BAYER
REDUCTION OF ON-FIELD GHG EMISSONS

Methodological Report

/////////// March 2025

The Crop Science division of Bayer

Methodological framework for calculating on-field GHG emissions of crops

Through this critical review, Bayer aims to demonstrate a method for measuring on-field GHG intensity in a reasonable approach and that the baselining and performance tracking methodology is adequate.

Version 1.4

Description of key changes	
Version (Date)	**Key changes compared to previous version**
1.0 (December 2021)	n/a – Initial draft before external panel review
1.1 (June 2022)	Incorporated feedback from the 1st external panel review cycle
1.2 (December 2022)	Incorporated feedback from the 2nd external panel review cycle
1.3 (October 2023)	Incorporated feedback from the 3rd external panel review cycle
1.4 (March 2025)	Shifted report focus to methodology only; outlier analysis integrated into the methodology; information on quantitative baseline and tracking of target removed and reported in the Bayer Impact Report

Disclaimer

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ANA Brazil	Agência Nacional de Águas e Saneamento Básico, Brasil National Water and Basic Sanitation Agency, Brazil
BL	Baseline
CCCs	Crop-country combinations
CDP	Carbon Disclosure Project
Cf.	Compare
CFA	Cool Farm Alliance
CFP	Cool Farm Platform
CFT	Cool Farm Tool
CH_4	Methane
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
CPP	Crop protection product
EASAC	European Academies Science Advisory Council
FAO	Food and Agriculture Organization of the United Nations
FAQ	Frequently asked questions
FU	Functional unit
GHG	Greenhouse gas
GHGp	Greenhouse Gas Protocol
ha	Hectare
ILCD	International Reference Life Cycle Data System
int	Intensity
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
kWh	Kilowatt per hour
LCA	Life Cycle Assessment
mt	metric tonne (1 mt equals 1,000 kg)
N	Nitrogen
N_2O	Nitrous oxide
NH_3	Ammonia
NO	Nitric oxide
pH	Potential of Hydrogen - Logarithmic expression of the hydrogen ions concentration in a solution
SBTi	Science Based Targets initiative
SDGs	Sustainable Development Goals
UN	United Nations
U.S.A.	United States of America
USDA-NASS	U.S. Department of Agriculture - National Agricultural Statistics Service
WRI	World Resources Institute
WWF	World Wide Fund for Nature
yr	Year

1 Context and Objectives

1.1 Context

Bayer is a Life Science company with a more than 150-year history and core competencies in the areas of agriculture and health care. Contributing to sustainable development has become a core element of Bayer's corporate strategy. For Bayer, sustainability focus areas and targets were developed to fulfill the aim to shape the future of sustainable agriculture. Bayer's sustainability focus areas were developed to address the end-to-end impacts of agriculture on the following: field GHG emissions, environmental impact reduction of crop protection, improving the livelihoods of smallholder farmers and driving positive change in water productivity in water scarce regional cropping systems.

According to a report of the Intergovernmental Panel on Climate Change (IPCC), agriculture, forestry and other land use account for about 22% of all GHG emissions worldwide. As one of the largest agricultural companies in the world, Bayer recognizes the impact of its products and aims to empower farmers to reduce the on-field GHG emissions of agriculture wherever the company operates. **Bayer aims to enable its farming customers to reduce their on-field greenhouse gas emissions per mass unit of crop produced by 30% by 2030 compared to the overall base year emission intensity. The overall base year greenhouse gas intensity includes the weighted emission intensities of 17 crop-country combinations. In 2024, the crop-country combination Australia-Cotton was removed from the scope due to the unavailability of data. Base years are defined individually for each crop-country combination, using data from either harvest year 2021 or 2022 depending on the availability of data. Base years were adjusted in 2024 due to additional data requirements based on an updated GHG calculator methodology and lack of data availability from prior years. This reduction target applies to the highest greenhouse gas-emitting crop systems in the regions Bayer serves with its products (with the exception of the crop-country combinations Italy-Corn and Spain-Corn that were not selected based on these factors but were additionally included because data were already available).** The scope of Bayer' efforts is focused on emissions of major GHGs (CO_2, CH_4, N_2O) from the field operations. To meet this objective, Bayer aims to foster and encourage the adoption of regenerative agriculture practices and technologies amongst its farming customer base.

The main objective of this report is to document how Bayer is quantifying GHG emissions and soil carbon sequestration. More specifically, this report documents how Bayer compiles inventory data and conducts a GHG impact assessment based on the GHG Protocol and IPPC special report on Climate Change and Land and IPCC GHG emission factors for agriculture, as well as internationally recognized and empirically validated Cool Farm Tool (CFT) calculator. The CFT & Cool Farm Platform (CFP) will further be used in the determination of improvement potential towards the GHG reduction target. While being aware of the potential risk of burden shifting, Bayer emphasizes that this assessment focuses on the GHG emissions and soil carbon sequestration resulting from field operations and does not cover other impact categories such as ecotoxicity and other Bayer sustainability focus areas, as they are assessed and documented in separate reports by different task forces.

In addition to setting a target on the GHG emissions resulting from farming, Bayer aims to reduce the treated-area-weighted environmental impact per hectare of Bayer's global crop protection portfolio by 30% by 2030 against a 2014–2018 average baseline. Bayer also will support a total of 100 million smallholder farmers in low- and middle-income countries (LMICs) by 2030 by improving their access to agricultural products and services, including in collaboration with Bayer's partners. Additionally, Bayer supports their smallholder customers to increase water productivity[1] by 25% by 2030 against a 2019-2021 average baseline[2] by transforming rice cropping in the relevant geographies where Bayer operates, starting in India[3].

[1] Water productivity is defined as kg of crop yield per volume of water applied (kg/m^3)

[2] Baseline validation still ongoing

[3] Bayer's water target is currently focusing on the 'DirectAcres Initiative' which aims at supporting farmers shift successfully from transplanted puddled rice to mechanized direct seeded rice.

In the context of this report, Bayer does not conduct a full-fledged LCA according to ISO 14040/44 but intends to use the standard as a framework to document the project in the present report. Additionally, Bayer's reporting methodology for downstream GHG emissions from arable crops are based on guidelines from GHG protocol Corporate Accounting and Reporting Standard as well as the GHG Protocol Agricultural Guidance. With the critical review by external experts, Bayer aims to demonstrate a method for measuring and accounting GHG intensities in a reasonable approach and that the baselining and performance tracking methodology is adequate. This report has gone through three rounds of review with an external expert panel, and subsequent updates will continue to be published without further external formal review process.

1.2 Review of GHG emissions related to agriculture, forestry, and land use activities with Bayer's role in GHG reduction

Food related emissions are those generated during production activities (crops and livestock), land use change and pre- and post-production processes. Production and land use change result in emissions generated on agricultural land, while pre- and post-production refer to emissions from supply chain processes including transportation, processing, and manufacturing of inputs. In 2019, the global anthropogenic emissions were estimated to be 54 billion tonnes of CO_2eq in which 17 billion tonnes CO_2eq (31%) comes from agricultural related activities. Breaking the share of agricultural related sources (31%) from the total anthropogenic emissions down to single gases, CO_2 accounts for 21%, methane (CH_4) accounts for 53% while nitrous oxide (N_2O) accounts for the highest which is 78 % (FAO., 2021). Aligning current production and consumption models in the agri-food sector with planetary boundaries[4] is vital for constructing a resilient food system and ensuring companies continue to thrive in a resource-constrained world.

According to the FAO (2021), farm gate emissions account for the largest share of the agricultural related emissions in 2019 with about 7 billion tonnes CO_2eq. Agriculture plays a role in GHG emission (Figure 1), and climate change also places significant pressures on agriculture in the form of reduced yields, land degradation, and increased threats from pathogens and disease. That means agriculture is confronted with tremendous challenges regarding climate change mitigation and adaptation.

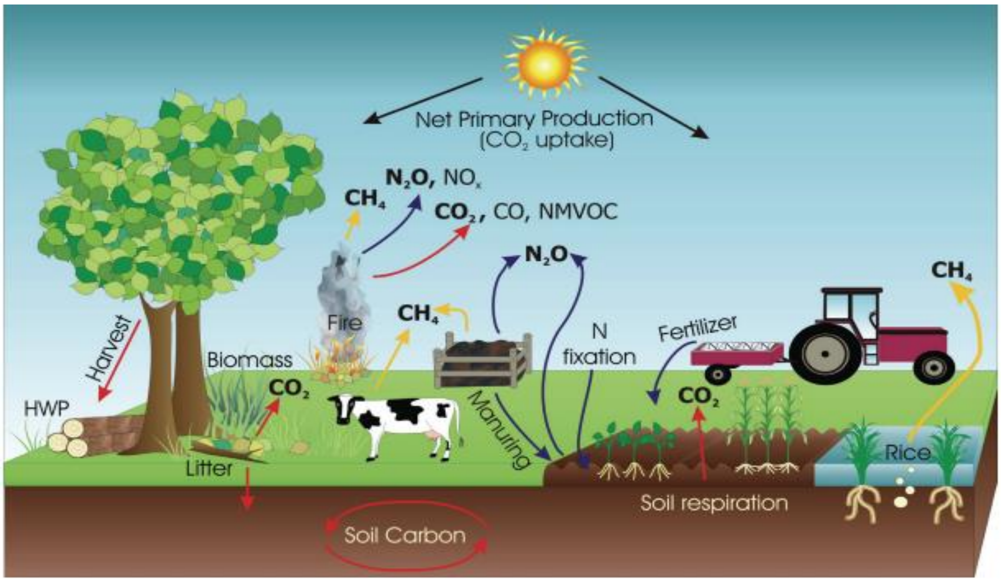

Figure 1: Main sources and sinks of emissions from agricultural system.
CH4: Methane, CO2: Carbon dioxide, N2O: Nitrous dioxide, NOx: Nitrogen oxides, CO: Carbon monoxide, NMVOC: Non-Methane Volatile Organic Compounds, HWP: Harvested Wood Products (Figure taken from (IPCC, 2006).

