# Development of Carbon Calculator to promote low carbon farming practices

## Methodological guidelines (methods and formula) Final

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# Executive summary

**Description of the project**

In 2010, direct emissions from agriculture accounted for 9.6 % of total EU-27 greenhouse gas (GHG) emissions (472 million tons of carbon dioxide equivalent ($CO_2$e)). The agricultural sector is an important source of nitrous oxide ($N_2O$) and methane ($CH_4$) emissions and contributes to a smaller extent to carbon dioxide ($CO_2$) emissions.
The European Parliament, in the framework of the EU Climate program, set as a target a reduction of 20 % of GHG emissions in 2020 when compared to the level of emissions in 1990.
In this context, "the European Parliament asked the European Commission to carry out a pilot project on the certification of low carbon farming practices in the European Union to promote reductions of global warming emissions from farming" (JRC).
The aim of the project is to develop a comprehensive tool assessing and promoting the efforts of European farmers to produce according to carbon-neutral or low emission farming practices. The operational objective is to develop a software model for the calculation of GHG emissions from farming practices and for proposing mitigation actions at farm level.
The Carbon Calculator methodology complies with the Organisation Environmental Footprint (OEF) guide.

**Description of the deliverables**

Solagro has designed this tool, called "Carbon Calculator". A simple and comprehensive user interface has been developed (Excel with Visual Basics for Applications (VBA) for macros and user forms). Thus, users with basic computer and agronomic knowledge should be able to carry out an assessment. The Carbon Calculator tool is available for free download, together with its User Guidance Manual, from an internal server of Solagro's website (https://carbone.solagro.org/). The User Manual presents the tool to help a novice user understand how to fill in the different modules. The modules are presented in details and the document describes, step by step, the progress from data entry to the analysis of the results.

Another document entitled "Methodological Guidelines (methods and formula)" presents the general principles of the tool and details the methodologies, formula and sources used for the design and development of the Carbon Calculator.

Finally, an Administrator Guide has been created for the JRC. It contains explanations about the administrator web interface (managed by Solagro during one year) and the description of all the formula in VBA code calculations that are implemented in the Carbon Calculator.

**Purpose and scope**

Assessments conducted with the Carbon Calculator are carried out at farm scale, on a reporting period of one year. Methods of calculation and emission factors have been adapted to cover EU-27 specificities (e.g. climate, electricity grid, etc.). The design of the Carbon Calculator is based on methodological choices informed by European and International literature and the expectations of the JRC. Also, a peer-review meeting (Ispra, July 2012) discussed and validated the general methodological choices and suggested some additional specifications.

The Carbon Calculator provides an assessment of GHG emissions from farming practices at farm scale and proposes mitigation actions. A life cycle approach is favoured for this tool's design, considering all emissions upstream of the farm (cradle) to the farm gate. Direct and indirect GHG emissions are considered, including emissions due to the processing and distribution of inputs at farm level. The perimeter of the assessment does not include emissions out of farm-gate and up to trailers and consumers: distribution, storage by industries, transportation of farm products, and processing out of the farm. Carbon stock changes in soils and on-farm trees are also considered in the analysis. The tool is adapted to a wide range of farming systems (main farming systems in the EU-27) but is not designed for specific farms (e.g. rice cultivation) or on-farm activities (e.g. agritourism and processing).

The tool offers 16 possible mitigation and sequestration actions. For each established mitigation action, the Carbon Calculator evaluates the impact of a change in farming practices on the GHG profile.

In the final presentation of results, the tool also mentions other environmental impacts (surplus of nitrogen, primary direct energy consumption and water consumption).

**Potential users and applications**

The Carbon Calculator can be used by a wide range of people (e.g. farmers, agricultural advisors and trainers). The Carbon Calculator is a tool to assess greenhouse gas (GHG) emissions from farming practices and mitigation potential at farm scale. The objective of the assessment is also to compare farm practices between other farms with similar productions. A kind of GHG label has been created, at the farm scale and for the five main products of the farm.

**Key assumptions and limitations**

For now, end-of-life of inputs used on the farm is not taken into account in the Carbon Calculator, as the emission factors do not include the handling of agricultural waste (e.g. recycling of plastics, packaging and machinery). The evaluation of greenhouse gases does not go beyond the gates of the farm.
The Carbon Calculator needs to be tested on field case studies in a diversity of farming systems in order to determine its robustness and reliability.

The current version of the Carbon Calculator does not include any database for comparison of its results. For now, there are no usable results in the literature because the available methodology of GHG assessment used in previous tools always differs from the Carbon Calculator's methodology.

**Main results**

The Carbon Calculator provides two levels of presentation of the results: at farm scale but also for one to five main products of the farm. GHG emissions are expressed in $tCO_2e/ha$ (farm scale) or per unit (product scale) including a graphic comparison to a group. A second table highlights the five main sources of emissions.

In accordance with the JRC, carbon stock changes (in soils and farmland features) and GHG emissions saved by renewables energy produced on farm are calculated apart from gross GHG emissions at farm scale. A "Nitrogen balance" between inputs and outputs is also carried out. Direct primary energy and water consumption are also reported.

Detailed emissions are also available in specific tables, and the presentation is based on the organisational environmental footprint (OEF) guide: GHG emissions from direct activities (machines and equipment, process emissions) and GHG emissions from indirect activities (indirect energy, purchases), and additional environmental information (changes in carbon stocks and avoided GHG emissions due to renewable energy).

**Main conclusions and recommendations**

It is well recommended that a novice user first read the User Guidance Manual before starting an assessment on his computer. It provides advice for data collection, for the user interface and paths/navigation and offers remarks and warnings (e.g. data quality and data input priority) in order to strengthen the use of the tool.

**Expected benefits of the achievements**

The Carbon Calculator contributes to assessing the impact of farming on GHG emissions as well as carbon sequestration and is a great help to identify relevant sequestration and mitigation measures at farm scale.

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This report is the final version of the methodological guidelines for the Carbon Calculator.

# Introduction

The Carbon Calculator is a tool to assess greenhouse gas (GHG) emissions from farming practices and mitigation potential at farm level.

This document, entitled “Methodology guidelines”, presents the general principles of the tool and details the methodologies, formula and sources used for the design and development of the Carbon Calculator.

The AgriClimateChange Tool (ACCT), created in the framework of a Life+ collaborative project, forms the basis of the Carbon Calculator. It builds on French methodologies (such as Dia’terre® and GESTIM) as well as on European or international sources (Life cycle assessment (LCA), ISO norm 14064, national and international GHG inventories).

The methods developed in the Carbon Calculator are based on the expertise of Solagro, of the JRC (Joint Research Centre) as well as that of other European experts.

In order to design a tool for the EU-27, various guidelines and emission factors have been taken from the Organisation Environmental Footprint guide (OEF) of the European Commission – Joint Research Centre (EC-JRC-IES) and from the Intergovernmental panel on climate change (IPCC)[1]. Various European and international publications have been reviewed to improve data quality (e.g. the study “Evaluation of the livestock sector’s contribution to the EU greenhouse gas emissions” (GGELS) of the JRC). The list is detailed at the end of this document.

# 1 The Carbon Calculator project

## 1.1 Context and objectives

In 2010, direct emissions from agriculture accounted for 9.6 % of total EU-27 GHG emissions. The agricultural sector represents an important source of nitrous oxide ($N_2O$) and methane ($CH_4$) emissions and contributes to a smaller extent to $CO_2$ emissions. Direct $N_2O$ emissions from agriculture contribute to almost 70 % of total $N_2O$ emissions and direct $CH_4$ from agriculture contribute to around 50 % of total $CH_4$ emissions. In the EU, farming emissions have decreased by 20 % between 1990 and 2005 due to an increase in productivity, lower mineral fertiliser consumption and a decline in cattle numbers.

In 2008, the European Parliament set as an objective, in the framework of the EU Climate program, to reach a reduction by 20 % of GHG emissions in 2020 when compared to 1990 levels. At the beginning of the year 2011, the European commission recommended going further and aiming at a reduction by 25 % of GHG emissions.

In order to reach these ambitious objectives, agricultural and environmental policies should support farmers involved in the development of low carbon farming practices and mitigation actions.

In that context, “the European Parliament asked the European Commission to carry out a pilot project on the certification of low carbon farming practices in the European Union to promote reductions of global warming emissions from farming” (JRC).

The aim of the Carbon Calculator is to assess GHG emissions from farming practices and to suggest climate change mitigation and sequestration actions at farm level. The Carbon

1 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use

Calculator reports the carbon footprint at the farm scale and for the main products of the farm. Mitigation actions are evaluated according to their GHG profile.

The tool will also allow comparing emissions from farming practices among similar farms. However, the current version of the Carbon Calculator does not include any database for comparison. At this time, there are no usable results in the literature because the methodology used in existing tools always differs from the Carbon Calculator's methodology.

## 1.2 System boundaries

The Carbon Calculator assessment has to be carried out at farm level over a reporting period of one year.

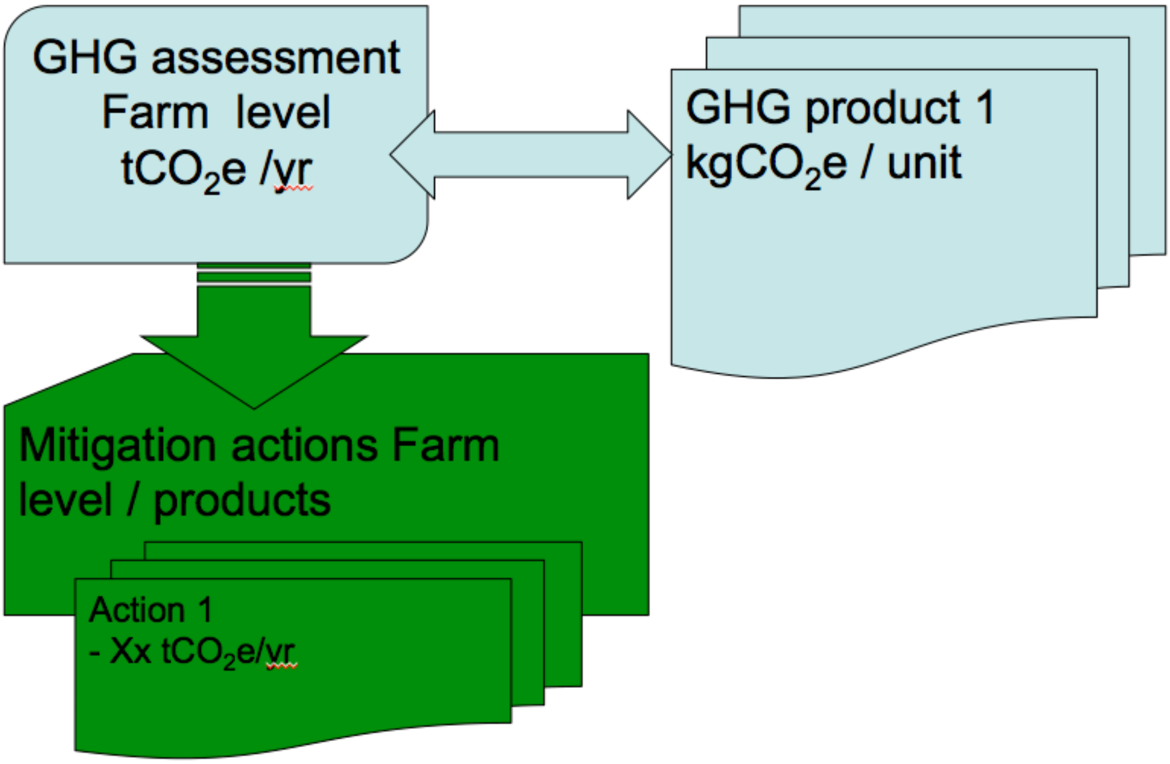



Figure 1: General scheme of the Carbon Calculator for farm level GHG assessment.

A life cycle approach has been favoured for the design of this tool, i.e. considering all emissions from upstream of the farm (cradle) to the farm gate. Direct and indirect GHG emissions are considered, including emissions from the processing and distribution of inputs (fertilisers, pesticides, feeds and other material). Carbon storage in soils (annual crops, annual pasture and bog) and in farm trees (vineyard, fruit trees, agroforestry and hedgerow) is also taken into account in the assessment.

### 1.2.1 Organisational boundaries

The Carbon Calculator focuses on the main farming systems of the EU-27:

- The farm is a physical land area with crops, livestock, buildings, machinery and inputs,

- “Control” approach (100%): the farm is owned by the farmer (financial) or the owner controls the farmer,
- Data for activities are available (the “farmer” knows them),
- In most of the cases: inputs purchased are used on the farm.

