano TF
Chlormequat 720	OCEAL	Dirigent SX	Lontrel 600	EFFIGO
CLEANSHOT	Peak	Duplosan Super	LONTREL 600	Efilor
Comet	PRIMERO	DuPont POINTER Plus	Lontrel 720 SG	Efilor
CONCERT SX	PRINCIPAL	Durano	LONTREL 720 SG	EVURE
CONNEX	Profi 360 TF	Durano TF	Mercury	Flusha
Cooper	Profi Glyphosat	ELATUS ERA	Mercury Pro	Focus Ultra

Wheat	Maize	Barley	Sugar beet	Rapeseed
Corail	RAIKIRI	ELATUS PLUS	Metafol SC	Folicur
CORIDA	Rimuron 25 WG	EMCEE	Metatron	Folicur
Countdown	Roundup PowerFlex	EPOXION	Mitron 700 SC	Fox
Countdown NT	Roundup REKORD	Epoxion Top	MTM700	FREQUENT
CTU 700	Samson 4SC	FABULIS OD	Nymeo	Fuego
Curbatur	SAMSON EXTRA 6 OD	FALKON	Oblix	Fuego Top
Cyperkill	Scooter	Fandango	Oblix 500	FURY 10 EW
Cyperkill Max	Simba 100 SC	FENCE	Ortiva	Fusilade MAX
Cythrin 250 EC	Spectrum	Finy	Panarex	Gajus
DANAR	Spectrum Gold	FLEXA	Pirimor Granulat	GALLANT SUPER
Decis forte	Starship	Flexity	Powertwin plus	Gamit 36 AMT
DIAGONAL	Stomp Aqua	FLUENT 500 SC	Profi 360 TF	Glyfos SUPREME
Dicopur M	STRETCH	Fluroxane	Roundup PowerFlex	Glyfosate 360 TF
DIFLANIL 500 SC	Successor T	Folicur	Roundup Rekord	GRAMFIX
Dirigent SX	SULCOGAN	FOLPAN 500 SC	Roundup Ultra	GRAMIN
Dithane NeoTec	Taifun forte	FRANZI	Rubric	GROOVE
Dominator 480 TF	TASK	FURY 10 EW	SCORE	HELOCUR
Don-Q	TEMSA SC	GENOLANE Defense 12	SELECT 240 EC	Helocur 250 EW
Duplosan Super	TITUS	GEXXO	Select 240 EC	Horizon
DuPont POINTER Plus	U 46 M-Fluid	Gigant	SHIRO	Horizon
Durano	UP BMX	Glyfos SUPREME	Shiro 500	Hunter
DURANO TF	Victus	Glyfosate 360 TF	Shock Down	Hunter WG
Durano TF	Zeagran ultimate	Halmstärker Ethephon	Spectrum	Hutton

Wheat	Maize	Barley	Sugar beet	Rapeseed
ELATUS ERA	Zingis	Helocur 250 EW	Sphere	Intuity
ELATUS PLUS		Herold SC	Stemat	JAGUAR
EMCEE		Hoestar Super	STEMAT	Kaiso Sorbie
EPOXION		Hunter	Synergy Generics Metamitron	Karate Zeon
FABULIS OD		Hutton	Taifun forte	KARIS 10 CS
FALKON		Imbrex	Tanaris	Katamaran Plus
Fandango		InnoProtect Pendi 400 SC	TARGA SUPER	Kerb FLO
FENCE		Input Classic	Targa Super	Korvetto
Fezan		Input Triple	Teppeki	Lambda WG
FINISH SX		Input Xpro	Tramat 500	Lamdex Forte
Finy		JAGUAR	VENZAR 500SC	Landmaster Supreme 480 TF
Flame		JORDI	Vertaza	Life Scientific Lambda-Cyhalothrin
Flame Duo		JURA	Vivendi 100	Limane
FLEXA		Karate Zeon	Zaftra AZT 250 SC	LONTREL 600
Flexity		KAROLUS WR		LS AZOXY
FLUENT 500 SC		Kayak		Lynx
Fluroxane		Lentipur 700		Matador
Folicur		Limane		MAVRIK
FOLPAN 500 SC		Lodin		Mavrik Vita
FRANZI		Lotus Lentipur 700		Mercury Pro
FURY 10 EW		LS AZOXY		Milestone
Fusilade MAX		LYSKAMM		Mospilan SG
GENOLANE Defense 12		Malibu		Nexide