[4] As defined by Steffen et al., (2015), "The planetary boundaries framework defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth system".

Bayer has a responsibility to advance a climate neutral future for agriculture. Great progress has already been made to reduce agriculture's overall carbon footprint, but Bayer must work collectively with farmers and global partners to do even more. This will require innovation and new advancements in agricultural technologies. To accelerate this shift, Bayer has developed ambitious targets to measure GHG reductions and sustainable intensification of key crops and regions in which Bayer operates.

1.3 Bayer GHG reduction target is consistent with its commitment to international frameworks and key initiatives

Bayer is part of the world's leading Science Based Targets initiative (SBTi) that reviews Bayer's greenhouse gas (GHG) reduction targets. SBTi is a joint initiative of the Carbon Disclosure Project (CDP), the United Nations Global Compact, the World Resources Institute (WRI) and the World-Wide Fund for Nature (WWF). SBTi focuses on providing companies with a scientifically based framework for setting ambitious and effective climate targets towards the long-term goal of achieving net-zero emissions. It outlines criteria for effective reduction of companies` GHG emissions in line with the Paris Agreement goal of limiting global warming to 1.5 °C, compared to pre-industrial levels.

Bayer has the aim to continuously reduce GHG emissions within the company and along the entire value chain in accordance with the set criteria and validation of the SBTi. In line with this, Bayer has signed the Business Ambition for 1.5°C and committed to achieve net zero GHG emissions including its entire value chain by 2050 or sooner. Further details regarding Bayer's climate objectives and initiatives can be found in the section titled "How We Protect the Climate | Bayer Global" on the Bayer global website.

Additionally, Bayer aims to enable its farming customers to reduce their on-field GHG emissions per mass unit of crop produced by 30% by 2030. This applies to the highest GHG emitting crop systems in the regions Bayer serves with its products. While SBTi Forest, Land and Agriculture Guidance (FLAG) was launched in 2022, Bayer is not required to set a separate FLAG target because it does not operate in a designated sector, and its FLAG-related emissions do not exceed 20% of overall emissions across scopes 1, 2 and 3.

Therefore, Bayer will contribute to the reduction of on-field GHG emissions and promote soil carbon sequestration in relevant crops and geographies. Bayer will do so by leveraging expertise and its innovative seeds and crop protection portfolio, promoting the use of modern and efficient farming practices as well as capitalizing on its digital farming solutions. Together with its partners, Bayer will strive to promote climate-smart solutions and combine different levers to profitable/customized tailored solutions that help farmers to increase their resilience to consequences of climate change (such as droughts, heavy rains, erosion). Consequently, Bayer will supply farmers with the right tools and technologies to sequester carbon in the soil, reduce and avoid emissions and grow crops in a sustainable manner. Such levers include high yielding crop varieties, precision application of crop protection agents, water use efficiency, soil management through no-till and cover crops, crop rotation, root health, (nitrogen-) fertilization management, shortening the time of flooding in rice, digital tools to support decision processes and use of biological crop protection products.

Thus, the Bayer on-field GHG reduction target will also contribute to several of the United Nations' Sustainable Development Goals (UN SDGs). The United Nations agreed on 17 SDGs to build a better world for people and our planet by 2030. The 2030 Sustainable Development Agenda emphasizes that development should be compatible with all three dimensions of sustainability: economic, social, and environmental. Implementing the 2030 Agenda presents an opportunity for collaborative action by many diverse actors, and at all levels, to mitigate climate change impacts of agriculture. Bayer's aim to reduce agriculture's GHG emissions aligns mainly to the UN Sustainable Development Goal: SDG 13 – Take urgent action to combat climate change and its impacts.

1.4 Objectives

In 2019, Bayer set the target to enable its farming customers to reduce their on-field greenhouse gas emissions per mass unit of crop produced by 30% by 2030 compared to the overall base year emission intensity. The overall base year greenhouse gas intensity includes the weighted emission intensities of 17 crop-country combinations. In 2024, the crop-country combination Australia-Cotton was removed from the scope due to the unavailability of data. Base years are defined individually for each crop-country combination, using data from either harvest year 2021 or 2022 depending on the availability of data. Base years were adjusted in 2024 due to additional data requirements based on an updated GHG calculator methodology and lack of data availability from prior years. This reduction target applies to the highest greenhouse gas-emitting crop systems in the regions Bayer serves with its products (with the exception of the crop-country combinations Italy-Corn and Spain-Corn that were not selected based on these factors but were additionally included because data were already available). To achieve this target, Bayer has set a comprehensive method for evaluating current on-field GHG emissions and tracking progress, with a focus on identifying opportunities for GHG emissions reduction, using the CFT framework. Therefore, this report is aimed at achieving the below objective:

- **Methodology Documentation**: Document a method to quantify GHG intensities using Bayer farming customers' on-field GHG emissions and soil carbon sequestration to account for the climate change contributions from farming operations on the field.

To achieve this, Bayer is using the CFT GHG emission quantification tool and inventory data from Kynetec to account for the GHG emissions from Bayer farming customers. Based on this method, Bayer calculated a baseline to track performance and progress against the 30% on-field GHG reduction target.

1.5 Critical review

This report is structured using the Life Cycle Assessment (LCA) methodology (according to the ISO 14040 and ISO 14044) as a template for documentation of methodological choices, and limitations. As such, Bayer acknowledges that this report only focuses on the field gate-to-gate[5] life cycle stage for quantifying GHG emissions and soil carbon sequestration resulting from farming operations. As Bayer intends to communicate to the public its sustainability targets and achievements, a critical review has been performed, following a three-step iterative process. This report provides the review panel composition, its conclusions and the details of the comments and final report adaptations.

[5] Field gate-to-gate refers to the GHG emission resulting from crop production, starting from on-field soil preparation until the moment the crop leaves the farmers` field.

Table 1: Critical review panel composition

Members	Country	Area of expertise
Thomas Nemecek	Switzerland	Deputy Lead Life Cycle Assessment Research Group Agroscope. Worldwide known researcher on Life Cycle Assessment, specifically in its applications on agriculture.
Jeffrey Jenkins	U.S.A.	Expertise in environmental analytical chemistry, ecological risk assessment, and agronomically based ecohydrologic modeling to characterize watershed scale pesticide use and the potential impact on water quality.
Valery Forbes	U.S.A.	Dean and Professor at Florida Atlantic University. Broad expertise in mechanistic effect modeling and ecological risk assessment of pesticides and other chemicals.
Assumpció Anton	Spain	Researcher at Food and Agricultural Research Institute, IRTA. Expertise in the development and application of LCA methodology in agriculture.
Tiago Rocha	Brazil	Consultant/Partner at ACV Brasil and PhD in Environmental Technology. Experience in life cycle assessment, specifically in the area of carbon footprint.
Lorie Hamelin	France	Researcher at the Federal University of Toulouse (France), studying the environmental impacts related to large-scale transitions towards low fossil carbon use.
Anne-Marie Boulay	Canada	Associate Professor in Chemical Engineering at Polytechnique Montreal and CIRAIG. Expertise on water footprint methodologies and impact assessment associated with plastic litter in LCA.
Jessica Hanafi	Indonesia	PhD in Life Cycle Engineering. Established the Indonesian Association of Life Cycle Assessment and Sustainability Professional. ISO Technical Committee on Life Cycle Assessment (TC 207/SC5), environmental labelling (SC3), Greenhouse Gas (SC7) and project leader for ISO/TS 14074 LCA normalization and weighting. Applied LCA based on ISO 14040/44 to various industrial sectors, including agriculture.
Laura Golsteijn (Chair of the panel)	Netherlands	Senior LCA Consultant at PRé. PhD in Toxic Impact Modelling. Supporting clients to understand, develop and embed environmental metrics to improve the sustainability of supply chains and products.

1.6 Organization of the study

The overall primary data collection and GHG impact calculation process can be summarized as follows: For the compilation of inventory data, Bayer uses inventory data from Kynetec's FarmTrak™ Crop Protection and Seed which tracks global agriculture in 52 countries, by surveying and interviewing global grower panels annually and collecting details of the crops grown (Kynetec, 2021). These data are supplemented with FarmTrak™ Sustainability data which contain other field operation data like machinery and cultivation techniques. The combined data set compiles relevant information related to seed, crop protection, fertilizer use, and yield. Based on these extensive crop input data sets, Kynetec calculates on-field GHG emissions following the calculation methodology of the Cool Farm Tool. Then, Bayer interprets the results to set a global on-field GHG baseline value across crop-country combinations (CCCs) and to determine improvement potentials. More details on the compilation of inventory data, and impact assessment follow in later sections of this report.

Table 2: Contact information for all parties

Organization	Task	Contact information (Role)
Bayer	• Identification of key CCCs for methodology • Calculate overall weighted on-field GHG intensity baseline across CCCs • Apply global on-field GHG baseline internally at Bayer to determine improvement potentials in line with the Bayer on-field GHG reduction target • Assess how to integrate learnings into business models. Enable Bayer organization to work with on-field GHG data	Dr. Miya Howell miya.howell@bayer.com (Director, Science, Sustainability & Carbon) Johanna Kremers Johanna.kremers@bayer.com (ESG Strategy & Reporting)
Kynetec	• Questionnaire development and data collection (based on FarmTrak™) • Data mapping to GHG models and data analysis for on-field GHG emission calculations per CCC	Dr. Christophe Labyt Christophe.labyt@kynetec.com (Director, Sustainability Products and Services at Kynetec) Stephen Hearn (Consultant, Kynetec)

1.7 Study application and target audience

This report is intended to describe the method transparently and publicly for baselining and performance tracking. Bayer incorporated the expert panels feedback to ensure completeness, transparency and strive for credibility. Therefore, the primary target audience are investors, press, academic partners, and the general public. Potentially, this report might also be used in the future for auditing processes.