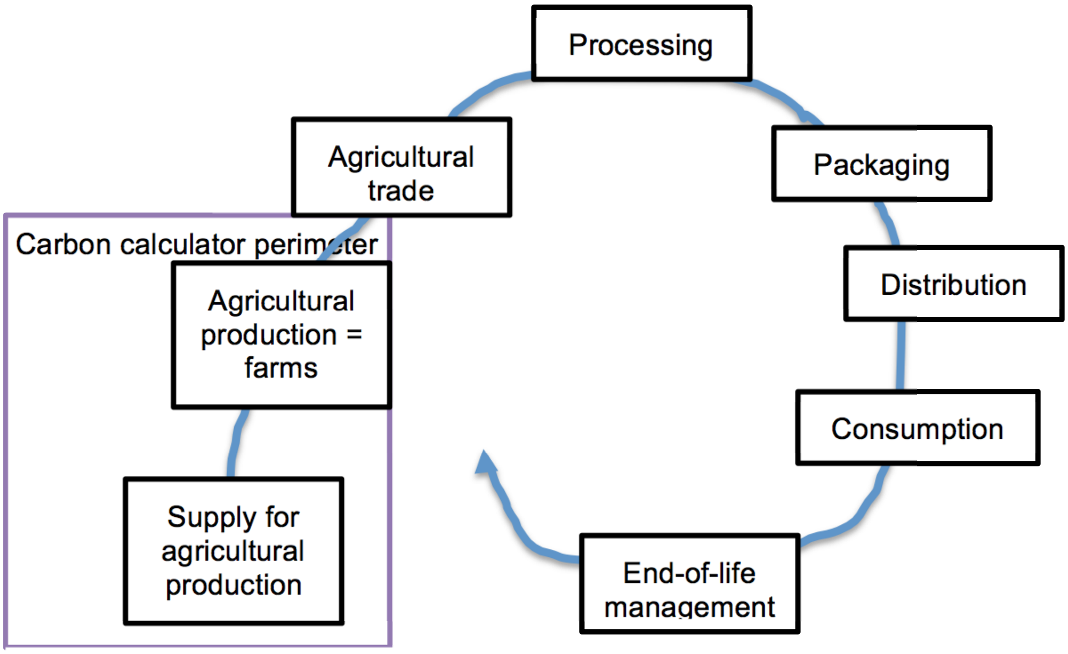



Figure 2: Generic food life cycle (from ENVIFOOD) and perimeter of the Carbon Calculator

The Carbon Calculator is not designed for the following specific farms or on-farm activities:

- processing and distribution of agricultural products,
- agritourism, offices, sale of heat,
- specific agricultural products with specific inputs and emission factors (EF),
- rice cultivation and other waterlogged farming systems,
- forest activity (Carbon Calculator is only restricted to trees and hedges along crops or grassland plots)
- fishery, and
- the lists of EF are not complete (for lack of specific research), especially for:
  - organic fertilisers for conventional or organic farming if not produced on farm,
  - organic fertilisers for greenhouse nutritive solutions,
  - specific inputs such as plastic pots, plants (vegetables, horticulture…) or seeds,
  - specific machineries or buildings.

### 1.2.2 Environmental Footprint boundaries

The Carbon Calculator takes direct and indirect activities and associated GHG impacts into account. The Carbon Calculator uses a “cradle to farm-gate” approach including:

- direct emissions on the site/farm: emissions for energy used, $CH_4$ and $N_2O$ (livestock, soils), C storage variations (soil, land use changes, farmland features like trees and hedges) and HFC emissions
- indirect emissions (downstream emissions, not on the site) from:
    - agricultural inputs,
    - end-of-life of plastics and organic matter output as waste, and
    - $NH_3$ volatilisation, leaching and run-off ($N_2O$).

The Carbon Calculator does not include emissions out of farm-gate and up to trailers and consumers: distribution, storage by industries, transportation of farm products, and processing out of the farm.

## 1.3 Emission sources

### 1.3.1 Type of emissions

The key GHG emissions sources considered in the Carbon Calculator are:

- Carbon dioxide ($CO_2$)
- Methane ($CH_4$)
- Nitrous oxide ($N_2O$)
- Hydrofluorocarbons (HFC)

These are the main GHG in the Kyoto Protocol that are relevant for farms.

GHG emissions due to sulphur hexafluoride “$SF_6$” as well as other gases impacting stratospheric ozone are not taken into account in this Carbon Calculator version. Those emissions are less significant than the main emissions sources ($CO_2$, $CH_4$, $N_2O$, HFC).

GHG emissions are expressed in tonnes of each gas emitted (tonnes of $CO_2$, $CH_4$ and $N_2O$) and in tonnes of $CO_2$ equivalent (t $CO_2$e). The conversion in t $CO_2$-equivalent is based on the Global Warming Potential (GWP) of each gas. This indicator is calculated on a 100 year-scenario, taking into account the persistence of the different substances in the atmosphere. The GWP used are drawn from the 2007 IPCC report. The equivalences obtained are:

- 1 tonne of $CO_2$ = 1 t$CO_2$e
- 1 tonne of $CH_4$ = 25 t$CO_2$e
- 1 tonne of $N_2O$= 298 t$CO_2$e
- and different GWP of HFCs from the Kyoto Protocol.

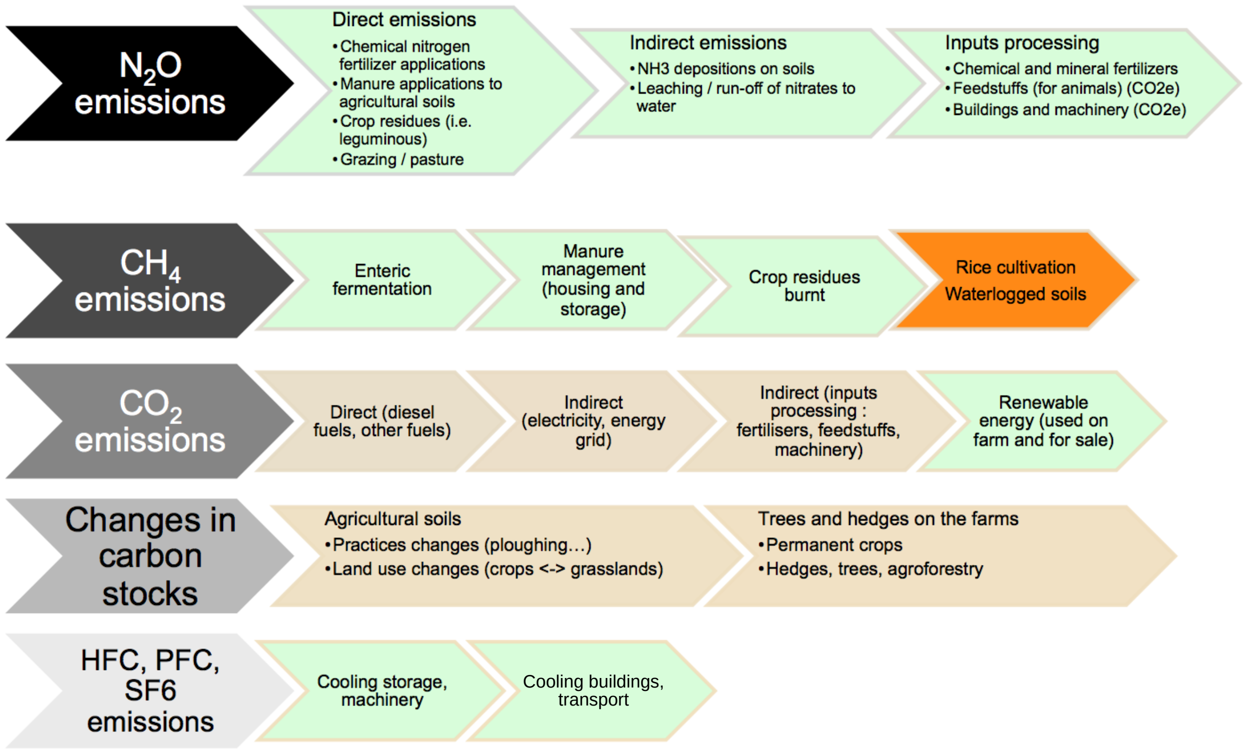



Figure 3: GHG emission sources and changes in carbon stocks at farm level. Sources in "orange" are not taken into account in the final version of the Carbon Calculator

Agricultural activities contribute to GHG emission through different processes. Emissions from the following sources are taken into account in the Carbon Calculator:

- Soils emissions (direct and indirect $N_2O$ and $CO_2$ from organic soils),
- Livestock emissions ($CH_4$ and $N_2O$ from enteric fermentation and manure management),
- Energy-use emissions (direct $CO_2$ from fuels, grid energy and indirect $CO_2$ from inputs processing and transportation),
- Refrigerant and air-conditioning emissions of HFC,
- Changes in carbon stocks in soils and farm trees.

$NH_3$ and $NO_x$ gases can be sources of air and water pollution. They are considered in the analysis and are expressed in kg of emitted nitrogen ($NH_3$-N, $NO_x$-N).

Table 1 shows the gases considered in the Carbon Calculator under different categories of emissions.

Table 1: Complete list of GHG emissions and carbon storage

| Emission source | Main GHG considered | Others gases considered |
|---|---|---|
| Managed soils: | | |
| • Direct: | | $NH_3$ / $N_2$ |

| | | |
|---|---|---|
| o Mineral fertiliser application<br>o Manure application<br>o Crop residues (including leguminous feed crops)<br>o Pasture<br>o Cultivation of organic soils | $N_2O$<br>$N_2O$<br>$N_2O$<br>$N_2O$<br>$N_2O$<br>$CO_2$ | |
| • Indirect:<br>o N deposition of $NH_3/NO_x$<br>o Leaching and runoff of nitrate | $N_2O$<br>$N_2O$ | $NH_3$ |
| Livestock: | | |
| • Enteric fermentation | $CH_4$ | |
| • Manure management (housing and storage) | $CH_4$, $N_2O$ | $NH_3$ / $N_2$ |
| Energy-use: | | |
| • Direct:<br>o Fossil fuels<br>o Electricity and grid energy (heating system) | $CO_2e$<br>$CO_2e$ | |
| • Indirect (processing and transportation of used inputs):<br>o Fertilisers and amendment<br>o Feedstuff<br>o Machineries and buildings<br>o Pesticides and seeds<br>o Other inputs (plastics, livestock fees etc.) | $CO_2e$<br>$CO_2e$<br>$CO_2e$<br>$CO_2e$<br>$CO_2e$ | |
| Refrigerant emissions: | | |
| • Refrigerants gases used in cooling, air conditioning, freezing on the farm | HFC | |
| Carbon storage: | | |
| • From agricultural soils (stock of organic carbon) and impacts of practices | C / $CO_2$ | |
| • From on farm trees | C / $CO_2$ | |

Table 2 presents the multiplication factors to convert atom of gas to gas.

Table 2: Conversion factors for gas units

| | Multiplication factor |
|---|---|
| From C-$CO_2$ to $CO_2$ | 44/12 |
| From C-$CH_4$ to $CH_4$ | 16/12 |
| From N-$N_2O$ to $N_2O$ | 44/28 |

### 1.3.2 Scopes considered for reporting

GHG emissions are divided in two perimeters according to the Organisational Environmental Footprint “OEF” requirements.

The determination of the perimeters is based on the document “Organisational Environmental Footprint Guide”. The Carbon Calculator declines these perimeters for the main European farming systems.

- “Direct activities”: the emissions are those of the area itself. They include $CO_2$ emissions from energy combustion in the area (mobile and fixed machines) and crop residues burnt, methane emissions (enteric fermentation and management of manure), $N_2O$ emissions (nitrogen input on soils and indirect $N_2O$ emissions from soils), and HFC emissions from leakage of gases.

- “Indirect activities”: includes indirect emissions due to energy spent to produce network electricity, energy for pumping drinking or irrigation water from a collective pumping system, and fuel used by a contractor for crop operations. Also included are indirect emissions due to the energy consumed for processing and transporting agricultural inputs such as purchased feedstuffs, organic matters and fertilisers, pesticides, seeds, plastics, machineries and buildings, emissions due to the N from $NH_3$ deposition, emissions from leaching and runoff as well as $N_2O$ emissions due to the $NH_3$ produced on the farm. It also includes fossil energy (the production, transport of fuel, petrol, mineral lubricants used on the farm).

Results of changes in the carbon stocks in soils (management practices and land use changes) and in farmland features (natural infrastructures), as well as GHG emissions avoided through the production of renewable energy (whether used on the farm or sold) are presented apart from the gross GHG emissions at farm scale, in the Additional Environmental Information section. Other environmental information is also available: water consumption and water pollution (nitrogen balance) and direct primary energy used.

These detailed results are useful to analyse different emission sources and contribute to detect the main GHG emission sources at farm level and for farm products.

### 1.3.3 Limitations

The Carbon Calculator is designed for the main farming systems through the EU-27, but is not adapted to all farms. The difficulties to run a GHG assessment in some specific farms is related mainly to the availability of emissions factors for this type of farm. For example, in horticulture systems, there are no emission factors for flowerpots and plants.

The evaluation of greenhouse gases does not go beyond the gates of the farm. The final version of the Carbon Calculator only includes a cradle to farm approach. The end-of-life of some inputs is not taken into account in this version because they are occasional: machinery, raw materials from buildings, pesticides and antibiotics.

### 1.3.4 Carbon stock changes

Farm practices can have a long-term impact (20 to 50 years) on carbon storage. Changes in the type of crop (annual, temporary, permanent) have an important impact on soil carbon content. Overturning of permanent grassland frees carbon into the atmosphere. Conversely, the conversion of arable land into temporary or permanent grasslands gives place to additional carbon storage.

## 1.4 Functional units

The first step for data entry in the Carbon Calculator is to define and quantify the production of relevant products at farm level. What is considered to be an agricultural product corresponds to its physical form beyond farm gate (before processing). The user can select up to a maximum of five different products from a drop-down menu. Simultaneously, a sixth category called "Other products" is always available.