Wheat	Maize	Barley	Sugar beet	Rapeseed
GEXXO		Manipulator		Nimbus CS
Gigant		Medax Top		Orius
Glyfos		Mertil		
Glyfosate 360 TF		MINISTER		Ortiva
GROPPER SX		Modan		Panarex
HAKSAR 500 SL		Modan 250 EC		Patel 300 EC
HELOCUR		MODDEVO		Pecari 300 EC
Helocur 250 EW		Moddus		PHYTAVIS Varlega
Helosate 450 TF		MODDUS START		PLEXEO
Herold SC		Morex		Proline
Hoestar Super		MOXA		Propulse
Horizon		Netzschwefel Stulln		Protendo 250 EC
Hunter		Nexide		Quadris
Hunter WG		NEXT		QUANTUM
Husar OD		OMNERA LQM		Quick 5 EC
Husar PLUS		Orius		Rapsan 500 SC
Hutton		Orlicht		Roundup PowerFlex
Imbrex		ORLICHT Plus		Roundup REKORD
Imbrex XE		PADAWAN PLUS		Runway
Input Classic		Pecari 250 EC		Runway VA
Input Triple		Pecari 300 EC		SCATTO
Input Xpro		Picona		Select 240 EC
JAGUAR		POINTER Plus		Setanta Flo
JORDI		POINTER SX		Shock DOWN
JURA		POTACUR SX		Sparviero

Wheat	Maize	Barley	Sugar beet	Rapeseed
Juwel Top		Potacur SX		STEFICUR 250EW
Karate Zeon		Priaxor		Stomp Aqua
KARIS 10 CS		Primus		Sumi Alpha 5 EC
Lambda WG		Prodax		Sumicidin Alpha EC
Leander		Profi Ethephon 660		Synero 30 SL
Lentipur 700		PROFI Fluroxy 200		Taifun forte
Limane		Profi Halmfestiger 660		Tanaris
Lodin		Profi Tribenuron 75 WG		Targa Super
Lodin EC		Proline		TEBU 25
Lotus CCC		Pronto Plus		Tebucur 250 EW
Lotus MCPA		Prosaro		Tilmor
Lotus PIXIE		PROTEG 250 EC		Tilmor
LS AZOXY		Protendo 250 EC		Toprex
LS Mesolodo		Protendo Forte		Toprex
Lynx		Pyrat		Torero
LYSKAMM		Refine Extra SX		TRACIAFIN
MAGNELLO		REFINE EXTRA SX		TRAFO WG
Malibu		Regucil		Trebon 30 EC
Manipulator		REGULATOR 720		TRESO
MAVRIK		Revystar		Tribeca SYNC TEC
Mavrik Vita		Revytrex		TRIVKO
MCPA 500		Roundup PowerFlex		UPSTAGE
Medax Top		Roundup REKORD		Valor

Wheat	Maize	Barley	Sugar beet	Rapeseed
Mertil		Rubric		VextaDim 240 EC
Mirage 45 EC		Salvo Plus		Vivendi 100
Modan		Saracen		Zenby
Modan 250 EC		SARACEN DELTA		ZETROLA
MODDEVO		Saracen Max		ZEUS
Moddus		SCREEN		
MODDUS START		Sempra		
Morex		Shock DOWN		
MOXA		Shortcut XXL		
MOXA 250		SONIS		
Nexide		Sparviero		
NIANTIC		STARANE XL		
OMNERA LQM		STEEPLE		
Orius		STEFICUR 250EW		
ORLICHT Plus		Stomp Aqua		
Osiris		Sumicidin Alpha EC		
Pacifica Plus		SUNFIRE		
Patel 300 EC		SYMPARA		
Pecari 250 EC		Taifun forte		
Pecari 300 EC		Taipan		
Picona		TALIUS		
Pirimor Granulat		TEBU 25		
Pixxaro EC		Tebucur 250 EW		
PLEXEO		TOKYO		
POINTER Plus		Toluron 700 SC		

Wheat	Maize	Barley	Sugar beet	Rapeseed
POINTER SX		Tomigan 180		
POTACUR SX		Tomigan 200		
Priaxor		Tomigan XL		
Primus		Torero		
PRIMUS		TOUCHDOWN QUATTRO		
Primus Perfect		TRACIAFIN		
Prodax		TRIBE 75 WG		
Profi Ethephon 660		Tribun		
PROFI Fluroxy 200		Tribun 75 WG		
Profi Halmfestiger 660		TRIMMER SX		
Profi Tribenuron 75 WG		Trimmer WG		
Proline		Trinity		
Pronto Plus		U 46 M-Fluid		
PROPERTY 180 SC		UP CTU		
Prosaro		UP CTU 700 SC		
PROTEG 250 EC		UPTON		
Protendo 250 EC		Variano Xpro		
Pyrat		Vegas		
Refine Extra SX		Viper Compact		
Regucil		Viverda		
REGULATOR 720		Vulcanus		
Revystar		ZOXIS SUPER		
Revytrex		Zypar		
Roundup PowerFlex				