This report is not Bayer's main vehicle for informing external stakeholders. Further details regarding Bayer's efforts to mitigate climate change can be found in the section titled "Climate Change" on the Bayer global website.

2 Scope

This section includes a description of the system boundaries, functional unit, and other relevant scenario and scope information.

2.1 Aggregated system studied: From individual farms to crop-country combinations (CCCs) and rationale for their selection

This report focuses on quantifying on-field GHG emissions and soil carbon sequestration to account for the most emitting crop systems in the regions where Bayer operates. To achieve this, CCCs were identified and ranked using the total production volume of a particular crop in a particular market from the FAO or USDA databases, Bayer market share and GHG estimated through public LCA databases. Data was then collected by Kynetec from farmers for each of the CCCs to allow for calculation of GHG intensities using CFT. Bayer then aggregates the GHG emissions of each crop country with the production volume, and market share to estimate the carbon intensity for each CCC. The following 17[6] CCCs were selected for the assessment:

Table 3: Selected crop-country combinations (CCC)

Country	Crop
Argentina	Corn
Argentina	Soybeans
Australia	Wheat
Brazil	Corn
Brazil	Soybeans
Canada	Rapeseed
Canada	Wheat
France	Wheat
India	Rice
Italy	Corn
Mexico	Corn
Spain	Corn
United States	Corn
United States	Cotton
United States	Soybeans
United States	Wheat, Spring
United States	Wheat, Winter

Through this approach, Bayer will target crops with the largest potential for reduction to meet its sustainability-related objectives. The CCCs were selected based on the following criteria:

- Business relevance based on production volume of a particular crop in a particular market (FAO / USDA database) and Bayer market share in a particular market.
- Climate change mitigation through reduction of carbon footprint of the cropping systems and GHG emissions (Arunrat et al., 2021).
- Italy-Corn and Spain-Corn were not selected based on these factors but were additionally included because data were already available and aligned with Bayer business.

2.2 System Boundaries: Defining the scope of the estimated emissions

This section provides an overview of the emissions included (in-scope) in this assessment. The GHG intensity is determined within the gate-to-gate boundaries, using survey data from Bayer farming customers and based on the CFT methodology for baseline establishment. For reporting on the progress towards the target , any updated versions of the CFT will be applied, and if necessary, a review of the previous results will be conducted to ensure consistency and accuracy.

The assessment excludes some emission categories that occur beyond the farmers field and are considered out of scope. The assessment focuses on emissions that farmers can directly influence. Information on the emissions considered (in-scope) in this assessment are listed in Table 4 below.

[6] Due to the unavailability of updated data on cotton in Australia, the CCC Australia cotton was removed in 2024 from the CCCs in scope.

Table 4: Overview of practices included in the system boundaries

In-scope emissions	Details
Fertilizer application	includes on-field emissions from fertilizer decomposition, encompassing CO_2, N_2O, NO and NH_3 emissions and the latter two gases are included due to their potential conversion to N_2O.
Energy sources consumed on the farm	includes farm machinery use during sowing, cultivation, application of fertilizer and crop protection products, harvesting, and irrigation.
Organic matter application	includes on-field emissions coming from decomposition of left-over residues, or from other ways of managing residue (incorporating it in the soil, taking it off field etc.).
Management changes	Includes changes in soil carbon stock due to soil management (tillage practices and cover crops), soil organic carbon accumulation (carbon sequestration) or decline.

Although the CFT calculates emissions related to the production of crop protection products and fertilizers, transportation, and land use change, these emissions are considered out of scope in this assessment. Transportation is excluded because it refers to activities outside the farmgate and land use change is considered out of scope due to lack of reliable data. The production of crop protection products and fertilizers is out of scope because of Bayers strategic decision to focus on on-field GHG emissions that farmers can directly influence.

2.3 Functional unit

Since the function of the system is to produce crop biomass for food, feed, fuel, or renewable materials, in line with the CFT methodology, the functional unit (FU) is defined as follows:

FU = 1 kilogram of crop produced in a growing season within a crop-country combination

3 Method

The performance measurement approach needed to report on the carbon intensity to support Bayer's target to reduce on-field GHG intensity follows the processes highlighted below.

1. Inventory data compilation
2. Determination of on-field GHG emissions using the Cool Farm Tool
3. Calculation of Bayer customer GHG intensities
4. Aggregation of all CCCs and weighting GHG intensities as a function of crop production and Bayer market share for baselining
5. Reporting and comparison to the calculated baseline annually, or when data is available

The individual steps of the methodology are described in detail in the following sections. Please refer to Figure 2 below for a visual overview of the process flow and structure of this methodological approach.

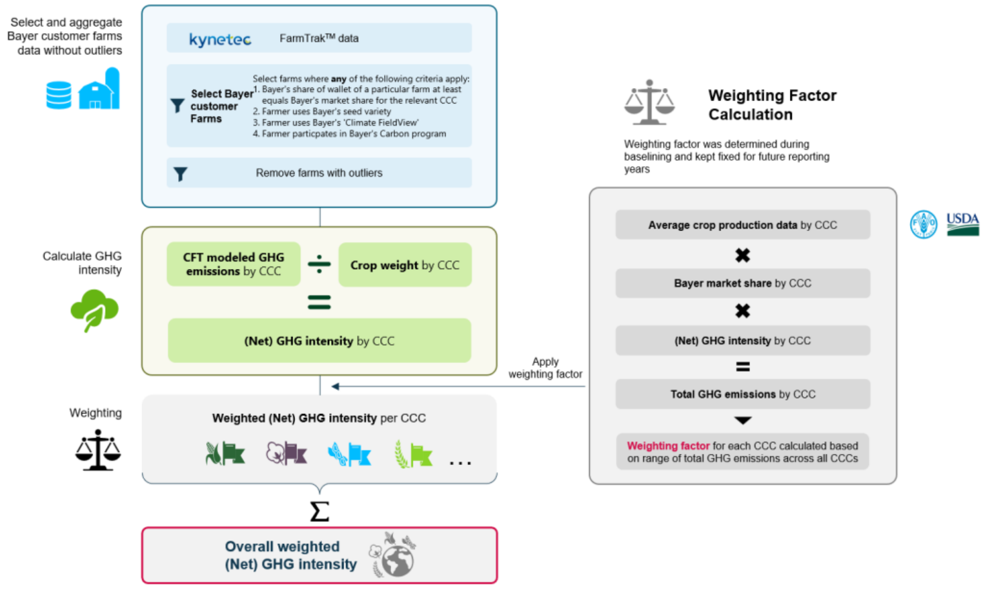

Figure 2: Illustration of the sequential steps and structure in the methodological process flow.

3.1 Description of the GHG Assessment Inventory data

Bayer uses primary inventory data from Kynetec's FarmTrak™ which tracks global agriculture in 52 countries, surveying and interviewing from amongst their 300,000 statistically representative grower community annually and collecting details of cropping systems used on over 43 million hectares of land each year. Kynetec, a global agricultural market research company, surveys customers to collect data and estimates GHG emissions using the science-based Cool Farm Tool calculator.

The inventory data used for this study as input for the CFT are sub divided into 2 categories/modules:

(a) Kynetec's FarmTrak™ primary panel data which focuses on all information related to crop protection, and seeds. These data are collected on an annual basis by interviewing farmers in the relevant markets. FarmTrak™ provides essential information for calculating carbon footprints but lacks data on other input domains.

(b) Kynetec's FarmTrak™ supplementary sustainability data used for other necessary input information such as fertilizer, soil characteristics, machinery, cultivation techniques etc. Each grower that is interviewed as part of the sustainability survey, was interviewed before on their crop protection activities. As such, Kynetec is able to create a data sequence of what happened on an agricultural field post-harvest of the previous crop until harvest of the crop of focus. This unique data sequence enables sustainability-related analyses for calculating GHG emissions at the field level using CFT, as shown in figure 3 below.

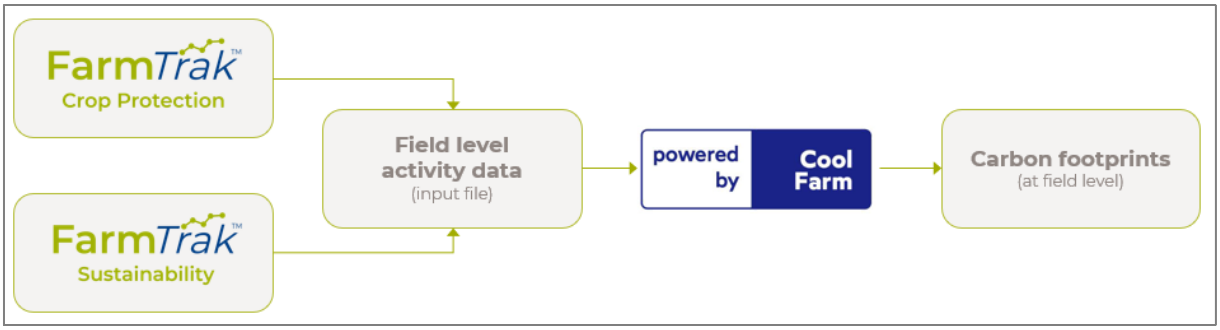

Figure 3: Workflow for the calculation of field level carbon footprints (supplied by Kynetec)

3.1.1 Sampling approach and processing

One of the aims of FarmTrak™ is to quantify input markets. A representative sampling design that accurately reflects the population is crucial. Kynetec sampling is based on official, statistical data for each crop across regions and is representative of all focus crops on the level of a particular region. The FarmTrak™ samples are built country-by-country while respecting local conditions.