In agricultural assessments[2], considering the scope of the Carbon Calculator, functional units are often areas or weight. The Carbon Calculator reports the GHG emissions as total GHG emissions in $tCO_2$-equivalent of functional unit:

- ✓ For the results at farm level, the functional unit used is the "ha of UAA" (Utilised Agricultural Area).
- ✓ For the results per product, the Carbon Calculator uses:
  - A tonne of milk, suitable for cow milk, sheep milk and goat milk.
  - A tonne of meat, suitable for meat from dairy cows, beef, pork meat, poultry meat and sheep meat.
  - A tonne of dry matter, suitable for cereals (including oleaginous and protein rich) and fodder (such as hay, silage…).
  - A tonne of raw matter, suitable for eggs, vegetables, fruit, wine and industrial crops (potatoes, tobacco, flax fibre and Miscanthus).

Units are also defined for each crop (for example, tonnes for wheat) and each animal product.

## 1.5 Attribution and allocation rules

Data needed for the Carbon Calculator are more often used to determine the links between one or several products of the farm.

Distribution of GHG emissions between products and co-products throughout the supply chain are determined according to three main rules:

[2] ENVIFOOD

- ✓ *Type 1: Direct assignment during the data input. For example, the GHG emissions (manufacturing) of mineral fertilisers applied on a crop will be directly attributed to this product (depending on the end-use of the crop).*
- ✓ *Type 2: automatic allocation. For example, on a specialised dairy farm (products = milk and meat from dairy animals) an automatic allocation rules 85%-15% base on protein content for enteric fermentation will be implemented.*
- ✓ *Type 3: assignment made by the user himself. For example, in case of propane gas used on a farm, the user will distribute the percentage/quantity of use of this input between different available products.*

Attribution and allocation rules are explained in more detail in paragraph 2.9.

## 1.6 Geographical scope

The Carbon Calculator has been designed to cover the EU-27. It is adapted to a wide range of farming systems and considers the climatic conditions and the dominant soil type as well as the presence of organic soils.

To run the Carbon Calculator, users have to indicate the type of climate, the type of mineral dominant soil, soil texture, soil pH and climate conditions of the year: average annual temperature (°C), mean spring temperature (°C), annual rainfall (mm), rainfall during winter (mm) and rainfall during summer (mm).

## 1.7 Results presentation

The presentation of the results is fully detailed in the User Guidance Manual.

The Carbon Calculator provides four main levels of presentation (see Figure 4):

- Total GHG emissions at farm level, expressed in $tCO_2e$/ha and including a graphic comparison to a group. A second table presents the 5 main sources of emissions at farm level.

- Total GHG emissions for one to five main products of the farm with:

  - Tables showing the sources of emissions per product, expressed in $tCO_2e$/unit including a graphic comparison to a group.

  - A second table presenting the top five GHG sources at product level.

- Total GHG emissions at farm level for the mains gases: $CO_2$, $CH_4$, $N_2O$, HFC and $CO_2$ from C stock changes

- GHG emissions avoided thanks to mitigation and sequestration actions are reported in a table.

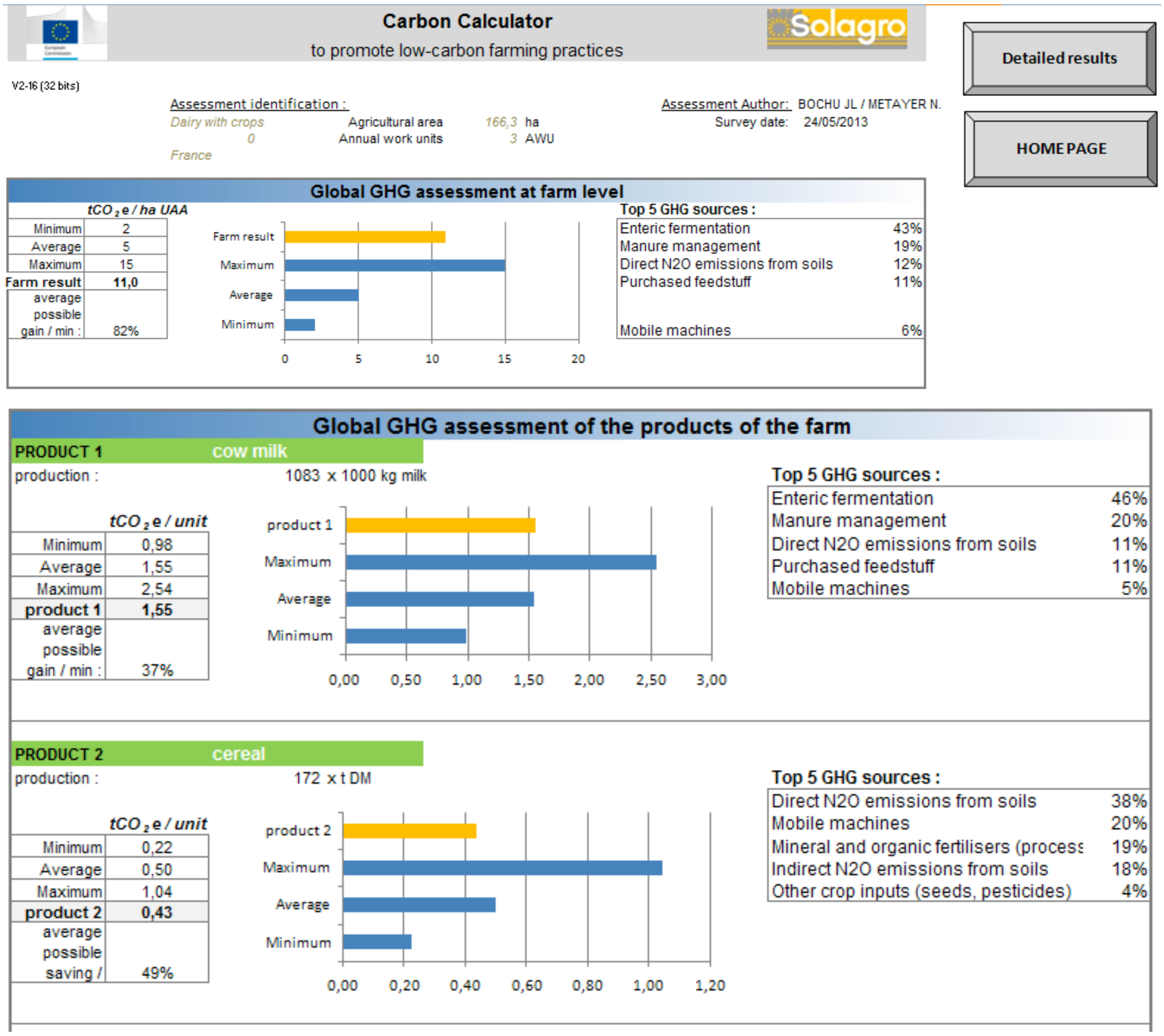



Figure 4: GHG assessment results presentation at farm level and for on-farm products

The presentation of results for detailed GHG emissions (by sources and gases) is based on the Organisational Environmental Footprint “OEF” guide:

- GHG emissions from direct activities (non-mechanical sources, enteric fermentation, manure management, direct and indirect emissions from soils, and burnt crop residues),
- GHG emissions from indirect activities: consumption of purchased electricity and other indirect energy sources like collective irrigation or water pumping, fuel from thirds (contractors, etc.), all other indirect sources from manufacturing and transportation (e.g. agrichemical production and product processing).

These detailed results are very useful to analyse different emission sources and contribute to detecting the main GHG emissions sources of the farm and of the products. GHG emissions by product (chosen at the beginning of the assessment by the user) are presented on the same model.

Carbon storage variations and GHG emissions avoided thanks to the production of renewable energies on the farm are not taken into account in this report, but are calculated apart, at farm level.

**Carbon Calculator**

**GHG Assessment (annual flow) of the farm**

V2-16 (32 bits)

Assessment
F_DairyCrops 166,3 ha
Dairy with crops 3,0 AWU
France 2010

**Detailed GHG emissions sources and carbon storage**

| Current situation (tonnes / year) | $tCO_2$ | $tCH_4$ | $tN_2O$ | tHFC (in $CO_2e$) | $tCO_2e$ | |
|---|---|---|---|---|---|---|
| **1 GHG emissions from direct activities** | **150** | **45** | **1** | **3** | **1 495** | **82%** |
| **1-1 Machines and equipment** | 102 | 0 | 0 | 3 | **105** | **6%** |
| Mobile machines | 102 | | | 0 | **102** | **6%** |
| Fixed machines | 0 | | | 3 | **3** | **0%** |
| **1-2 Process emissions** | 48 | 45 | 1 | | **1 390** | **76%** |
| Enteric fermentation | | 31 | | | **785** | **43%** |
| Manure management | | 13 | 0 | | **338** | **19%** |
| Direct $N_2O$ emissions from soils | | | 1 | | **215** | **12%** |
| Indirect $N_2O$ emissions from soils | | | 0 | | **52** | **3%** |
| Crop residues burnt | | 0 | 0 | | **0** | **0%** |
| **2 GHG emissions from indirect activities** | **48** | **0** | **0** | **0** | **327** | **18%** |
| **2-1 GHG emissions of energy used on the farm and purchased by thirds** | 35 | 0 | 0 | | **35** | **2%** |
| Electricity purchased (i.e. on the grid) | 28 | | | | **28** | **2%** |
| Collective irrigation (electricity or fuel for pumping) | 8 | | | | **8** | **0%** |
| Fuels from thirds (operations done by contractors) | 0 | | | | **0** | **0%** |
| **2-2 GHG emissions for other purchased inputs** | 12 | 0 | 0 | | **292** | **16%** |
| Mineral and organic fertilisers (processing and transportation) | | | | | **65** | **4%** |
| Other crop inputs (seeds, pesticides) | | | | | **4** | **0%** |
| Secondary inputs (plastics and other petrochemicals) | | | | | **3** | **0%** |
| Purchased feedstuff | | | | | **197** | **11%** |
| Other animal inputs (purchased animals, rearing costs) | | | | | **0** | **0%** |
| Farm buildings and materials | | | | | **5** | **0%** |
| Machinery (and other equipments) | | | | | **6** | **0%** |
| Fuels manufacturing and transportation | 12 | | | | **12** | **1%** |
| **3 Total GHG emissions** | **197** | **45** | **1** | **3** | **1 822** | **100%** |
| **4 Additional environmental information** | **92** | **0** | **0** | **0** | **92** | |
| Changes in carbon stocks in natural infrastructures | 30 | | | | **30** | **2%** |
| Changes in carbon stocks due to changes in soil management practices and land use | 62 | | | | **62** | **3%** |
| Avoided GHG emissions due to the use of renewable energies in the farm instead of non renewable ones | 0 | | | | **0** | **0%** |
| Avoided GHG emissions from the production and sale of renewable energies | 0 | | | | **0** | **0%** |

Figure 5: Detailed GHG emissions sources and carbon storage at farm scale reported by the Carbon Calculator

The Carbon Calculator provides an assessment of GHG emissions from farming practices at farm level and proposes mitigation actions.

16 actions could be suggested because literature and data collection were sufficient for designing these actions. For each established mitigation action, the Carbon Calculator evaluates the impact of a change in farming practices on the GHG profile. Economic gains are also evaluated for some of the actions.

## 1.8 User interface

The Carbon Calculator is designed based on the AgriClimate Change Tool (ACCT), a European tool co-designed by Solagro in the framework of the Life+ project 09 ENV/ES/000441. This tool consists in an Excel file, composed of 8 spreadsheets devoted to data entry.

It is not always easy for the user to identify by himself which data are necessary. For that reason, a training session is often necessary for users to better understand: data needs, how to collect them with a farmer, where to put them in the tool and GHG and energy results provided at the end of the assessment.

The aim for the Carbon Calculator is to create a tool, easy to understand and friendly to use.

A simple and accessible user interface has been developed. Users with basic computer and agronomic knowledge should be able to carry out an assessment with the Carbon Calculator.

The tool is developed on Excel with Visual Basics for Applications (VBA) for macros and user forms. The Excel options must be modified for that use.