Wheat	Maize	Barley	Sugar beet	Rapeseed
Roundup REKORD				
Rubric				
Salvo Plus				
Saracen				
SARACEN DELTA				
Saracen Max				
SCREEN				
Sempra				
SENIOR				
Shock DOWN				
Shortcut XXL				
Siltra Xpro				
Sirena EC				
Skyway Xpro				
Soleil				
SONIS				
Sparviero				
Stabilan 720				
STARANE XL				
STEEPLE				
STEFES CCC 720				
STEFICUR 250EW				
Stomp Aqua				
Sumicidin Alpha EC				
Sumimax				

Wheat	Maize	Barley	Sugar beet	Rapeseed
SUNFIRE				
SWORD				
SYMPARA				
Taifun forte				
Taipan				
TALENDO				
TALIUS				
TEBU 25				
Tebucur 250 EW				
Teppeki				
TOKYO				
Toluron 700 SC				
Tomigan 180				
Tomigan 200				
Tomigan XL				
Torero				
TOUCHDOWN QUATTRO				
TRACIAFIN				
Traxos				
TRIBE 75 WG				
Tribun				
Tribun 75 WG				
TRIMMER SX				
Trimmer WG				
Trinity				

Wheat	Maize	Barley	Sugar beet	Rapeseed
Turbine 50G				
U 46 M-Fluid				
ULTRALINE				
UNIVERSE				
UNIX				
UP CTU 700 SC				
UPTON				
Variano Xpro				
Vastimo				
Vegas				
Viper Compact				
VITAGO				
Viverda				
Vulcanus				
WARAN				
Zypar				

C.5 Emission factors for inputs (background data)

Table 37: Emission factors for inputs (background data)

	Greenhouse gas emission			
Materials	*$gCO_{2fossil}$/kg*	*gCH_{4l}/kg*	*gN_2O/kg*	*gCO_{2-eq}/kg*
N- fertiliser	3680.0	7.49	2.35	4.567.8
Ammoniumnitrat (AN)	2671	6.90	2.10	3.469.0
Ammoniumsulfat (AS)	2560	6.50	0.00	2.724.0
Ammoniumnitratsulfat (ANS)	2561	8.90	1.30	3.162.0
Ammonia, wasserfrei	2662	6.80	0.00	2.832.0
Kalkammonsalpeter (CAN)	2863	7.30	2.10	3.670.0
Calciumnitrate (CN)	2653	7.00	5.10	4.348.0
Urea	1703	9.30	0.00	1.935.0
Urea Ammonium nitrate solution (UAN)	2182	7.50	1.10	2.693.0
Average for other N fertiliser				*3.307.0*
P2O5-Dünger	1128.5	2.09	0.03	1.190.9
Triple-Superphosphate (TSP)	517.0	0.9	0.00	544.0
Phosphorite 21 % P_2O_5 23 % SO_3	95.0	0.0	0.00	95.0
Monoammoniumphosphate (MAP) 11 % N 52 % P_2O_5	967.0	2.5	0.00	1.029.0
Diammoniumphosphate (DAP) 18 % N 46 % P_2O_5	1459.0	3.7	0.00	1.552.0
K2O-fertiliser	579.4	1.10	0.01	610.8
CaO (kg CaCO3)	42.0	0.09	0.00	44.7
CaO (kg CaO)	82.9	0.2	0.00	89.7
CaO (kg CaO)	119.1	0.2	0.02	130.4
CO2 from CaCO3 per kg CaO)	785.7			785.7

	Greenhouse gas emission			
Pesticides	18870	35.87	0.03	19.781.3
Energy	*$gCO_{2fossil}$/MJ*	*$gCH_{4fossil}$/MJ*	*gN_2O/MJ*	*gCO_{2-eq}/MJ*
Natural gas	65.09	0.12	0.00	68.2
LPG	77.23	0.09	0.00	79.5
Methane				
Diesel	95.1			95.1
Electricity mix Germany medium voltage				388.0
Electricity mix Germany low voltage				398.0
Emissions Diesel use		0.0008	0.0032	0.973
Emissions Diesel use (agriculture)		0.0013	0.0032	0.972