A stratified sampling approach was used when selecting the FarmTrak™ panel respondents for initial baseline information and will be used for reporting methodology in the future. The three elements considered are (1) crop grown (2) location where the crop is grown and (3) size of the farm on which the crop is grown. Consequently, the entire population is split into subgroups considering these criteria. Size of each subgroup is determined by their relative importance in the market. Within each of those subgroups Kynetec applies a random sampling approach, i.e., each respondent belonging to one of these subgroups has the same a priori chance of being interviewed. Quota per subgroup is used and monitored to ensure a representative view of the market. An additional set of criteria are considered when selecting the respondents, to ensure Kynetec is interviewing the relevant person. For example, the surveyed respondent must be the farm manager or the person in charge of field level decisions (such as choice of fertilizer, seed, or CP product). (See Figure 4 below)

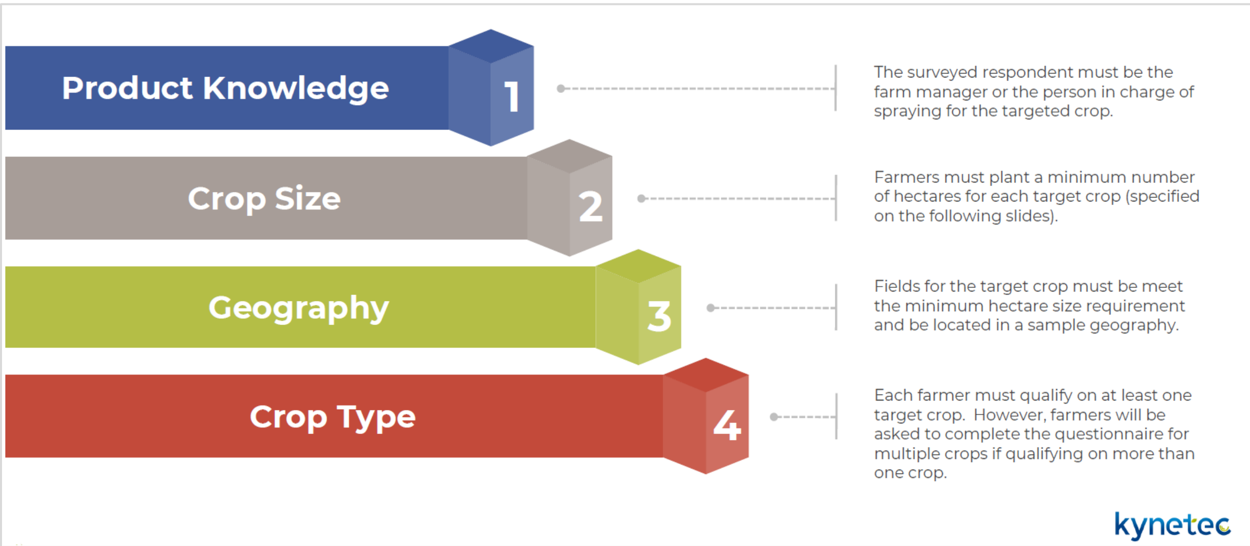

Figure 4: Qualifying criteria to be met by farmers for selection as part of survey respondents.

FarmTrak™ primary panel and the supplementary sustainability data collection rely on the same sampling approach, with the only difference being the number of interviews conducted. Usually, no less than one third of the initial FarmTrak™ panel are re-interviewed. In collecting these data, multiple data collection methodologies are deployed such as face-to-face (F2F) interviews, telephone interviews and online surveys. Kynetec achieves a high rate of panel retention thereby ensuring year-to-year data collection. The consistency of sample over the years will be between 60-90%. However, each time it is a statistically representative sample of randomly selected farmers by Kynetec, third-party independent market research which Bayer cannot influence.

Sampling Plan

Based on approximately 240K hectares
Minimum qualifying maize hectares = 3

<table>
<tr><th>Farm Size (ha) =</th><th>10-19.9</th><th>20-29.9</th><th>30-49.9</th><th>50-99.9</th><th>100+</th><th>Total</th></tr>
<tr><td>Flanders</td><td colspan="6">F2F | Telephone</td></tr>
<tr><td>Antwerp</td><td>3 | 4</td><td>3 | 3</td><td>10 | 11</td><td>13 | 15</td><td>9 | 11</td><td>38 | 44</td></tr>
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<tr><td>Flemish Brabant</td><td>5 | 5</td><td>3 | 4</td><td>6 | 6</td><td>8 | 10</td><td>7 | 9</td><td>29 | 34</td></tr>
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<tr><td>Wallonia</td><td colspan="6">F2F | Telephone</td></tr>
<tr><td>Hainaut</td><td>3 | 4</td><td>3 | 4</td><td>13 | 12</td><td>28 | 30</td><td>33 | 35</td><td>80 | 85</td></tr>
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<tr><td>Walloon Brabant</td><td>-</td><td>-</td><td>2 | 3</td><td>6 | 7</td><td>11 | 13</td><td>19 | 23</td></tr>
<tr><td>Total</td><td>34 | 38</td><td>34 | 38</td><td>79 | 88</td><td>146|163</td><td>157|173</td><td>450 | 500</td></tr>
</table>

Figure 5: A stratified sampling plan for data collection on corn cultivation in Belgium.

3.1.2 Data quality check by Kynetec

Several data quality control measures are implemented during and after data collection. First, the interviewers attend a professional training course related to research best practices and are given comprehensive instructions on the research procedures. All interviewers are initially accompanied and test-checked for their knowledge and competence.

The following methods are also adopted:

1. Collected data are checked for accuracy and consistency, including (telephone) back-checks.
2. Constant monitoring by fieldwork supervisors checking that all questions are asked correctly, proper responses are recorded, and that interviewers do not need further coaching/training.
3. Tablet and online questionnaires are equipped with proper logic so that farmers only answer questions relevant to them.
4. Based on knowledge and experience in data collection, Kynetec knows the acceptable ranges at product/application level with data collected therefore checks the data against extreme ranges to remove outliers.
5. Identified problem questionnaires are thoroughly reviewed by analysts and are subject to further telephone checks. This survey integrity stage is truly one of the most critical phases of producing this study.
6. Farmers are asked to report all behaviors and decisions. To achieve this, the respondent's anonymity is guaranteed. As a result, the panel data reflects the market realities of some off-label usage that would not otherwise be known.

3.1.3 CCCs production volume quantity and Bayer market share

The production volume of a particular crop in a particular market was derived from the Food and Agriculture Organization of the United Nations Statistics or from USDA database, depending on the CCC. This assessment uses the average crop production of five years for the 17 CCCs (2015-2019 for CCC with base year 2021; 2016-2020 for CCC with base year 2022).

The Bayer market share data for each of the 17 CCCs were calculated based on data extracted from internal databases. The data represents the internal market view with market share assumptions for 2021 and 2022, depending on the CCC specific base year.

The production volume and the Bayer market share are used in deriving the weighting factor (further explanation in section 3.4.2).

3.1.4 Definition of Bayer customer base used for the on-field GHG assessment

For the on-field GHG assessment, Bayer uses compiled inventory data for all 17 CCCs. The GHG emissions are measured and aggregated on the CCC level (for CCC-specific baseline values), and a consolidated global GHG performance across all CCCs selected (for a global aggregated baseline value) is calculated.

The Bayer GHG target is measured as a 30% reduction of on-field GHG emissions per mass unit of crop produced by Bayer's farming customers by 2030 for the highest GHG emitting crop systems in the regions Bayer serves with its products. Therefore, the focus of the Bayer on-field GHG target is on the GHG emissions and carbon sequestration of Bayer's farming customer base (i.e., field gate-to-gate GHG intensities per mass unit of crop produced) for any Bayer's farming customer in a particular CCC.

Because farmers in the FarmTrak™ panel data might use solutions from different competitors simultaneously, Bayer's farming customers were identified and distinguished in FarmTrak™ following the below mentioned reasoning. The farms will be identified relying on "share of wallet" calculations, comparing it with Bayer's market share in a CCC.

Farmers are Bayer's customers based on the following principles (also shown in Figure 2):

1. Bayer's share of wallet of a particular farm at least equals Bayer's market share for the relevant country/crop combination (see equation 1 and 2 below) and / or
2. They use Bayer's seed variety and / or
3. They use Bayer's 'Climate Field View[7]' and / or
4. They are being incentivized by Bayer for adoption of climate-smart practices by participating in Bayer's Carbon programs

[7] Climate Field View is Bayer's digital farming software platform that helps farmer to monitor and make agronomic decisions on their fields for yield optimization and profit maximization.

$$\text{Market share (in a CCC, fraction)} = \frac{\text{Hectares treated with Bayer products in entire market}}{\text{Total hectares treated with crop protection in entire market}} \quad (1)$$

Market share per country will be calculated considering hectares treated with Bayer's products relative to total hectares treated with crop protection in that market. Market share will be calculated considering all product lines. Hectares treated refers to "Super Developed Area" and takes multiple applications on same field into account. For example: if a field of 10 hectares is treated twice, Bayer considers hectares treated/super developed area to be 20 hectares.

$$\text{Share of wallet (on a farm)} = \frac{\text{Hectares treated with Bayer products on the farm}}{\text{Total hectares treated with crop protection on the farm}} \quad (2)$$

In the current calculations, share of wallet states how much respondents spend/use on Bayer's products exclusively. Share of wallet can be calculated considering hectares treated with Bayer products relative to total hectares treated on the same farm.

Share of wallet allows to evaluate how Bayer is performing against competitors and allows to benchmark against Bayer's market share of a particular country-crop combination. All farms will be identified as Bayer customers if Bayer's share of wallet of a particular farm at least equals Bayer's market share for the relevant country-crop combination. Farms will be identified as non-customers, if Bayer's share of wallet of a particular farm is smaller than Bayer's market share for the relevant country-crop combination OR does not meet the other 3 criteria listed above.