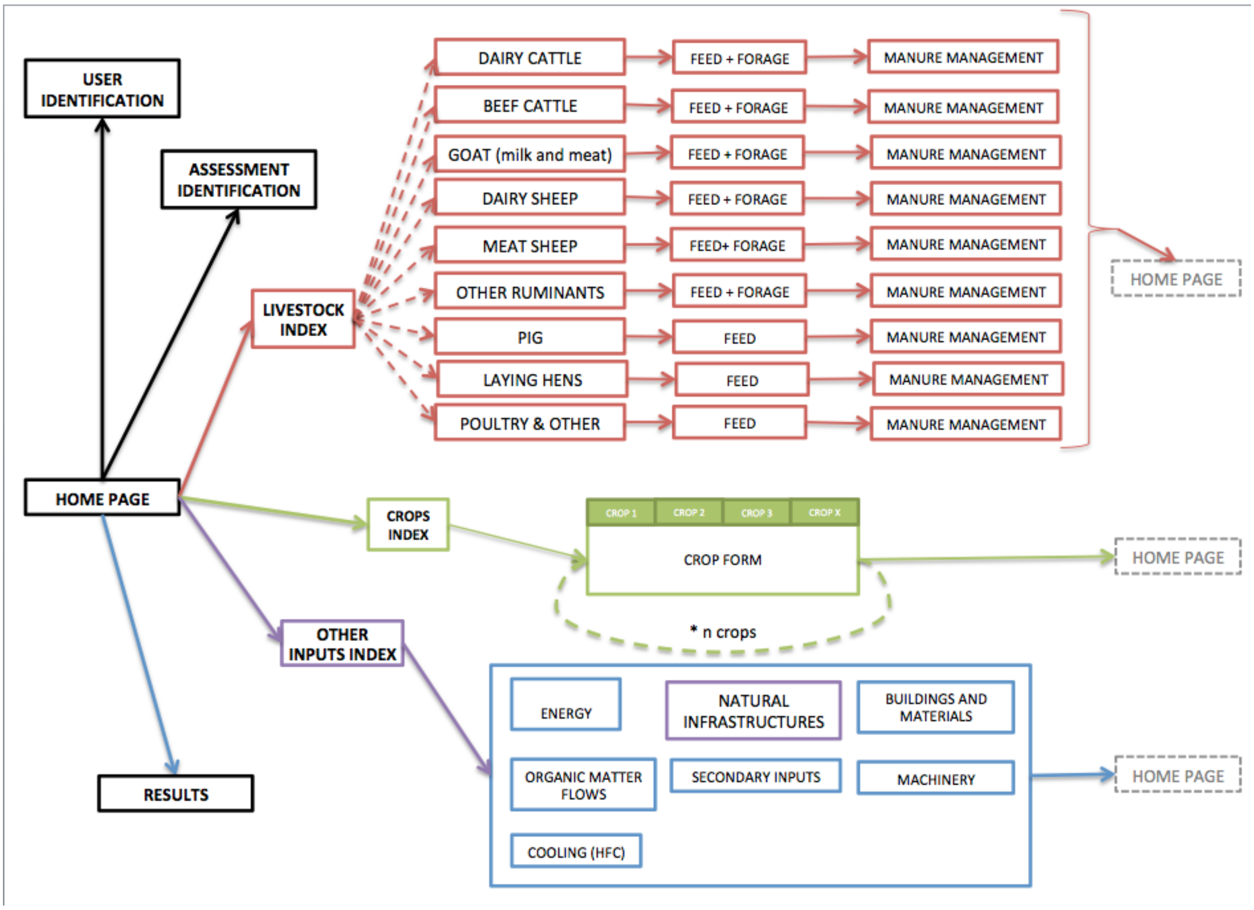



Figure 6: Pathways through the Carbon Calculator

The data needed (questionnaire) to run the Carbon Calculator has been defined based on the implementation of the methodology.

Additional data are required linked to methodology developments, about climatic conditions, soil type, pH, etc. in order to describe the environment of the farm.

Buttons have been created in each screen to facilitate the navigation between the different modules. Also, the user can modify the data entered as many times as necessary. As the calculations in the tool are done immediately, the user can directly check changes in the GHG results after a modification of a data entry.

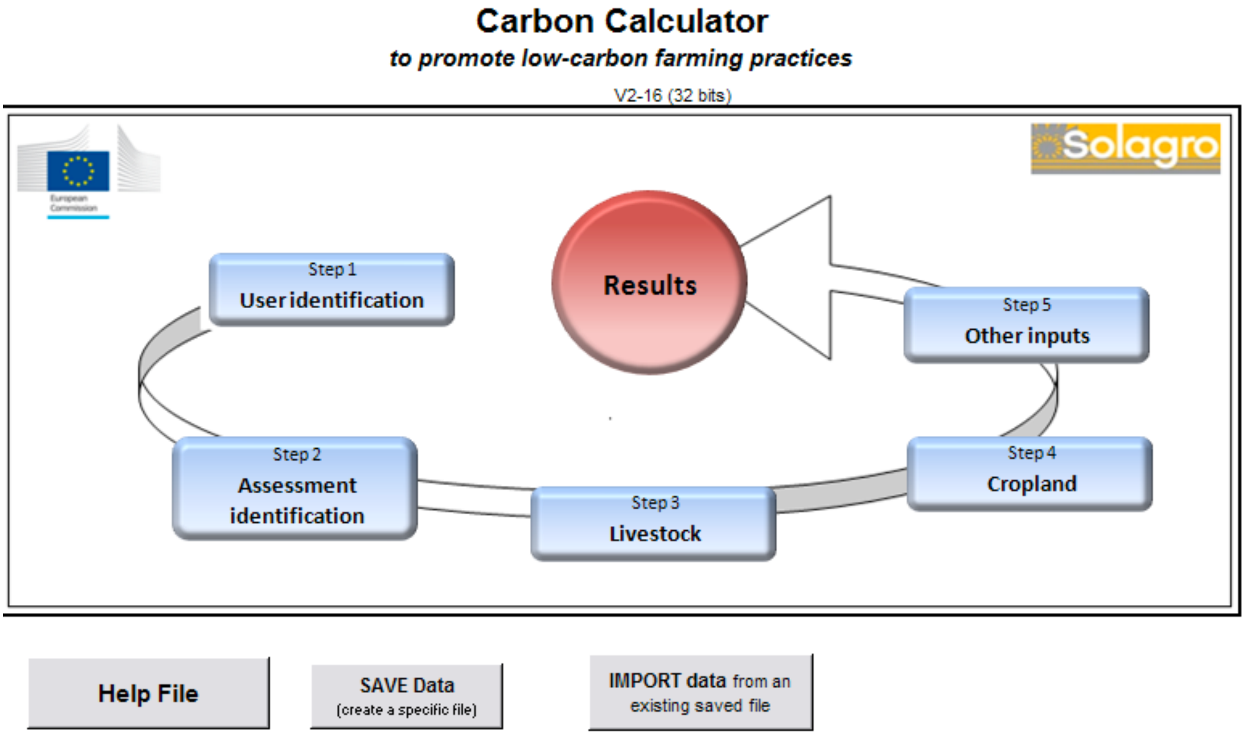



Figure 7: Home page of the Carbon Calculator.

The User Guidance Manual gives more details about data needed and how to run the Carbon Calculator.

The Carbon Calculator is available for free downloading from an internal server of Solagro's website at this address: https://carbone.solagro.org/.

# 2 Quantification of GHG emissions and Carbon sequestration at farm level

The general methodology developed in the Carbon Calculator for assessing GHG emissions and sequestration is described below. The methodology is mostly based on the 2006 IPCC Guidelines for national greenhouse gas inventories – 2006 / Volume 4: Agriculture, forestry and other land use. IPCC guidelines have been adapted to farm level for the Carbon Calculator. Emissions directly linked to the farming activity (such as emissions from managed soils, livestock and manure management) as well as from energy use are estimated. Indirect emissions, through the use of agricultural inputs, are also considered. Carbon storage in croplands and grasslands as well as mitigation and sequestration actions are presented.

## 2.1 Livestock and manure

The general methodology used for emissions from livestock is a Tier 2 simplified method based on the 2006 IPPC Guidelines for national greenhouse gas inventories and adapted for a GHG assessment **at farm level**. Chapter 10 “Emissions from livestock and manure management” is the reference for the following methodology.

The Carbon Calculator methodology for emissions from livestock and manure management aims at reconciling:

- Easiness of data collection for farmers and other users of the tool. The Carbon Calculator excludes minor crop and livestock production systems.
- And the relevance of GHG assessments at farm level.

Usually, farms have no more than two livestock categories. However, since the detailed methodology is the same, users have the possibility to choose all available livestock categories.

### 2.1.1 Enteric fermentation ($CH_{4enteric}$)

Methane is produced by herbivores as a result of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules. Digestive systems and feed intakes are two major parameters influencing the rate of methane emissions.

The assessment of GHG emissions from enteric fermentation is based on the 2006 IPCC, tier 2 simplified method (p.10-22) for all livestock categories.
The rate of methane emissions depends on diet (DMI/day), gross energy (MJ/day) and a methane conversion factor ($Y_m$) per animal and type of diet.

Equation 1: Quantification of methane emission from livestock

$$CH_{4enteric} = DMI * Y_m * \frac{18.45}{55.65}$$

Where:

$CH_{4enteric}$: quantity of methane for one animal, kg.day$^{-1}$

$DMI$: dry matter intake, kg.day$^{-1}$

$18.45$: mean energy content, of dry matter intake, MJ.kg$^{-1}$

$Y_m$: methane conversion factor, %, specific for each livestock category

$55.65$: energy conversion of methane, MJ.kg$^{-1}$

$CH_4$ emissions from the different categories of livestock are then summed-up to obtain total annual $CH_4$ emissions from enteric fermentation on the farm.

#### 2.1.1.1 Methane conversion factor for livestock category ($Y_m$)

Methane conversion factor ($Y_m$) depends on livestock category and diet.

##### 2.1.1.1.1 Methane conversion factor for cattle, sheep, goats and other ruminants ($Y_m$)

Methane conversion factors depend on husbandry practices: specific live weight, daily dry matter intake and type of diet. The FAO (2010) methodology uses the digestibility energy of the diet for cattle and other ruminants.

The user has the possibility to choose between different types of digestibility for each type of forage. Table 3 provides data from the 2006 IPCC and the FAO method.

When the digestibility energy is unknown, default values are provided (see table 4).

Equation 2: Methane conversion factor for cattle and other ruminants

$$Ym = 9.75 - 0.05 * DE\%$$

Where:

$Ym$: methane conversion factor (%)

$DE\%$: % digestibility energy for the diet (%)

Source: FAO, 2010, GHG from the Dairy sector: a Life Cycle Assessment

Table 3: List of choices for the type of diet for cattle, sheep, goat and other ruminants and $Y_m$ values

| Category | Sub-category | Type of annual diet (example) | Type of DE | %DE | $Y_m$ (%) |
|---|---|---|---|---|---|
| Cattle, ruminants | animals fed-low quality forage | low quality forage (straw, mature grasses etc.) | very low DE | 45% | 7.50 |
| Cattle, ruminants | animals fed-low quality forage | low quality forage (straw, mature grasses etc.) | medium low DE | 50% | 7.25 |
| Cattle, ruminants | animals fed-low quality forage | low quality forage (straw, mature grasses etc.) | better low DE | 55% | 7.00 |
| Cattle, ruminants | pasture fed animals | moderate quality forage (mid season legumes and grasses) | low moderate DE | 55% | 7.00 |
| Cattle, ruminants | pasture fed animals | moderate quality forage (mid season legumes and grasses) | medium moderate DE | 60% | 6.75 |
| Cattle, ruminants | pasture fed animals | moderate quality forage (mid season legumes and grasses) | better moderate DE | 65% | 6.50 |
| Cattle, ruminants | pasture fed animals | high quality forage (vegetative legumes and grasses) | low high DE | 65% | 6.50 |
| Cattle, ruminants | pasture fed animals | high quality forage (vegetative legumes and grasses) | medium high DE | 70% | 6.25 |
| Cattle, ruminants | pasture fed animals | high quality forage (vegetative legumes and grasses) | high DE | 75% | 6.00 |
| Cattle, ruminants | feedlot animals (or similar) | high grain diet > 90% concentrate | low concentrate DE | 75% | 6.00 |
| Cattle, | feedlot animals (or | high grain diet > 90% | medium | 80% | 5.75 |

| | | | | | |
|---|---|---|---|---|---|
| ruminants | similar) | concentrate | concentrate DE | | |
| Cattle, ruminants | feedlot animals (or similar) | high grain diet > 90% concentrate | high concentrate | 85% | 5.50 |

Source: FAO, 2010, GHG from the Dairy sector: a Life Cycle Assessment /2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10)

Table 4: Default values[3] for the digestibility energy for forages and feedstuff when specific data is not provided

| Forage | %DM / fresh product | Default Value of DE |
|---|---|---|
| Grazing (grasslands) | 0.17 | 0.60 |
| Grass silage | 0.33 | 0.70 |
| Maize silage | 0.33 | 0.80 |
| Hay from natural or temporary grasslands | 0.85 | 0.60 |
| Lucerne hay | 0.85 | 0.70 |
| Barn dried hay | 0.88 | 0.70 |
| Beet feed | 0.13 | 0.80 |
| Green rape | | 0.75 |
| Sorghum feed | | 0.75 |
| Fodder kale | | 0.75 |
| Dehydrated beet pulp | 0.89 | 0.80 |
| Squeezed beet pulp | 0.22 | 0.80 |
| Sugar beet molasses | 0.76 | 0.90 |
| By-products of beer production (squeezed) | 0.23 | 0.80 |
| Dehydrated alfalfa | 0.91 | 0.80 |
| Fresh beet pulp | | 0.80 |
| $NH_3$ treated straw | 0.88 | 0.60 |
| Non treated straw | 0.88 | 0.50 |
| Standard feedstuffs for ruminants | 0.88 | 0.85 |
| | | |

##### 2.1.1.1.2 Methane conversion factor for pigs and poultry ($Y_m$)

For other livestock categories (pigs and poultry), the Carbon Calculator uses data provided by GGELS.

Pigs and poultry are not major contributors to emissions from enteric fermentation emissions. The GGELS report (2010), estimates that a pig produces around 1.5 kg $CH_4$. A methane conversion factor of 0.6 % is applied to both pigs and poultry.

Table 5: $CH_4$ conversion factors for enteric fermentation of pigs and poultry ($Y_m$)

| Livestock category | $Y_m$ |
|---|---|
| Pigs | 0.6 % |
| Poultry | 0.6 % |

Source: Leip A, 2010, Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS) – JRC.

[3] Note: in all the tables, the administrator can change the default values.

Table 6: Digestibility of diet proposed by IPCC and default values retained for the Carbon Calculator

| Main categories | Class | Digestibility (DE%) range IPCC 2006 | Value for Carbon Calculator (DE%) |
|---|---|---|---|
| Pigs | Mature swine – confinement | 70-80% | 75% |
| | Growing swine – confinement | 80-90% | 85% |
| | Swine – free range | 50-70% | 60% |
| Poultry | Broiler Chickens – confinement | 85-93% | 93% |
| | Layer Hens – confinement | 70-80% | 80% |
| | Poultry – free range | 55-90% | 90% |
| | Turkeys – confinement | 85-93% | 93% |
| | Geese, duck - confinement | 80-90% | 90% |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10 - Tier 2- table 10.2.)

#### 2.1.1.2 Dry matter intake for livestock categories (DMI)

Generally, data on daily feed intake is not easily available, particularly for grazing livestock. Dry matter intake depends on body weight, feed digestibility or dietary net energy concentration (2006 IPCC- p10.22) and type of animals.

The calculation of dry matter intake depends on livestock category and diet types. The different equations determining the dry matter intake for the different categories of livestock are presented below.

##### 2.1.1.2.1 Dry matter intake for cattle

Dry matter intake assessment for cattle is based on body weight and dietary energy concentration or digestible energy values.

Equation 3: Estimation of dry matter intake for growing and finishing cattle

$$DMI = BW^{0.75} \times \left[\frac{0.2444 \times NE_{ma} - 0.0111 \times NE_{ma}{}^{2} - 0.472}{NE_{ma}}\right]$$

Where:

*DMI*: dry matter intake, kg.day$^{-1}$

*BW*: live body weight, kg

$NE_{ma}$: estimated dietary net energy concentration of diet or default values, MJ kg$^{-1}$

Equation 4 : Estimation of dry matter intake for <u>mature beef cattle</u>

$$DMI = BW^{0.75} \times \left[ \frac{0.0119 \times NE_{ma}^{2} + 0.1938}{NE_{ma}} \right]$$

Where:

*DMI*: dry matter intake, $kg.day^{-1}$

*BW*: live body weight, kg

$NE_{ma}$: estimated net energy concentration of diet or default values, MJ $kg^{-1}$

The dietary net energy concentration is estimated through the ratio of net energy available and the digestible energy.

Equation 5: Estimation of net energy concentration

$$NE_{ma} = REM * 18.45 * DE\%$$

Where:

$NE_{ma}$: net energy concentration, MJ.kgDM

*DE%*: digestible energy as a percentage of gross energy (in value for per cent, i.e. 65 and not 0.65)

*REM*: ratio of net energy available in diet for maintenance to digestible energy consumed

The calculation of the REM is the same for cattle, buffalo and sheep.

Equation 6: Net energy ratio

$$REM = \left[ 1.123 - \left( 4.092 * 10^{-3} * DE\% \right) + \left[ 1.126 * 10^{-3} * \left( DE\% \right)^{2} \right] - \left( \frac{25.4}{DE\%} \right) \right]$$

Where:

*REM*: ratio of net energy

*DE%*: digestible energy as a percentage of gross energy

Table 7 (below) indicates for relevant types of diet the typical value for $NE_{ma}$.

Table 7: Examples of typical $NE_{ma}$ in cattle feeds

| Diet type | $NE_{ma}$ (MJ. $kgDM^{-1}$) range |
|---|---|
| High grain diet > 90% | 7.5 – 8.5 |
| High quality forage (e.g., vegetative legumes & grasses) | 6.5 – 7.5 |
| Moderate quality forage (e.g., mid-season legumes & grasses) | 5.5 – 6.5 |
| Low quality forage (e.g., straw, mature grasses) | 3.5 – 5.5 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10 - Tier 2- Table 10.8.)

#### 2.1.1.2.2 Dry matter intake for mature dairy cows

Estimation of dry matter intake for mature dairy cows

$$DMI = \left[\frac{\left((5.4 \times BW)/500\right)}{\left((100 - DE\%)/100\right)}\right]$$

Where:

$DMI$: dry matter intake, kg day$^{-1}$

$BW$: live body weight, kg

$DE\%$: digestible energy as a percentage of gross energy (in value for percent i.e. 65 and not 0.65)

#### 2.1.1.2.3 Dry matter intake for pigs and poultry

The dry matter intake for pigs and poultry depends on the quantity of grains consumed and the rate of dry matter in grains.

Equation 7: Estimation of dry matter intake for pigs and poultry

$$DMI = Qgrains * \%DM / 365$$

Where:

DMI: dry matter intake, kg.day$^{-1}$

$Q_{grains}$: Quantity of grains (cereals etc.) given by year and by animal (kg cereals/yr)

%DM: % of dry matter in cereals for pigs and poultry, average around 90%

365: number of days in one year

When the user fills the feed quantity, the dry matter intake is calculated based on grain quantities and dry matter. In cases where no information is provided about grain quantities eaten by animals, standard data will be used to calculate the dry matter intake by type of animals and the $CH_4$ emissions from enteric fermentation. Standard data of technical production are provided in Tables 7 for pigs and 8 for poultry: days for growth, initial and final live weight, number of flocks by year, matter intake by average weight gain and nitrogen excretion by animal.

Table 8: Example of dry matter intake for different categories of pigs and poultry (default values)

| Swine | Days for growth / on the farm | live weight BEGIN (kg) | live weight FINAL (kg) | nb of flocks /yr | kg $DM_{Intake}$ / day | kg $DM_{Intake}$ / kg AWG | kg N excreted /animal | Animal purchased (kg $CO_2$e / animal) |
|---|---|---|---|---|---|---|---|---|
| Sow - 1 type protein fed | 365 | 200 | 200 | 1.0 | 3.2877 | 1250 | 24.60 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sow - 2 types protein fed | 365 | 200 | 200 | 1.0 | 3.4400 | 1250 | 20.40 | |
| Sow - free range | 365 | 200 | 200 | 1.0 | 3.4247 | 1250 | 28.00 | |
| Weaner - 1 type protein | 42 | 8 | 30 | 7.6 | 0.91 | 1.74 | 0.62 | 6.59 |
| Weaner (pigs 8->30 kg) 2 types protein | 42 | 8 | 30 | 7.6 | 0.91 | 1.74 | 0.56 | 6.59 |
| Weaner - free range | 50 | 8 | 30 | | | | | 6.59 |
| fat Pigs - 1 type protein | 110 | 30 | 112 | 3.0 | 2.13 | 2.86 | 4.56 | 29.57 |
| fat Pigs (30->112 kg) - 2 types protein | 108 | 30 | 112 | 3.0 | 2.17 | 2.86 | 3.79 | 29.57 |
| fat pigs - free range | 150 | 30 | 112 | | | | | 29.57 |
| boar | 365 | 200 | 200 | 1.0 | | | 24.60 | |
| boar - free range | 365 | 200 | 200 | 1.0 | | | 28.00 | |
| Gilt - 1 type protein | | 30 | 170 | 1.0 | | | | 183.45 |
| Gilt - 2 types protein | | 30 | 170 | 1.0 | | | | 183.45 |
| Gilt - free range | | 30 | 170 | 1.0 | | | | 183.45 |

Source: ADEME, 2011. Guide des valeurs Dia'terre® and ACCT.

Table 9: Example of dry matter intake for different categories of poultry

| Poultry | Days for growth / No eggs | live weight BEGIN (kg) | live weight FINAL (kg) | nb of flocks /yr | kg $DM_{Intake}$ / day | kg $DM_{Intake}$ / kg AWG | N excreted kg/yr | N excreted in housing (g /yr) | N excreted on free-range (g / yr) | Animal purchased (kg CO2e / yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| hens in PEN | 350 | 1.490 | 1.950 | 1.0 | 0.1009 | 0.1121 | 0.713 | 713.000 | 0.000 | 0.033 |
| hens CERTIFIED | 336 | 1.490 | 2.030 | 1.0 | 0.1065 | 0.1183 | 0.777 | 583.000 | 194.000 | 0.033 |
| hens AB | 335 | 1.490 | 1.883 | 1.0 | 0.1012 | 0.1124 | 0.718 | 539.000 | 180.000 | 0.033 |
| hens FREE RANGE | 333 | 1.490 | 0.800 | 1.0 | 0.1035 | 0.1150 | 0.734 | 551.000 | 184.000 | 0.033 |
| hens on GROUND | 333 | 1.490 | 1.885 | 1.0 | 0.0991 | 0.1101 | 0.703 | 703.000 | 0.000 | 0.033 |
| young hens | 125 | 0.040 | 1.550 | 2.3 | 0.0006 | 0.0516 | 0.139 | | | 0.033 |
| (Broilers) Chickens STANDARD | 40.5 | 0.040 | 1.875 | 6.2 | 0.0758 | 1.8600 | 0.038 | 51.000 | 0.000 | 0.033 |
| Chickens LIGHT/EXPORT | 35.1 | 0.040 | 1.417 | 6.8 | 0.0632 | 1.7910 | 0.051 | 38.000 | 0.000 | 0.033 |
| Chickens HEAVY | 49.9 | 0.040 | 2.249 | 5.4 | 0.0791 | 1.9860 | 0.068 | 68.000 | 0.000 | 0.033 |
| Chickens CERTIFIED (buildings) | 86.0 | 0.040 | 2.187 | 3.3 | 0.0703 | 3.1300 | 0.118 | 88.000 | 29.000 | 0.033 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Chickens CERTIFIED (cabins) | 87.0 | 0.040 | 2.195 | 3.1 | 0.0709 | 3.1800 | 0.121 | 72.000 | 48.000 | 0.033 |
| Chickens ORGANIC (buildings) | 95.7 | 0.040 | 2.323 | 3.0 | 0.0733 | 3.4120 | 0.129 | 97.000 | 32.000 | 0.033 |
| Chickens ORGANIC (cabins) | 96.3 | 0.040 | 2.387 | 3.0 | 0.0700 | 3.1920 | 0.119 | 71.000 | 47.000 | 0.033 |
| Guinea CERTIFIED | 102 | 0.040 | 1.966 | 2.9 | 0.0642 | 3.7800 | 0.143 | 107.000 | 36.000 | 0.033 |
| Guinea INDUS | 80 | 0.040 | 1.639 | 3.6 | 0.0517 | 2.8560 | 0.087 | 87.000 | 0.000 | 0.033 |
| Guinea ORGANIC | 94 | 0.040 | 1.700 | 2.6 | 0.0588 | 3.7000 | 0.120 | 72.000 | 48.000 | 0.033 |
| Chikens HEAVY Christmas | 164 | 0.040 | 4.376 | 1.0 | 0.1041 | 4.3760 | 0.298 | 223.000 | 74.000 | 0.033 |
| Turkey - Farm | 206 | 11.000 | 11.000 | 1.6 | 0.0000 | 0.1500 | 1.576 | 1576.000 | 0.000 | 0.07 |
| (broilers) Turkeys INDUS | 62 | 0.050 | 3.838 | 1.0 | 0.1029 | 1.8560 | 0.143 | 143.000 | 0.000 | 0.07 |
| Turkeys - medium INDUS | 116 | 0.050 | 8.774 | 2.6 | 0.1566 | 2.3150 | 0.381 | 381.000 | 0.000 | 0.07 |
| Turkeys - heavy INDUS | 152 | 0.050 | 12.678 | 2.0 | 0.1929 | 2.5800 | 0.573 | 573.000 | 0.000 | 0.07 |
| Turkeys ORGANIC | 140 | 0.050 | 4.300 | 2.1 | 0.0656 | 2.4000 | 0.169 | 127.000 | 42.000 | 0.07 |
| Turkeys CERTIFIED | 140 | 0.050 | 4.300 | 2.1 | 0.0656 | 2.4000 | 0.166 | 125.000 | 42.000 | 0.07 |
| Ducks (Barbarie) | 85 | 0.050 | 3.956 | 3.4 | 0.1145 | 2.7690 | 0.179 | 179.000 | 0.000 | 0.033 |
| Ducks (Mulard) | 77 | 0.050 | 3.350 | 3.5 | 0.1292 | 3.3500 | 0.220 | 0.220 | 0.000 | 0.033 |
| Duck 'Ready to cram' OUTDOOR | 87 | 0.050 | 4.130 | 3.6 | 0.1702 | 4.0100 | 0.277 | 55.000 | 222.000 | 0.033 |
| Duck - Crammed | 13 | 4.130 | 5.750 | 19.0 | 1.1314 | 9.7000 | 0.118 | 118.000 | 0.000 | |
| Pheasant (22 weeks) | 133 | 0.010 | 1.500 | 1.0 | 0.0561 | 5.5600 | 0.192 | 77.000 | 115.000 | 0.033 |
| Geese - Roasting | 165 | 0.050 | 5.500 | 1.0 | 0.1891 | 6.3600 | 0.671 | 336.000 | 336.000 | 0.033 |
| Geese - 4ready to cram" | 93 | 0.050 | 5.100 | 3.5 | 0.1997 | 4.0900 | 0.408 | 204.000 | 204.000 | 0.033 |
| Geese - Crammed | 15 | 5.100 | 6.750 | 14.0 | 1.4459 | 14.8000 | 0.177 | 177.000 | 0.000 | |
| Pigeons (couple) | 365 | 0.010 | 6.760 | 1.0 | 0.1182 | 7.1000 | 0.827 | | | 0.033 |
| Partridge - Mature 15 weeks | 105 | 0.010 | 0.500 | 1.0 | 0.0204 | 4.8600 | | | | 0.033 |
| Quail | 42 | 0.001 | 0.277 | 5.9 | 0.0178 | 3.0140 | | | | 0.033 |

Source: ADEME, 2011. Guide des valeurs Dia'terre® and ACCT.