3.2 Determination of on-field GHG emissions and carbon sequestration with the Cool Farm Tool

3.2.1 Cool Farm Tool model description

The Cool Farm Tool (CFT) was developed by the Cool Farm Alliance (CFA) and is used to measure GHG emissions from agricultural production. Bayer has been a member of Cool Farm Alliance since 2020. CFT is a GHG calculator that quantifies the carbon footprint of crops in kg CO_2 equivalents (kg CO_2e) over a 100-year time horizon. The tool offers quantified, credible, and standardized metrics based on empirical research and a broad range of published data sets and IPCC methodologies. It has a specific farm-scale, decision-support focus making it possible to calculate GHG emissions on the field. It further provides farmers with the opportunity to evaluate different management options that will lead to positive impact on the total emissions from the farm. Additionally, CFT enables calculation of both emissions reductions and removals, the latter being an important aspect of agriculture GHG accounting in terms of adaptation and mitigation benefits. As a result of its use of readily available farm data, there is considerable scope for its use in global surveys to inform on current practices and potential for mitigation (Hillier, et al., 2011).

The CFT was originally developed by Unilever and researchers at the University of Aberdeen to help growers measure and understand on-farm GHG emissions. The use of the tool is designed to be simple, but scientifically robust in accounting for farm GHG emissions. It has been tested and adopted by many multinational companies which are using it to work with farmers to measure, manage and reduce GHG emissions arising from crop production towards contributing to the mitigation of climate change. More information about CFT can be found at http://www.coolfarmtool.org.

The CFT was selected for this assessment because of its ease of use, widespread adoption, global applicability, decision-support focus, and its ready availability of farm data for the intended purpose which is to calculate GHG emissions. The CFT is being used by diverse array of stakeholders which includes food retailers, manufacturers, input suppliers, NGOs, universities, and consultancies. A list of CFT partner members can be found at https://coolfarmtool.org/cool-farm-alliance/members/.

The methodology used in the CFT calculates GHG emissions and removals associated with the production of an agricultural product. A carbon footprint is reported for the three major sources of on-farm emissions associated with the production of agricultural products, namely, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). For crops, the CFT incorporates IPCC Tier 1 and Tier 2[8] when it comes to N_2O emissions and soil carbon sequestration. A simplified Tier 3 multi-factorial empirical model based on Bouwman et al., (2002), which is widely acknowledged, is used for N_2O emission. The Cool Farm Tool is moving towards Tier 3 when possible. Currently, CFT (v2.0) is based on the IPCC 2019 refined guidelines and uses the Global Warming Potentials from the IPCC Assessment Report 6 (Cool Farm Alliance, 2022). Detailed information on the data needed to calculate GHG emissions from crops is summarized in the CFT data input guide. Please refer to the CFT data input guide, the CFT FAQ, and Hillier et al., (2011) for a detailed technical description of the CFT methodology. Methods for CFT are continually updated, and current projects include aligning CFT with the GHG protocol land-sector removal guidance and the scope 3 standard.

The CFT has several input sections listed below. Each section requires provision of information related to the crop being assessed. The carbon footprints are calculated for one selected growing area/parcel/field per farm, assuming similar soil characteristics and input/management practices on that same area/parcel/field. For each crop and growing area, a full annual production cycle is considered. The scope of the current project is to consider emissions before the crop leaves the farm (i.e., everything on-field before 'farmgate').

3.2.2 Cool Farm Tool input data

The CFT is structured according to the following sections:

a. Farm settings
b. Crop
c. Soil
d. Inputs
e. Fuel & Energy
f. Irrigation
g. Carbon
h. Transport (excluded)

When using the CFT for emission calculation, some input parameters have been predefined in the model while some are to be defined by the user. In the next sub-chapters, we will go into the details of the input parameters used in the calculation of GHG emissions. The Bayer inputs used in the next sections are based on Kynetec data (see section 3.1 for details).

a. Farm settings

This is the base section where details about the farm location and the climate condition are defined. The input parameters are described in Table 5 below.

[8] A tier represents a level of methodological complexity used in GHG calculation. There are three tiers namely Tier 1, Tier 2, Tier 3. Tier 1 is the basic method; Tier 2 represents the intermediate while Tier 3 is the most complex in terms of the methodology.

Table 5: Cool Farm Tool Input parameters on farm settings

Variable	Options / Unit	Description
Country	-	Country where the farm is located.
Annual average temperature	°C	This information is not collected during the interview with farmers, instead Kynetec relies on external sources (such as the National Oceanic and Atmospheric Administration - NOAA)
Climate	- Temperate - Tropical	Climate zones are defined following the logic of Bouwman et al. (2002) who categorize all Global Ecological Zones (FAO, 2010) as either temperate or tropical: - Tropical: tropical and subtropical - Temperate: temperate and boreal
Longitude & Latitude	- IPCC Climate Zone	Climate is no longer required input, but IPCC climate zones are required and based on latitude/longitude as direct inputs. Resolution is 0.001

b. Crop

This section is divided into three input sections which are crop details, crop residue management and co-products.

Crop details

Information here includes the type of crop, area for crop growing and the crop yield (see Table 6 below for details on the Input data required for crop details). The CFT has an additional emission calculation for rice when cultivated as paddy rice. This is because paddy rice plays a significant role in the overall emission from agriculture. The CFT accounts for the emission from paddy production using the IPCC approach based on Xiaoyuan Yan et al., (2005). The emission factor from this approach considers water regime during cultivation, water regime in the pre-season and organic amendments. The model considers emissions from seeds to be quite low, compared to the other sources of emission.

Table 6: Cool Farm Tool Input parameters on crop details.

Variable	Options / Unit	Description
Crop name	-	Name of the crop.
Harvest year	-	Calendar year during which the crop was harvested.
Crop area	Hectare	Size of the parcel, including buffer zones.
Harvested amount	Metric tonne	Total harvested crop from the crop area for the relevant harvest year before on-farm processing (e.g., drying, grading, sorting) of crops i.e., Fresh matter
Farm-gate ready amount	Metric tonne	Total marketable yield from the crop area for the relevant harvest year after on-farm processing.
Assessment name	-	A reference name for the identification of the assessment.

Crop residue management

Crop residue refers to the plant matter from crop production that is not used as a sellable product and remains on the field after harvest. Often, harvest does not cover the full biomass of a crop and thus crop biomass remains as residue both above and below ground. Examples of residue from crop production typically include leaf lamina, leaf mid-rib, pseudostem sheath, fruit peelings etc.

For the calculation of emissions from residue in the CFT, the amount of residues generated per year and the way residues are managed are required as input data. The amount of plant residue is estimated by CFT based on IPCC method (V4, Chapter 11, Table 11.2) and GHG emission of it is calculated based on IPCC report (V4, Chapter 2.). If residues are used to create compost, the tool will calculate the possible emissions associated with this compost production process. However, if compost is then used on crops, an emission factor of zero is associated with the compost since it is already accounted for in the residue section. When residues are used as compost, the emission increases depending on the technology (forced aeration or non-forced aeration) used during composting. Non-forced aeration accounts for more emission compared to forced aeration. Detailed description of the required input can be found in Table 7 below.

Table 7: Cool Farm Tool Input parameters on crop residue management

Variable	Options / Unit	Description
Residue amount	Tonne/ha	The default residue amount estimated by the CFT for various crops is used in this assessment.
Residue management	-	The CFT provides the following pre-defined options for selection. - Removed from field for use or for sale. - Used for composting: Forced aeration or non-forced aeration compost. - Left untreated in heaps. - Burnt on the field. - Distributed on the field, incorporated, or mulched. The above options are selected for the assessment based on the responses from the farmers on how they manage crop residues.

Co-products

This section of the CFT allows allocating the total crop emissions between main product (e.g., wheat) and co-product (e.g., straw). However, Bayer excludes co-products because it does not allocate a proportion of emissions of the main crop to one or more co-products. The estimated GHG emissions from co-products are associated with main product. Therefore, this assessment uses the default by allocating all emissions to a single main product.

c. Soil

This section is where the soil characteristics of the field being assessed are specified. In defining the soil characteristics, the CFT considers input from the soil characteristics, soil texture, soil organic matter, soil moisture, soil drainage and soil pH. The pre-defined chosen input range for soil organic matter is used in determining the soil organic carbon. Detailed description of the required input can be found in Table 8 below.

Table 8: Cool Farm Tool Input parameters on soil characteristics

Variable	Options / Unit	Description
Soil characteristics	- Sandy, wetland, volcanic, sodic, high activity clay, low activity clay	IPCC2019 requires additional soil characteristics. CFT can retrieve these based on latitude/longitude in soilgrids.
Soil texture	- Fine - Medium - Coarse	Soil texture is based on soil type, as stated by the grower, and grouped accordingly: - Fine: sandy clay, clay, silty clay - Medium: sandy clay loam, clay loam, silty clay loam - Coarse: sand, loamy sand, sandy loam, loam, silt loam, silt
Soil organic matter	- SOM <= 1.72% - 1.72% < SOM <= 5.16% - 5.16% < SOM <= 10.32% - SOM > 10.32%	The soil organic matter is expressed as percentage. As stated by the grower, selection is made based on the four categories. In case soil organic matter is unknown (e.g. because soil was not tested recently), this information is gap-filled by relying on https://soilgrids.org/ (based on lat/long, 30cm top layer of soil).
Soil moisture	- Moist - Dry	As stated by the grower. Moist soils are those without any water constraints during the growing season.
Soil drainage	- Good - Poor	As stated by the grower. Soils which are often saturated or show surface water were classified by the grower as 'Poor,' other soils are classified as 'Good.'
Soil pH	- pH <= 5.5 - 5.5 < pH <= 7.3 - 7.3 < pH <= 8.5 - pH > 8.5	As stated by the grower, selection is made based on the four categories. In case soil pH is unknown (e.g. because soil was not tested recently), this information is gap-filled by relying on https://soilgrids.org/ (based on lat/long, 30cm top layer of soil).