### 2.1.2 $CH_4$ from manure management

This section describes how $CH_4$ emissions produced during storage and treatment of manure, and from spreading are estimated. The methodology used is the IPCC Tier 2, with estimation of manure production for 17 types of manure concerning all livestock categories.

#### 2.1.2.1 Methane emission factor ($CH_{4mms}$)

Emissions depend on type of manure (solid manure, liquid manure, management and treatment), the organic matter excreted by livestock category and the methane potential by livestock.

Equation 8: $CH_4$ emission factor from manure management

$$CH_{4\,mms} = VS * NbDay * (Bo * 0.67) * \%MCF_{\,mms}$$

Where:

$CH_{4\,mms}$: $CH_4$ emission factor for manure management system by livestock category, kg $CH_4$ animal$^{-1}$ year$^{-1}$

*VS:* daily volatile solid in excreted livestock manure, kg DM animal$^{-1}$ day$^{-1}$

*NbDay:* number of living days of livestock in a year (max 365 days year$^{-1}$)

*Bo:* maximum methane producing capacity for manure produced by livestock, $m^3 CH_4$ kg$^{-1}$ of VS excreted

$\%MCF_{\,mms}$: methane conversion factor (in %) for the manure management system

#### 2.1.2.2 Volatile solid excretion rates (*VS*)

Volatile solids are the organic material in livestock manure and consist of both biodegradable and non-biodegradable fractions.

Equation 9: Volatile solid excretion rates

$$VS = DMI * (1 - \%DE - \%UE) * (1 - \%ashes)$$

Where:

*VS:* daily volatile solid in excreted livestock manure, kg DM animal$^{-1}$ day$^{-1}$
*DMI*: dry matter intake, kg day$^{-1}$ = GE / 18.45
GE: Gross energy, MJ day$^{-1}$
18.45: conversion factor for dietary GE per kg of dry matter, MJ kg$^{-1}$
*%DE*: digestibility of the diet, in % (0.0.85→85%) (see previous tables)
*%UE*: urinary energy (4% for most ruminants and 2% for feedlot cattle and for swine)
*%ashes*: 8% for cattle, 4% for horses and other, 2% for swine and poultry

#### 2.1.2.3 Maximum methane producing capacity of manure (Bo)

The potential of $CH_4$ production (Bo) is presented in table 9 and depends on animal category and diet.

Table 10: Relevant data for different livestock categories

| Animals | mass (kg) live weight | digest (%) | intake/d (kg feed) | %Ash (dry basis) | VS/d (kgVS) | B0 ($m^3$/kgVS) | %MCF for MMS at 15°C | EF ($kgCH_4$/head/yr) at 15°C |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| sheep | 48.5 | 60% | 1.08 | 8% | 4.000 | 0.19 | 1.50% | 0.28 |
| goats | 38.5 | 60% | 0.76 | 8% | 0.300 | 0.18 | 1.50% | 0.2 |
| camels | 217 | 50% | 5.42 | 8% | 2.490 | 0.26 | 1.50% | 2.37 |
| horses | 377 | 70% | 5.96 | 4% | 2.130 | 0.30 | 1.50% | 2.34 |
| mules/ asses | 130 | 70% | 3.25 | 8% | 0.940 | 0.33 | 1.50% | 1.14 |
| layers (dry) | 1.8 | | | | 0.020 | 0.39 | 1.50% | 0.03 |
| layers (wet) | 1.8 | | | | 0.020 | 0.39 | 75% | 1.3 |
| broilers | 0.9 | | | | 0.010 | 0.36 | 1.50% | 0.02 |
| turkeys | 6.8 | | | | 0.070 | 0.36 | 1.50% | 0.09 |
| ducks | 2.7 | | | | 0.020 | 0.36 | 1.50% | 0.03 |
| deer | | | | | | | | 0.22 |
| reindeer | | | | | 0.390 | 0.19 | 2.00% | 0.6 |
| rabbits | 1.6 | | | | 0.100 | 0.32 | 1.00% | 0.08 |
| fur-bearing animals | | | | | 0.140 | 0.25 | 8.00% | 0.68 |
| ostrich | | | | | 1.160 | 0.25 | 8.00% | 5.67 |
| dairy cows | 600 | 70% | see formula and table | | 5.100 | 0.24 | | 34 |
| other catlle | 420 | | | | 2.600 | 0.18 | | 10 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10 - Tier 2-Annex 10A-4 to 10A-9)

### 2.1.2.4 Methane conversion factor ($MCF_{mms}$)

Methane conversion factors ($MCF_{mms}$) depend on the type of manure management and the temperature (annual average temperature °C). 17 manure management systems are defined in table 11. The default MCF values by temperature, used in the Carbon Calculator, can be consulted in the 2006 IPCC Guidelines (chapter 10 - table 10.17.).

Table 11: Definitions of 17 manure management systems

| System | Definition |
|---|---|
| Pasture/Range/Paddock | The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed. |
| Daily spread | Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion. |
| Solid storage | The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation. |
| Dry lot | A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically. |
| Liquid/Slurry | Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year. |
| Uncovered anaerobic lagoon | A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields. |
| Pit storage below animal confinements | Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year. |
| Anaerobic digester | Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to $CO_2$ and $CH_4$, which is captured and flared or used as a fuel. |
| Burned for fuel | The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel. |
| Cattle and Swine deep bedding | As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture. |
| Composting - in-vessel[a] | Composting, typically in an enclosed channel, with forced aeration and continuous mixing. |
| Composting - Static pile[a] | Composting in piles with forced aeration but no mixing. |
| Composting - Intensive windrow[a] | Composting in windrows with regular (at least daily) turning for mixing and aeration. |
| Composting - Passive windrow[a] | Composting in windrows with infrequent turning for mixing and aeration. |
| Poultry manure with litter | Similar to cattle and swine deep bedding except usually not combined with a dry lot or pasture. Typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl. |
| Poultry manure without litter | May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly. |
| Aerobic treatment | The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight. |

[a] Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10 - table 10.18.)

### 2.1.3 $N_2O$ from manure management (direct $N_2O$ emissions)

Direct $N_2O$ emissions from the treatment and the storage of manure are estimated with the IPCC method, Tier 2.

Direct $N_2O$ emissions depend on several factors:

- N excretion per head and by animal category ($N_{ex}$)
- % manure management system for each category ($MS$)
- EF for each manure management system ($EF_3$)

Equation 10: Direct $N_2O$ emissions from manure management

$$N2O_D = \left[\sum_S \left(\sum_T (N_{ex} \times MS)\right) \times EF_3\right] \times 44/28$$

$N2O_D$: direct $N_2O$ emissions from manure management, kg $N_2O$ $yr^{-1}$

$N_{ex}$ : annual N excretion rates by animal, kg N $animal^{-1}$ $year^{-1}$

$MS$: fraction of total annual nitrogen excretion for each livestock category T that is managed in manure management system S

$EF_3$: emission factor for direct $N_2O$ emissions from manure management system S, kg $N_2O$-N/kg N in manure management system S

#### 2.1.3.1 N excretion by head and by category ($N_{ex}$)

ACCT uses standard values for N excreted by category of livestock for cattle, sheep and goats (table 12). The values for pigs and poultry are provided in tables 7 and 8. These values will also be used in the first version of the Carbon Calculator. The 2006 IPCC methodology, taking into account N intake in the diet ($N_{intake}$) and daily N retained per animal of category ($N_{retention}$), have not been used because the percentage of crude protein in diet ($CP\%$) and the net energy for growth ($Neg$) are not easily available. The IPCC methodology for N excreted is presented in annex 1.

Table 12: Standard values for N excreted by cattle, sheep and goats, average live weight and dry matter intake (DMI)

| | Average live weight (kg) | N excreted (kg N / animal) | DMI (kg/day) |
|---|---|---|---|
| **Goats** | | | |
| Goats | 70 kg | 14.04 kg | 3.00 kg |
| Strain female young goat | 35 kg | 7.02 kg | 1.00 kg |
| Billy goat | 70 kg | 13.89 kg | 3.00 kg |
| Fattening young goats sold 1 | 14 kg | 0.00 kg | 0.00 kg |
| | | | |
| **Dairy and meat sheep** | | | |
| Ewes | 70 kg | 14.04 kg | 2.50 kg |
| Strain female lambs | 35 kg | 7.02 kg | 1.30 kg |
| Rams | 90 kg | 13.89 kg | 2.50 kg |
| Fattening lambs sold 1 | 35 kg | 1.50 kg | 0.70 kg |
| | | | |
| **Dairy cow** | | | |

| | | | |
|---|---|---|---|
| Dairy cows ~5000 kg milk | 610 kg | 107.35 kg | 13.00 kg |
| Dairy cows ~6000 kg milk | 650 kg | 113.00 kg | 14.25 kg |
| Dairy cow ~8000 kg milk | 700 kg | 124.58 kg | 16.25 kg |
| Cull cows | 650 kg | 113.00 kg | 12.00 kg |
| Calves cows | 60 kg | 6.00 kg | 1.00 kg |
| 0-1 year old heifers | 200 kg | 20.00 kg | 4.50 kg |
| 1-2 year old heifers | 350 kg | 52.00 kg | 6.50 kg |
| Heifers over 2 years old | 550 kg | 61.00 kg | 8.10 kg |
| 0-1 year old bullocks | 200 kg | 12.00 kg | 4.50 kg |
| 1-2 year old bulls | 500 kg | 75.00 kg | 6.50 kg |
| Bulls over 2 years old | 750 kg | 91.00 kg | 8.10 kg |
| | | | |
| **Meat cow** | | | |
| Suckler cows | 750 kg | 101.00 kg | 12.00 kg |
| Cull cows | 750 kg | 101.00 kg | 12.00 kg |
| Calves sold | 60 kg | 6.00 kg | |
| 0-1 year old heifers | 350 kg | 20.00 kg | 4.50 kg |
| 1-2 year old heifers | 500 kg | 52.00 kg | 6.50 kg |
| Heifers over 2 years old | 600 kg | 61.00 kg | 8.10 kg |
| 0-1 year old bullocks | 350 kg | 12.00 kg | 4.50 kg |
| 1-2 year old bulls | 650 kg | 75.00 kg | 6.50 kg |
| Bulls over 2 years old | 750 kg | 91.00 kg | 8.10 kg |

#### 2.1.3.2 $N_2O$ emission factors for manure management system ($EF_3$)

Table 13: Emission factors for direct $N_2O$ emissions from manure management systems

| System | $EF_3$ (kg $N_2O$-N/kg nitrogen excreted) | Uncertainty ranges of $EF_3$ |
|---|---|---|
| Pasture/range/paddock | See Emission from soils (2.2.) | |
| Daily spread | 0 | Not applicable |
| Solid storage | 0.005 | Factor of 2 |
| Dry lot | 0.02 | Factor of 2 |
| Liquid/Slurry with natural crust cover | 0.005 | Factor of 2 |
| Liquid/slurry without natural crust cover | 0 | Not applicable |
| Uncovered anaerobic lagoon | 0 | Not applicable |
| Pit storage below animal confinements | 0.002 | Factor of 2 |
| Anaerobic digester | 0 | Not applicable |
| Cattle and swine deep bedding-no mixing | 0.01 | Factor of 2 |
| Cattle and swine deep bedding-active mixing | 0.07 | Factor of 2 |
| Composting Static Pile | 0.006 | Factor of 2 |
| Composting intensive windrow | 0.006 | Factor of 2 |
| Composting passive windrow | 0.01 | Factor of 2 |

| | | |
|---|---|---|
| Poultry manure with litter | 0.001 | Factor of 2 |
| Poultry without litter | 0.001 | Factor of 2 |
| Aerobic treatment - natural aeration systems | 0.01 | Factor of 2 |
| Aerobic treatment - Forced aeration systems | 0.01 | Factor of 2 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10 - table 10.21.)

### 2.1.4 $N_2O$ from manure management (indirect $N_2O$ emissions)

The methodology of the Carbon Calculator for indirect $N_2O$ emissions is based on the 2006 IPCC Guidelines. Indirect $N_2O$ emissions come down to $NH_3$ volatilisation and $NO_3$ leaching/runoff during manure storage. On average, these emissions account for about 30 % of total emissions from manure management systems.
Indirect $N_2O$ emissions are calculated by livestock category, type of manure management system and N volatilisation for each one. The reduction of $NH_3$ emissions through crust cover from liquid manure or slurry has been estimated based on the GAINS database (Leip, 2010). For all animal categories, the reduction of $NH_3$ emissions is 50 percent.

Equation 11: N losses due to volatilisation from manure management

$$N_{volatilisation-MMS} = \left[\sum_S \left(\sum_T \left[(N_{ex} \times MS) \times \left(\frac{Frac_{GasMS}}{100}\right)\right]\right)\right]$$

$N_{volatilisation-MMS}$: amount of manure nitrogen that is lost due to volatilisation of $NH_3$ and $NO_x$, kg N $yr^{-1}$

$N_{ex}$ annual N excretion rates by animal, kg N $animal^{-1}$ $year^{-1}$

$MS$: fraction of total annual nitrogen excretion for each livestock category T that is managed in manure management system S

$Frac_{GasMS}$: percentage of managed manure nitrogen for livestock category T that volatilises as $NH_3$ and $NO_x$ in the manure management system, %

Equation 12: Indirect $N_2O$ emissions due to volatilisation of N from manure management

$$N2O_{G(mm)} = (N_{volatilisation-MMS} \times EF_4) \times \frac{44}{18}$$

$N2O_{G(mm)}$: indirect $N_2O$ emissions due to volatilisation of N from manure management, kg $N_2O$ $yr^{-1}$

$N_{volatilisation-MMS}$: emission factor for $N_2O$ emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg $N_2O$ (kg $NH_3$-$NO_x$ volatilised)$^{-1}$; default value is 0.01 kg $N_2O$ (kg $NH_3$-$NO_x$ volatilised)$^{-1}$ (see 2.2.1. Direct and indirect $N_2O$ emissions from managed soils).

Table 14: N losses from MMS by livestock category

| Animal type | MMS (most relevant) | $FRAC_{gasMS}$ N loss due to | N loss due to $N_2$ | $FRAC_{loss\ MS}$ total N loss |
|---|---|---|---|---|

| | | volatilisation N-$NH_3$ and N-$NO_x$ | | from MMS |
|---|---|---|---|---|
| Swine | Anaerobic lagoon | 40% | 38% | 78% |
| | Pit Storage | 25% | 0% | 25% |
| | Deep bedding | 40% | 10% | 50% |
| | Liquid / slurry | 48% | 0% | 48% |
| | Solid storage | 45% | 5% | 50% |
| | Slurry with crust cover | 24 % | 0 % | 48 % |
| Poultry | Poultry without litter | 55% | 0% | 55% |
| | Anaerobic lagoon | 40% | 37% | 77% |
| | Poultry with litter | 40% | 10% | 50% |
| Dairy cow | Anaerobic lagoon | 35% | 42% | 77% |
| | Liquid / slurry | 40% | 0% | 40% |
| | Pit Storage | 28% | 0% | 28% |
| | Dry lot | 20% | 10% | 30% |
| | Solid storage | 30% | 10% | 40% |
| | Daily spread | 7% | 15% | 22% |
| | Slurry with crust cover | 20 % | 0 % | 40 % |
| Other cattle | Dry lot | 30% | 10% | 40% |
| | Solid storage | 45% | 5% | 50% |
| | Slurry with crust cover | 20 % | 0 % | 40 % |
| | Deep bedding | 30% | 10% | 40% |
| Other (sheep, horses, fur-bearing animals) | Deep bedding | 25% | 10% | 35% |
| | Solid storage | 12% | 3% | 15% |
| | Slurry with crust cover | 20% | 0% | 40% |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 10 - table 10.22. and 10.23).

## 2.2 Emissions from soils

The method is based on Chapter 11 « $N_2O$ emissions from managed soils and $CO_2$ emissions from lime and urea application » of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (GNGGI). The assessment of soils emissions considers, to some extent, soil types and climate.

### 2.2.1 Direct and indirect $N_2O$ emissions from managed soils

Nitrous oxide ($N_2O$) emissions from managed soils can occur through direct and indirect pathways.

Direct emission is due to nitrogen addition to soils (such as synthetic or organic fertilisers, manure, sewage sludge, crop residues) or N mineralisation linked to land use or management change. The addition of nitrogen on soils leads to an increase of N amounts in soils and increases nitrification and denitrification phenomena.

Volatilisation, deposition, leaching and runoff are indirect sources of $N_2O$ emissions. On the one hand, volatilisation releases $NH_3$ and $NO_x$ from managed soils and from managed fossil fuel combustion and is followed by the redeposition of these gases and their products $NH_4^+$ and $NO_3^-$ to soils and waters. On the other hand, leaching and runoff produce mainly $NO_3^-$.

In the 2006 IPCC Guidelines, direct and indirect $N_2O$ emissions are estimated separately. The following methodology does not include all the equations needed for $N_2O$ emissions calculations but focuses on the differences or adjustments for the Carbon Calculator at farm level, from the IPCC Guidelines.

### 2.2.1.1 Direct emissions

Nitrous oxide is produced naturally in soils through nitrification and denitrification processes. The addition of N inputs increases available quantities of N in soils and consequently nitrification and denitrification rates.

Sources of direct $N_2O$ emissions considered in the 2006 IPCC Guideline are:

- Synthetic N fertilisers ($F_{SN}$)
- Organic N applied as fertiliser ($F_{ON}$)
- Urine and dung N from grazing animals ($F_{PRP}$)
- N in crop residues, including N-fixing crops and forage and pasture renewal to soils ($F_{CR}$)
- N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils ($F_{SOM}$)
- Drainage or management of organic soils (i.e. Histosols) ($F_{OS}$)

Equation 13: Direct $N_2O$ emissions from managed soils

$$N_2O_{Direct} - N = N_2O_{PRP} - N + N_2O_{N\,inputs} - N + N_2O_{OS} - N$$

$$N_2O - N_{N\,inputs} = [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \times EF_1] + (F_{SN} + F_{ON} + F_{CR} + F_{SOM})_{FR} \times EF_{1_{FR}} + \sum F_{SN} \times EF_{1_{MN}}$$

$$N_2O - N_{PRP} = \left[\left(\left(F_{PRP,CPP}\right) \times EF_{3\,PRP,CPP}\right) + \left(\left(F_{PRP,SO}\right) \times EF_{3\,PRP,SO}\right)\right]$$

$$N_2O - N_{OS} = (F_{OS}) \times EF_2$$

$N_2O_{Direct} - N$ : direct $N_2O$-N emissions produced from managed soils, kg $N_2O$-N, $yr^{-1}$

$N_2O - N_{N\,inputs}$: direct $N_2O$-N emissions from N inputs to managed soils, kg $N_2O$-N $yr^{-1}$

$N_2O - N_{OS}$: direct $N_2O$-N emissions from managed organic soils, kg $N_2O$-N $yr^{-1}$

$N_2O - N_{PRP}$: direct $N_2O$-N emissions from urine and dung inputs to grazed soils, kg $N_2O$-N $yr^{-1}$

$F_{SN}$: amount of synthetic fertiliser N applied to soils, kg N $yr^{-1}$

$F_{ON}$: amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N $yr^{-1}$

$F_{CR}$: amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N $yr^{-1}$

$F_{SOM}$: amount of N mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land uses or management, kg N $yr^{-1}$

$F_{OS}$: area managed/drained organic soils. ha

$F_{PRP}$: amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N $yr^{-1}$ (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep, Other animals, respectively)

$EF_1$: emission factor for $N_2O$ emissions from N inputs (excepted mineral fertilisers), kg $N_2O$-N (kg N $inputs)^{-1}$

$EF_{1_{FR}}$: emission factor for $N_2O$ emissions from N inputs to flooded rice, kg $N_2O$-N (kg N $inputs)^{-1}$

$EF_{1_{MN}}$ : emission factor for $N_2O$ emissions from mineral fertilisers, kg $N_2O$-N (kg N $inputs)^{-1}$

$EF_2$ : emission factor for $NO_2$ emissions from drained/managed organic soils, kg $N_2O$-N $ha^{-1}$ $yr^{-1}$

$EF_{3\ PRP}$: emission factor for $NO_2$ emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg $N_2O$-N (kg N $inputs)^{-1}$

Table 15 provides emissions factors by type of inputs, soils and climatic conditions. Except for mineral fertilisers, the default values of the IPCC 2006 are applied. Depending on fertiliser type, emission factors vary.

Table 15: Overview of emissions factors and particular mineral fertiliser factors to estimate direct $N_2O$ emissions from managed soils

| **Emission factors** | **Value of the Carbon Calculator** | **Sources** |
|---|---|---|
| $EF_{1_{MN}}$ N additions from mineral fertilisers | | |
| *- Ammonitrate, kg $N_2O$-N (kg N $input)^{-1}$* | 0.007 | Bouwman et al., 2002 |
| *- Ammonium sulphate, kg $N_2O$-N (kg N $input)^{-1}$* | 0.011 | Bouwman et al., 2002 |
| *- Nitrogen solution, kg $N_2O$-N (kg N $input)^{-1}$* | 0.011 | Bouwman et al., 2002 |
| *- Urea, kg $N_2O$-N (kg N $input)^{-1}$* | 0.011 | Bouwman et al., 2002 |
| *- Other N mineral fertiliser*s, kg $N_2O$-N (kg N $input)^{-1}$ | 0.010 | Bouwman et al., 2002 |
| $EF_1$ Organic amendments, kg $N_2O$-N (kg N $input)^{-1}$ | 0.010 | IPCC 2006 Table 11.1. |
| $EF_1$ Crop residues, kg $N_2O$-N (kg N $input)^{-1}$ | 0.010 | IPCC 2006 Table 11.1. |
| $EF_1$ N mineralised from mineral soil as a result of loss of soil carbon, kg $N_2O$-N (kg N $input)^{-1}$ | 0.010 | IPCC 2006 Table 11.1. |
| $EF_2$ Temperate organic crop and grassland soil, kg $N_2O$-N $ha^{-1}$ $year^{-1}$ | 8 | IPCC 2006 Table 11.1. |
| $EF_{1_{FR}}$ Flooded rice fields, kg $N_2O$-N kg $N^{-1}$ | 0.003 | IPCC 2006 Table 11.1. |
| $EF_{3\ PRP,CPP}$ Grazing for Cattle, poultry and pigs | 0.020 | IPCC 2006 Table 11.1. |

| | | |
|---|---|---|
| kg $N_2O$-N (kg N input)$^{-1}$ | | |
| $EF_{3\ PRP,SO}$ Grazing for Sheep and other animals kg $N_2O$-N (kg N input)$^{-1}$ | 0.010 | IPCC 2006 Table 11.1. |

No country specific emission factors were available. Emission factors can vary according to N source, crop type, management, land use, climate and soil. As the farmer knows exactly what type of mineral fertilisers are applied, the Carbon Calculator will use the more accurate methodology. We exclude forest and forestry from our scope. The emission factor "Temperate organic crop and grassland soils" is applicable on histosoils.

Details are given in the section below.

##### 2.2.1.1.1 Direct $N_2O$ emissions from grazing animals (urine and dung) ($F_{PRP,CPP}$)

The calculation of direct $N_2O$ emissions from grazing animals is determined by the amount of N deposited on pasture by grazing animals through urine and dung. The calculation of N amount takes into account the number of animals, the average amount of N excreted by each livestock category and the real time spent on pasture. The calculation of N excreted by animal is detailed in the part "Emissions from livestock and manure management" and based on chapter 10 of the 2006 IPCC Guidelines.

Emission factors for $N_2O$ emissions from urine and dung are assumed to be 2 % of total N content for cattle, pigs and poultries and 1 % for other animals categories (sheep, goats and horses) (table 14).

##### 2.2.1.1.2 Direct $N_2O$ emissions from manure application ($F_{ON}$)

Direct $N_2O$ emissions from manure management depend on the amount of animal manure, sewage sludge, compost, other organic amendments (rendering waste, guano, brewery waste) applied to soils. The calculation of nitrogen applied is considered after building and storage. N-$NH_3$ and N-$N_2O$ volatilisation during building and storage is detailed in the part "Emissions from livestock and manure management". The emission factor provided for manure application and organic amendment is 1% (table 14).

##### 2.2.1.1.3 Direct $N_2O$ emissions from mineral fertilisers applications to agricultural soils ($F_{SN}$)

The estimation of direct $N_2O$ emissions from mineral fertilisers applications are based on the amount of spreading of mineral fertilisers (kg N).

For each type of fertiliser:

Equation 14: Amount of synthetic N fertiliser applied to soils

$$F_{SN} = \sum_{crops} area\ crops\ x\ N\ applied$$

$F_{SN}$ : Amount of synthetic fertiliser N applied to soils, kg N

$Area$ : Crop surface developed, ha

$N_{applied}$: Nutrient quantities applied by hectare, kg N ha$^{-1}$

Bouwman et al. (2002) provide emission factors according to the type of mineral fertilisers (table 14). Compared to the default emission factors provided by the IPCC Guidelines (1 % (IPCC 2006) and 1.25 % (IPCC 1996)), ammonium nitrate has a lower coefficient of 0.7 %. The highest emission factor of 1.1 % concerns ammonium sulphate, nitrogen solution and urea fertilisers.

#### 2.2.1.1.4 Direct $N_2O$ emissions from crop residues $(F_{CR})$

Crop residues contribute to increasing the amount of nitrogen in soil and thus are involved, in the same way as mineral fertilisers or manure, in $N_2O$ emissions. The evaluation of crop residues includes N-fixing crops returned to soils annually and the forage through pasture renewal returned to soils. It also integrates burnt residues and other residues removal. We differentiate above-ground and below-ground residues.

Emission factor is assumed to be 0,01 kg N-$N_2O$ by kg N (inside the residues) for all crop residues (table 14).

The following equations are used to calculate the amount of N from crop residues and forage/pasture renewal:

Equation 15: N from crop residues and forage and pasture renewal

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

$F_{CR}$: Amount of N in crop residues (above and below ground, including N-fixing and from forage/pasture renewal, returned to soils annually, kg N

$Q_{AG(T)}$: Amount of N in above-ground crop residues, kg N

$Q_{BG(T)}$: Amount of N in below-ground crop residues, kg N

Equation 16: Amount of N in above-ground residues

$$Q_{AG(T)} = (Area) \times Frac\,renew(T) \times Nag(T) \times AGdm(T) \times (1 - Frac\,remove\,(T))$$

Equation 17: Amount of N in below-ground crop residues

$$Q_{BG(T)} = (Area\,) \times Frac\,renew(T) \times Nbg(T) \times Rbg - bio \times (Crop(T) + AGdm(T))$$

$Area$: Area harvested of crop T, ha

$Nag(T)$: N content of above-ground residues for crop T, kg N kg $DM^{-1}$

$Nbg(T)$: N content of below-ground residues for crop T, kg N kg $DM^{-1}$

$Frac\,renew(T)$: fraction of area under crop T that is renewed (For annual crops, pastures renewed perennial grasses and grass/clover pastures) : $Frac\,renew(T)$ = 1).