d. Inputs

This section is divided into two input sections which are fertilizer inputs and crop protection inputs. These inputs have influence on the GHG emission of the farm. The emissions resulting from the fuel used in applying of these inputs are entered in the 'Fuel & Energy' section. Detailed description of how emissions from fertilizer and crop protection inputs are calculated are described below:

Fertilizers

In the case of fertilizers, the CFT accounts for two types of emission pathways: emissions released during fertilizer manufacturing and emissions from the application of fertilizer on the field. Since emissions from fertilizer manufacturing are considered out of scope for the Bayer on-field GHG target, only emissions from the application of fertilizer on the field are covered: These emissions are mainly triggered by bio-chemical process related to the addition of nitrogen fertilizers and limestone. Although emissions from soils may happen without the use of fertilizer, fertilizer application is one of the major sources of N_2O emissions. From the input of the type of fertilizer used on the field, the CFT tool defines the N:P: K ratio of the fertilizer. For nitrous oxide (N_2O) and nitric oxide (NO) emissions resulting from nitrification and denitrification process, the factor values from the multivariate empirical model of Bouwman et al. (2002) were used. NO and NH_3 emissions are converted to N_2O using recommended IPCC factor. Volatilization of NH_3 is also considered using the equation from FAO and IFA (IFA and FAO, 2001), and the recommended IPCC conversion factor is used for NH_3 to N_2O. In moist soils, some of the added nitrogen fertilizers are lost through leaching. Factors from IPCC are used to estimate the amount of nitrogen that are lost through this pathway and the resulting N_2O emissions. The emission effect from the presence of nitrification inhibitors in fertilizers are modelled using the methodology by

Akiyama et al., (2010). The CFT methodology used in accounting for emissions associated with field application of fertilizers considers the different types of fertilizers, crop type, soil properties and fertilizer application methods (see Table 9 below).

Table 9: Cool Farm Tool Input parameters on fertilizer management

Variable	Options / Unit	Description
Fertilizer type	Pre-defined list of applicable fertilizers	As stated by the grower, the fertilizer used during crop production is selected here from the CFT predefined list.
Application date	Date	CFT V2 considers application date in combination with lat/long. Emissions following fertilizer applications are wet/dry factor depending on monthly averages.
Application rate	Kg or L per Hectare	The amount of fertilizer used per hectare, as stated by the growers
Fertilizer weights or units	Product or Units of active element	Units of product (kg or liter) is used as default option.
Application method	- Broadcast - Incorporate - Apply in solution - Fertigation	As stated by the grower, a selection is made on how the fertilizer is applied on the field.
Emission inhibitors	- None - Nitrification inhibitor	For each fertilizer applied, the growers mention if the fertilizer contains an emission inhibitor or not. None is chosen when the applied fertilizer contains no inhibitor.

Crop protection inputs

The CFT assumes that a part of the emissions from use of crop protection products occur during their production. Since this type of embodied emissions take place off-field, they are out-of-scope and not considered in this report. Emissions related to the energy use from applying the crop protection products on the field are accounted for in the direct energy section.

e. Fuel & Energy

This section deals with the estimation of emission resulting from energy consumption in the growing area. Possible energy sources that are considered are electricity and fuels. This includes on site energy use for machinery and irrigation. The consumption of fuel and the use of energy for farm operation adds to the overall emissions from agricultural production. The emission calculation includes both electricity and liquid fuel use. For energy sources which consist of diesel, petrol, bioethanol, biodiesel, electricity (grid, hydroelectricity, and wind), the CFT uses emission factors derived from the GHG protocol (2003). The CFT does not assume a zero emissions factor for renewable energy. Emissions for electricity from renewable energy are significantly lower than for electricity from the grid but not accounted as zero due to emissions released during the development of renewable energy technology and construction of plants. In situations when the data of annual amounts of energy sources consumed for certain activities are not available, indirect figures such as number of applications, machinery/vehicle type, fuel type, and size of area treated are used to compute emissions.

In the CFT, this section is divided into three parts: Direct energy use, field operations energy use and wastewater.

Direct Energy Use

Energy consumption related to irrigation is accounted for in direct energy use. See Table 10 below for details on the input paraments for this section.

Irrigation

For estimating irrigation volume, we first calculate potential evapotranspiration by crop for every week between planting and harvesting for every location (lat/long of farm). Second, we compare it with precipitation by week for same location. From survey data we know during which weeks they irrigated. Lastly, we assume mm of irrigation by looking at the gap between potential evapotranspiration (i.e., what the crop needs) and precipitation. If there is a gap between requirements and what has been supplied for a given week (during which they irrigated) we assume that growers were able to supply the missing water. Efficiency associated with different irrigation methods is taken into account (e.g., drip is more efficient than flooding, thus less water is lost, and smaller amounts can be added). The CFT calculates the energy requirements in kWh for irrigating 1 mm/ha depending on irrigation method and fuel used. These reference values are used to estimate energy consumption.

*Table 10: Cool Farm Tool Input parameters on direct energy use**

Variable	Options / Unit	Description
Energy source	Predefined list of different sources of energy	Electricity or diesel is assumed to be the relevant energy sources.
Energy used	- Kwh - liter	Volume of energy used (liter of diesel or KWH electricity)
Category	- Field - Facility	Energy consumption from irrigation is categorized as 'field.'

*CFT has an embedded calculator for calculating emissions from irrigation water. This was used instead of direct energy inputs.

Field Operations Energy Use

Energy consumption related to on-field machinery operations is considered in the section 'field operations energy use.' The CFT supports estimating fuel use for common agricultural machinery from tillage, sowing, spraying crop protection, fertilizer applications and harvesting. The focus of this section is to determine energy used based on machinery operation on the field. Required inputs are the type of machine (obtainable from a pre-defined list), fuel used and number of field operations. Type and number of field operations are entered following the below mentioned logic.

- Sowing and cultivation practices: As part of the 'sustainability' data collection, growers are asked to mention which one of three cultivation practices they adhere to (1) conventional tillage (2) reduced tillage (3) zero tillage. Building on the logic as described in Khaledian et al. (2014) these cultivation practices result in the below mentioned machinery operations. These are mapped accordingly on the CFT machinery typology. Machinery passes associated with different tillage regime differ by country and crop. The source used for these estimates is FAO Leap (https://www.fao.org/partnerships/leap/applications/en/)

Table 11: Cool Farm Tool Input parameters on cultivation practices and field operations

Cultivation practice	Machinery operations
Conventional tillage	Plowing, Harrow, Disc Harrow, Seed Drill
Reduced tillage	Harrow, Disc Harrow, Seed Drill
Zero tillage	No-till Seed Drill

- CPP spraying and fertilizer applications: Number of times the field was visited for applying crop protection products and fertilizers is derived from the FarmTrak™ crop protection data and sustainability data. Both databases provide information on the timing of the different applications. All applications that happen on the same date are aggregated and are assumed to happen during one single pass for fertilizers and crop protection (Cf. concept of tank mix for crop protection data).
- Harvesting and residue management: Kynetec assumes that harvesting is mainly done with a combine (e.g., cereals, soybean, corn), or could be done manually in some smallholder markets (e.g., India rice). A special 'Corn combine' is selected for harvesting corn. In case the grower

mentioned that the crop residue is taken off field, a pass with a baler for collecting the residue is added.

Table 12: Cool Farm Tool Input parameters on field operations energy use

Variable	Options / Unit	Description
Machine category	Pre-defined list of different farm operation	Selection is made based on different farm operations. E.g. Harvesting, tillage, spraying, sowing, fertilization.
Machine	Pre-defined list of different machines based on the selected farm operation	Selection is made based on different machines used in farm operations. For example, when spraying was selected as machine category, herbicide sprayer was selected here.
Fuel use	- Diesel - Petrol	Diesel is used as a default fuel type for machinery.
Number of operations	-	Number of completed field operations related to the farm operation being assessed during the growing cycle for the crop. Filled based on response from the growers.

Wastewater Emissions

Most crops do not have wastewater emissions and are thus not accounted for in the GHG emission calculation. Methane emissions from wastewater arises from the decomposition process of organic material. This is common in coffee where a wet milling process is used to separate the pulp from the bean. The Bayer CCC list has no coffee as part of the selected crops, therefore wastewater emission is not relevant for this report.

f. Irrigation

In the irrigation section, we use the irrigation module in CFT. Irrigation water applied (mm) is calculated by estimating the difference between crop water requirements and the actual amount of precipitation (weekly basis). Crop water requirements are calculated following the FAO 56 irrigation and drainage paper methodology (Allen, et al., 1998). ERA5 (EMCWF) is used as a source of precipitation data. When estimating irrigation water applied, we consider (in)efficiency of farmers' irrigation systems as well as the level of water availability / scarcity (i.e., growers' ability to meet water demand based on available water). Water availability is being considered, as we only focus on the weeks of the crop season when the grower was able to irrigate. Irrigation water applied was only calculated when the farmer indicated that the field was irrigated.

g. Carbon

This section describes the emission resulting from changes in management practices that alters the carbon stocks i.e., carbon stored by or released from the soil and above ground biomass of the growing area. Changes in carbon stocks can occur from alterations in land use, soil management, and biomass. They can affect net carbon capture or release, thereby impacting emissions. Land use change (e.g., deforestation) is not considered in this report (see section 4 on limitation for more information). Soil management practices considered are tillage and cover crops. The CFT v2 only considers changes in farm management practices that have occurred within the last 20 years because this time frame is assumed by IPCC and other GHG accounting standards as the period that soil carbon stocks need to reach a new equilibrium. Any management change that has happened before is assumed to be no longer relevant.

In the CFT, determination of the carbon stocks in the top 30 cm of the soil are based on the user soil characteristics input and are determined mathematically using bulk density and carbon density. The carbon density describes the carbon available in the top 30 cm of 1 ha of soil based on an assumed bulk density of 1 g/cm3 and 1% soil organic matter equals 1.72% of soil organic carbon. The IPCC Tier 1 method is used for the estimation of soil carbon stock changes using coefficients from (Ogle S.M.,

2005) for carbon stock changes related to change in management practice for a period of 20 years. The resultant amount of a change in soil carbon is dependent on climate (Hillier, et al., 2011). The changes in carbon were converted to an annualized CO_2 emission (can either be positive or negative) when land management changes in relation to carbon input practice and tillage practice. The carbon input classification scheme for cropping systems is mapped based on Tier 2 IPCC to group each field by low, medium and high carbon input. Low refers to minimal residue return as a result of residue removal, medium category accounts for annual cropping with cereals where residues are returned to the field while high is in addition to medium with higher inputs due to production of high residue yielding crops, cover crops, improved vegetated fallows and frequent use of perennial grasses in annual crop rotations. The tillage classes (conventional, reduced, or no till) are defined following IPCC classification. The changes in soil carbon stock as a result of manure and compost addition are derived from Smith et al., (1997).

Table 13:Cool Farm Tool Input parameters on tillage and cover crops management

Variable	Options / Unit	Description
Changed from …		Based on the information Kynetec gets from the growers, these types of management change are considered: - Tillage: Comparison of how the field was tilled (conventionally, reduced or not) - Cover crops: Checking if a cover crop is grown
Number of years ago	-	Number of years ago the situation changed.
Percentage of field	%	For changes related to tillage and cover crops, it is assumed the change occurred on the entire field.

3.3 Uncertainty assessment

Outlier calculations were performed to reflect the quantitative uncertainty estimates of the data within the CFT calculations. Fields were identified and outliers were removed based on the following steps and considering 20 years of practice change:

(1) Calculate confidence interval using the z-score method (based on standard deviation and mean of population) for all crop-country combinations,
(2) Calculate 99th quantile for each crop-country combination using "average + 2.33*SD",
(3) Separation of all crop-country data based on source of emissions (fertilizer soil, irrigation, machinery, management changes, paddy methane),
(4) Finding the outliers in each group of data using threshold of 3 standard deviation from the mean. If any emission source falls above or below the threshold, the entire farm is removed from the dataset (see Figure 6 below).

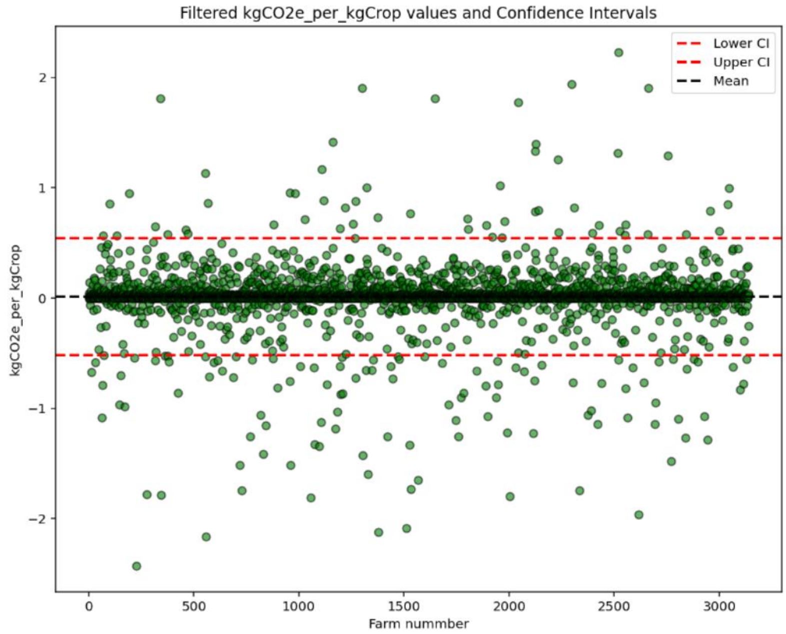

Figure 6: Example of distribution of all sources of GHG emissions for each farm plotted around the mean, upper and lower limits of the confidence interval

Reporting the 99% confidence interval reflects the uncertainty associated with this carbon calculation and supports a conservative approach also used in other company reporting methodologies. Until CFT has an uncertainty analysis, this approach is aligned with GHG protocol Land Sector and Removals Guidance (still in development) to assess statistical uncertainties and IPCC Guidelines for uncertainty assessment.

3.4 Calculation of Bayer Customers GHG intensities

In the following section, we describe in detail the methodology in the calculation of the overall Bayer Customer GHG intensity weighted across all CCCs for the baseline year (baseline year = harvest year 2021 or 2022 depending on the availability of data for the respective CCC). This section further includes the formulae that will be used for future tracking of the performance.

3.4.1 Calculation of baseline GHG intensities for CCC´s

The GHG intensity (kg CO_2e per kg crop) is the normalized gate-to-gate GHG emissions calculated for an individual CCC. For a baseline and a specific base year, the GHG intensity is calculated as shown in equation 3 below:

$$GHG_{BL,int}^{CCC} = \frac{\sum_{i=1}^{k} GHG_{i,BL}^{CCC}}{\sum_{i=1}^{k} W_{i,BL}^{CCC}} \qquad (KgCO2/KgCrop)$$

3

For *k* farmers assessed in a base year for a particular CCC:

- $GHG_{BL,int}^{CCC}$ = GHG intensity for a particular CCC in the base year
- $GHG_{i,BL}^{CCC}$ = Absolute GHG emissions of a farmer i for a particular CCC in the base year
- $W_{i,BL}^{CCC}$ = Crop weight (Kg) of a farmer i for a particular CCC in the base year

For a future year (t), the GHG intensity for a particular CCC is calculated based on the following formula:

$$GHG_{t,int}^{CCC} = \frac{\sum_{i=1}^{n} GHG_{i,t}^{CCC}}{\sum_{i=1}^{n} W_{i,t}^{CCC}} \qquad (KgCO2e/kgCrop)$$

4

For *n* farmers assessed in a year t for a particular CCC:

- $GHG_{t,int}^{CCC}$ = GHG intensity for a particular CCC in a year t
- $GHG_{i,t}^{CCC}$ = Absolute GHG emissions of a farmer i for a particular CCC in a year t
- $W_{i,t}^{CCC}$ = crop weight (kg) of a farmer i for a particular CCC in a year t

As the absolute emissions and crop weight values are separately summed up, Bayer intensities are weighted according to different crop weights and, indirectly, field sizes.

3.4.2 Setting an aggregated baseline for GHG intensity reduction across CCCs

To calculate the **GHG intensity across all CCCs for a baseline and a particular year (for an overall aggregated baseline value)**, the individual baseline results which are specific for each CCC (as described above) need to be aggregated. For this aggregation, the baseline GHG intensity for a particular CCC in the base year ($GHG_{BL,int}^{CCC}$) is weighted with a weighting factor (Wf_{CCC}) which is also specific for each CCC.

$$GHG_{BL,agg} = \sum_{CCC} GHG_{BL,int}^{CCC} \; x \; Wf_{CCC} \qquad (KgCO2e/kgcrop)$$

7

- $GHG_{BL,agg}$ = Aggregated GHG intensity baseline weighted across CCCs (weighted to represent Bayer market)
- $GHG_{BL,int}^{CCC}$ = GHG intensity for a particular CCC in the base year
- Wf_{CCC} = Weighting factor for a particular CCC in the base year

The weighting factors (Wf_{CCC}) are determined by the total production volume of a particular crop in a particular market multiplied by Bayer market share and by the GHG intensity of Bayer customers in this CCC (baseline). The combination of the production volume, the Bayer market share and the GHG intensity is referred to as the Total GHG emission (kg CO_2e). To avoid complexity, these weights are determined once during baselining and then kept fixed[9] (for the future). Therefore, all variables to determine the weighting factor, i.e., the production volume, the Bayer market share and the GHG intensity are also kept fixed.

$$Wf_{CCC} = \frac{P_{CCC} \; x \; M_{CCC} \; x \; GHG_{BL,int}^{CCC}}{\sum_{CCC} P_{CCC} \; x \; M_{CCC} \; x \; GHG_{BL,int}^{CCC}} = \frac{Total\ GHG}{range\ of\ Total\ GHG\ across\ CCC's} \quad (unitless)$$

8

- Wf_{CCC} = Weight of a particular CCC in the portfolio (determined during baselining and fixed) (dimensionless)
- P_{CCC} = Production volume of a particular crop in a particular market (FAO or USDA database) (mt)
- M_{CCC} = Bayer market share in a particular market (fraction)
- $GHG_{BL,int}^{CCC}$ = GHG intensity for a particular CCC in the base year (kgCO_2e / kg Crop)

[9] Note: Base year is CCC-specific.

Also, for future target years, the GHG intensity for a particular CCC in a year t ($GHG_{t,int}^{CCC}$) will be weighted with the fixed weighting factor (Wf_{CCC}).

$$GHG_{t,agg} = \sum_{CCC} GHG_{t,int}^{CCC} \; x \; Wf_{CCC} \qquad (kgCO2e/kgcrop)$$

9

- $GHG_{t,agg}$ = Aggregated GHG intensity weighted across CCCs in a year t (weighted to represent Bayer market)
- Wf_{CCC} = Weight of a particular CCC in the portfolio (determined during baselining and fixed)
- $GHG_{t,int}^{CCC}$ = GHG intensity for a particular CCC in a year *t*

Finally, a GHG intensity reduction (i.e., relative) is calculated across CCCs as:

$$R_t = \left[1 - \frac{GHG_{t,agg}}{GHG_{BL,agg}}\right] x \; 100 \qquad (\%)$$

10

- R_t = GHG intensity reduction (i.e., relative) across CCCs in a year *t* as compared with the baseline

Additionally, **target achievemen**t across CCCs can be calculated as:

$$TA_t = \left[\frac{R_t}{30\%}\right] x \; 100 \qquad (\%)$$

11

- TA_t = Target achievement across CCCs in a year *t* at the overall target of 30%

3.5 Performance tracking

The performance will be tracked by frequently collecting data, calculating the GHG performance in future years based on the same methodology as described in the above sections, and then comparing the future performance with the baseline performance.

The next steps are to estimate the aggregated GHG intensity based on the data to be collected by Kynetec annually, or as data becomes available, through 2030. Information related to the quantitative baseline and tracking of target achievement will be reported in the Bayer Impact Report.

Following guidance from the Greenhous Gas Protocol Corporate Accounting and Reporting Standard (WRI, World Resources Institute, 2004), for consistent tracking of emissions over time, the base year emissions may need to be retroactively recalculated/restated as Bayer undergo significant structural changes such as:

- Inclusion or exclusion of crop-country combinations.
- Investments or divestments.
- Change of boundaries.
- Changes in calculation methodology or improvements in the accuracy of emission factors or activity data that result in a significant impact on the base year emissions data.
- Discovery of significant errors, or several cumulative errors, which are collectively significant.

Consequently, Bayer shall clearly articulate the basis and context for any recalculations.

It is the responsibility of Bayer to determine the ‘significance threshold’ that triggers base year emissions recalculation and to disclose it. Based on recommendations of the California Climate Action Registry, the change threshold is set to 10 percent of the overall base year GHG intensity, determined across CCCs from the time the base year is established.

In sum, if Bayer realizes in the future that significant structural changes as described above happen, Bayer will re-check the baseline performance value. If the re-checked baseline performance value differs by 10% from the currently calculated baseline value, Bayer will restate the baseline and re-evaluate the further implications for the progress tracking towards the 30% reduction target.

3.6 Uncertainty analysis discussion in extant literature

In the assessment of GHG emissions, uncertainty evolves from three sources: Uncertainties on activity data (inventory), uncertainty resulting from year-to-year variability (i.e., changes in climate and management practice), and uncertainty resulting emission factors (i.e., characterization; Gibbons et al., (2006).

- Uncertainty arising from inventory data can be controlled by avoiding under-representation. At the farm scale, only a little uncertainty relates to the inventory data, as data are provided directly by farmers. At landscape or regional scale, data are often based on statistical averages or expert knowledge, thus, the degree of uncertainties are typically higher compared to farm scale (Colomb, et al., 2012). Therefore, Bayer has decided to partner with Kynetec to collect primary data based on interviews with farmers to ensure high accuracy of all reported activities especially those with strong influence on results, such as amount of N fertilizers reported.
- Uncertainty resulting from year-to-year variation can be reduced by using average climatic data and management practices over several years. For example, the same quantity of Nitrogen will result in different nitrification-denitrification rates due to variation in climatic condition (Colomb, et al., 2012). Bayer has initiated data collection for harvest years 2020-2022 and therefore, multi-year data for a crop and country are not yet available but planned to be included in future to avoid such uncertainty.
- Uncertainty resulting from emission factors are associated with the chosen GHG emission calculators. Specifically, for the CFT, Clavreul et al., (2017) found that the influence of model uncertainties on the GHG results are low.

3.7 Sensitivity analysis discussion in extant literature

This report only provides sensitivity analysis insights on the CFT GHG calculations using v1.0 and 1.11 based on existing literature. In a CFT case study example on the carbon footprint of open-field tomato production from 198 farms, Clavreul et al. (2017) found that several factors contribute to the variability in the carbon footprint results from CFT GHG calculation. Using a one-factor-at-a-time technique and Monte Carlo simulations, they conducted a sensitivity analysis to understand the impact of the different input parameters (farmer's inputs and model parameters) on the CFT GHG emissions results.

The results showed that the variability of total GHG emissions per mt of tomato produced was highly sensitive to variations in the production yield. Clavreul et al (2017) stated that a 70% reduction in yield resulted in a threefold increase in the GHG emission per mt of tomato. Furthermore, GHG emissions results were discovered to be sensitive towards variability in farm practices (underlined in Figure 7 below); in particular, to the ones related to fertilizer and diesel uses (e.g., for irrigation pumping).

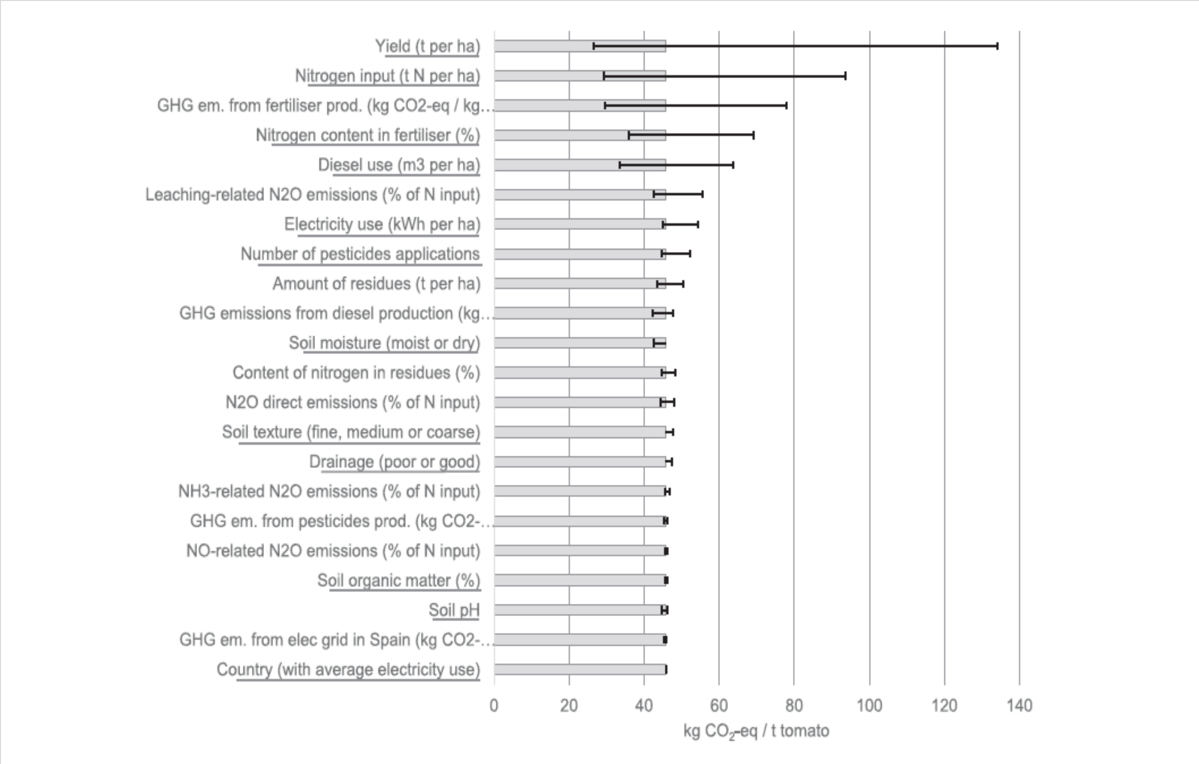

Figure 7: Factors that contribute to the variability in the carbon footprint results from CFT GHG calculation (Figure taken from Clavreul et al. (2017))

The Figure 7 above shows the total GHG emissions obtained (tomato production case) with error bars portraying the minimal and maximal GHG emissions obtained when testing minimal and maximal values for each parameter one at a time. Underlined are farmer related input data. The others are model parameters.

In a more recent study, Lam et al (2021) used the CFT to evaluate possible sources of variability in GHG footprint (in terms of kg CO2-eq/kg crop produced) of 26 crops using data from 4565 farms in 36 countries from 2013 through 2016. Across all crops and countries, they found that fertilizer use was the most important source of GHG emissions. Furthermore, they found negative relationships between GHG footprints and yields for the vast majority of the crops, suggesting that an increase in yield e.g., by growing more productive crop varieties) typically results in lower GHG footprints. According to the researchers, the reduction of GHG footprints with yield reflects that yield increase measures do not typically lead to a proportional increase in emissions. The researchers state that increases in yield are typically obtained through an increased farming efficiency which in turn does not increase GHG emission. An example is by synchronizing fertilizer application with crop nutrient requirements or by adopting more efficient crop varieties.

However, Lam et al. (2021) also found several non-linear negative relationships between GHG footprints and yields for certain crops in their dataset, suggesting that optimum yield values may exist in terms of GHG footprints. For example, the GHG footprints of parsley and strawberry decreased with increasing yield, up to a certain yield value and then increased again. Therefore, several GHG improvement levers (along with yield increase) should be implemented in an orchestrated and coordinated way (Lam, et al., 2021).

- For example, with precision farming that seeks to optimize amounts, types, methods and timing of fertilizer application, yields can be increased while limiting or reducing GHG emissions from the production and application of synthetic nitrogen fertilizers.
- Other opportunities to reduce GHG emissions without reducing yields are efficiency improvements of electricity and fossil fuel (e.g., by replacing inefficient machinery or substituting fossil energy).

- GHG emissions caused by electricity use for irrigation can be reduced by optimizing the efficiency of the irrigation technologies and strategies or transitioning to alternative electricity sources such as solar power.

4 Main limitations of the assessment

Relating to the limitation of the emission calculation using the CFT, the tool only considers seed emissions from potatoes and not for other crops. This could lead to an underestimation of emissions. However, these emissions are reported to be quite low, compared to the other sources of emissions. The CFT plans to include this emission category in future.

In relation to Land use change (LUC), Bayer acknowledges that LUC is one of the biggest contributors of GHG emissions in the global food systems. However, LUC emissions are not covered in this report due to the lack of reliable data and estimation difficulties. Therefore, Bayer only included emissions which can be reliably measured in the scope of its GHG target. Regarding the exclusion of the production of crop protection products and fertilizers, and transportation, this is considered out of scope because the assessment focusses on emissions resulting from operations on the field.

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