$Frac\,remove\,(T)$: fraction of above-ground residues of crop (T) removed for purposes such as feed, bedding and construction (%)

$Crop(T)$: harvested dry matter yield crop T, t DM $ha^{-1}$

$Rbg - bio$ : Ratio of below-ground residues to above-ground biomass

$AGdm(T)$: Above-ground residue dry matter, t $ha^{-1}$

$T$: Crop or forage type

With

Equation 18: Above-ground residue dry matter

$$AGdm(T) = Crop(T) \times slope(T) + intercept(T)$$

Equation 19: Dry-weight correction of reported crop yield

$$Crop(T) = Yield\ Fresh(T) \times DRY$$

$Crop(T)$: harvested dry matter yield for crop T, t DM $ha^{-1}$

$Yield\ Fresh(T)$: harvested fresh yield for crop T, t fresh weight $ha^{-1}$

$DRY$: dry matter fraction of harvested crop T, t DM t fresh $weight^{-1}$

Concerning the fraction of area under crop T that is renewed, all temporary pasture are included in the calculation.

#### 2.2.1.1.5 Burnt crop residues:

In cases where crop residues are burnt, the methodology used is based on the 2006 IPCC Guidelines (Chapter 2: Generic methodologies applicable to multiple land-use categories).

Equation 20: $N_2O$ emissions from burnt crop residues

$$N_2O_B = AGdm(B) \times Cf \times Gef \times 1000$$

$N_2O_B$: Amount of greenhouse gas emissions from burnt crop residues, kg $N_2O$

$AGdm(B)$: Above-ground residue dry matter, t $ha^{-1}$

$Cf$ : Combustion factor

$Gef$: Emission factor, g (kg DM $burnt^{-1}$)

B: crop residues burnt

The EF $Gef$ provided for agricultural residues has a default value of 0.07 (Table 15).

The values of *Cf* coefficient are provided in table 16 and are 0.8 for all crop residues except for wheat (0.9).

The same methodology is applied for $CH_4$ emissions from burnt crop residues. The emission factor $Gef$ is the only data that differs in the formula.

Equation 21: $CH_4$ emissions from burnt crop residues

$$CH_{4\,B} = AGdm(B) \times Cf \times Gef \times 1000$$

$CH_{4\,B}$: Amount of greenhouse gas emissions from burnt crop residues (kg CH4)

Table 16: Emission factors $Gef$ (g/kg DM burnt) for burnt agricultural residues

| Emission factors | $CH_4$ | $N_2O$ |
|---|---|---|
| Agricultural residues | 2.7 | 0.07 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 2 - table 2.5. - Andreae and Merlet, 2001)

Table 17: Combustion factor $(Cf)$ values for agricultural residues

| Residues | $Cf$ |
|---|---|
| Wheat | 0.9 |
| Maize | 0.8 |
| Others crops | 0.8 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 2 - table 2.4.)

##### 2.2.1.1.6 Direct $N_2O$ emissions from N mineralisation associated with loss of soil organic matter resulting from change in land use or management of mineral soils $(F_{SOM})$

This section refers to the amount of N mineralised from loss in soil organic C in mineral soils through land-use change or management practices.

Equation 22: N mineralised in mineral soils as a result of loss of soil C through land use or management changes

$$\mathrm{Fsom} = \sum_{\mathrm{LU}} \left[ \left( \Delta \mathrm{Cmineral, LU} \times {}^{1}/_{\mathrm{R}} \right) \times 1000 \right]$$

$\mathrm{Fsom}$ : Amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta\mathrm{Cmineral, LU}$ : Loss of soil carbon for each land-use type (LU), t C

$\mathrm{R}$ : C/N ratio of soil organic matter.

$\mathrm{LU}$: Land-use and/or management system

The loss of soil carbon $\Delta\mathrm{Cmineral, LU}$ is provided by the carbon storage methodology (§ 2.5.6 Land use changes).

Table 18: Default values for C/N ratio

| | Default value | Uncertainty range |
|---|---|---|
| Conversion from forest to cropland / Conversion from grassland to cropland | 15 | 10-30 |
| Management changes on cropland remaining cropland (no-tillage/reduced tillage/ploughing) | 10 | 8-15 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 11 – tier 1)

The default emission factor for N mineralisation is the same as for mineral, organic fertilisers and crop residues: 1%. Default values from table 4 will be used for the C/N ratio of soil organic matter if no country data are available.

##### 2.2.1.1.7 Direct $N_2O$ emissions from drained and managed organic soils $(F_{OS})$

The organic matter content in soils evolves from anaerobic to aerobic conditions by releasing carbon and nitrogen. This phenomenon appears when a parcel is drained. As EU-27 countries are not located in tropical regions (specific conditions in the IPCC), direct $N_2O$ emissions refer to the area of drained and managed organic soils.

In the Carbon Calculator, the annual drained surface is taken into account.

The emission factor from drained and managed organic soils for temperate crops and grassland soils is 8 kg $N_2O$-N/ha/year (table 14).

#### 2.2.1.2 Indirect emissions

Adding nitrogen to soils generates emissions through direct and indirect pathways.

The two main sources of indirect emissions are:

- Volatilisation of N as $NH_3$ and oxides of N ($NO_x$) and deposition of the gases and their products $NH_4^+$ and $NO_3^-$ onto soils and water surfaces.
- Leaching and runoff of N mainly under $NO_3^-$ form.

Indirect emissions can occur from N application but uncertainties are very high.

The IPCC method determines two default emission factors, one concerning volatilised and redeposited N and the second associated to N lost though leaching and runoff.

##### 2.2.1.2.1 Indirect $N_2O$ emissions following leaching and runoff

Losses of nitrogen mostly occur through leaching and runoff under nitrate form ($NO_3^-$). Some parts of N lost via leaching and runoff are transformed into $N_2O$ and therefore have to be included in the $N_2O$ emissions.

The formula applied in the Carbon Calculator at farm level is different from the one mentioned in the 2006 IPCC Guidelines. The nitrogen amount potentially submitted to leaching and runoff is calculated through a nitrogen amount at farm level resulting in differences between N input and N output estimations. The N balance does not include the N released from N mineralisation through land use change and from drained organic soils.

Nitrogen balance at crop level: a nitrogen balance is also estimated at crop level. Livestock manure and organic amendment quantities are brought back to aggregated crop surfaces.

Equation 23: Nitrogen balance from nitrogen inputs and outputs at farm scale

$$\Delta N(L) = N\ inputs - N\ outputs$$

$\Delta N(L)$ : Amount of surplus nitrogen, kg N $ha^{-1}$

$N\ inputs$ : Total amount of nitrogen inputs, kg N ha$^{-1}$
$N\ outputs$ : Total amount of nitrogen ouputs, kg N ha$^{-1}$

Equation 24: Total amount from N inputs

$$N\ inputs = Fatd + Fleg + Fsn + Fon + Fprp$$

$N\ inputs$ : Total amount of nitrogen inputs, kg N ha$^{-1}$
$Fatd$ : Amount of N produced from atmospheric depositions of N volatilised, kg N ha$^{-1}$
$Fleg$ : Amount of N provided from symbiotic fixation, kg N ha$^{-1}$
$Fsn$ : Amount of synthetic fertiliser N applied, kg N ha$^{-1}$
$Fon$ : Amount of compost, sewage sludge and other organic N additions applied to soils, kg N ha$^{-1}$
$Fprp$ : Amount of urine and dung N deposited by grazing animals, kg N ha$^{-1}$

Equation 25: Total amount from N outputs

$$N\ outputs = Fomo + Fcr$$

$N\ outputs$ : Total amount of nitrogen ouputs, kg N ha$^{-1}$
$Fomo$ : Amount of organic matter ouputs, kg N ha$^{-1}$
$Fcr$ : Amount of crop residues, kg N ha$^{-1}$

Equation 26: $N_2O$ emissions from leaching and runoff on managed soils

$$N_2O(L) = \Delta N(L) \times UAA \times EF(L) \times \frac{44}{28} \times \frac{W_{drain}}{FC_{RZe}} \times C_{cc}$$

$N_2O(L)$: $N_2O$ emissions by leaching and runoff, kg $N_2O$
$\Delta N(L)$: Nitrogen balance, kg N/ha
$UAA$: Utilised agricultural area, ha
$EF(L)$ : Emission factor from leaching and runoff, kg $N_2O$-N (kg N leaching runoff)$^{-1}$
$W_{drain}$ : Drainage water rate, mm
$FC_{RZe}$: Field capacity in the effective rooting system, mm
$C_{cc}$: nitrate leaching rate due to cover cropping

The 2006 IPCC Guidelines provide a default EF for runoff and leaching of 0.75 % (table 18).

Table 19 Default emission leaching factor for indirect soil $N_2O$ emissions

| | Default value | Uncertainty range |
|---|---|---|
| EF(L) leaching and runoff (kg $N_2O$-N /kg N leaching/runoff)) | 0.0075 | 0.0005-0.025 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 11 – table 11.3.)

## - NITRATE LEACHING AND RUNOFF ESTIMATE

The model for evaluating $NO_3$ leaching rates is based on the publication of Brentrup (2000) and is commonly used for LCA methodology. Parameters considered for $NO_3$ leaching are soil and climate.

Equation 27: Field capacity in the effective rooting system

$$FC_{RZe} = FC_a \times RZ_e$$

$RZ_e$: Effective rooting zone, dm

$FC_a$ : Available field capacity, mm $dm^{-1}$

The field capacity and the effective rooting systems depend on the soil texture. According to the soil texture (figure 1), the German soil association has defined six classes to evaluate the available field capacity and five classes to evaluate the effective rooting zone (table 20 and 21).

In order to characterise the soil texture, the available field capacity and the effective rooting systems, the USDA provides the following figure. Some categories of soil texture have been adapted to fit the classes determined by the German soil association.

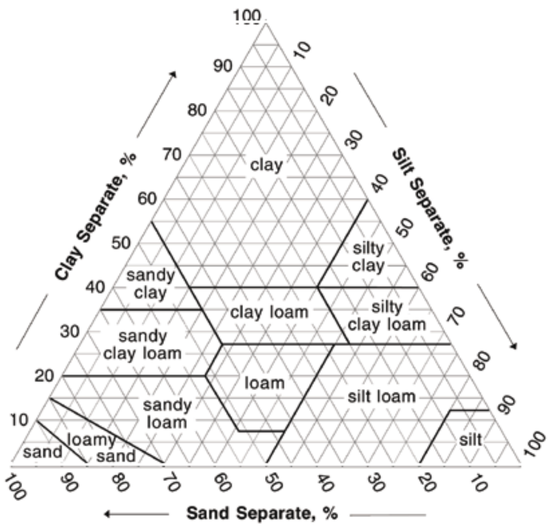



Figure 8: Soil texture triangle (USDA, soil survey staff, 1951)

Table 20: Assignment of soil textures to six classes of available field capacity ($FC_a$), medium soil density

| Class | Soil texture | $FC_a$ (mm/dm) | |
|---|---|---|---|
| (evaluation) | | range | average |
| 1 (very low) | Sand | < 10 | 8 |
| 2 (low) | Clay loam | 10 to 14 | 12 |
| 3 (medium) | Loamy sand, sandy clay, sandy loam, silty clay, clay, loam, sandy clay loam, silty clay loam | 14 to 18 | 16 |
| 4 (high) | Silt loam | 18 to 22 | 20 |
| 5 (very high) | Silt | >22 | 24 |

Source: USDA, soil survey staff, 1951; DGB, 1992

Table 21: Assignment of soil textures to five classes of effective rooting zone ($RZ_e$), medium soil density

| Class | Soil texture | $RZ_e$ (dm) | |
|---|---|---|---|
| (evaluation) | | range | average |
| 1 (very low) | | < 3 | 2 |
| 2 (low) | Sand | 3 to5 | 4 |
| 3 (medium) | Loamy sand | 5 to 7 | 6 |
| 4 (high) | Sandy clay | 7 to 9 | 8 |
| 5 (very high) | Silt, clay, clay loam, silt loam, sandy loam, silty clay, loam, sandy clay loam, silty clay loam | > 9 | 10 |

Source: USDA, soil survey staff, 1951 ; DGB, 1992

Equation 28: Drainage water rate

$$W_{drain} = 0.86 \times W_{precip_{year}} - 11.6 \times \left(\frac{W_{precip_{summer}}}{W_{precip_{winter}}}\right) - 241.2$$

$W_{precip_{year}}$: Yearly precipitation rate, mm

$W_{precip_{summer}}$: Summer precipitation rate, mm

$W_{precip_{winter}}$: Winter precipitation rate, mm

#### - In the particular case of cover cropping ($C_{cc}$)

Depending on the percentage of cover-cropping, the nitrate leaching estimate is reduced. If every plot is covered during autumn, the nitrate leaching rate is decreased by 40 % (Scheffer and Ortseifen, 1996 in Brentrup et al., 2000).

#### 2.2.1.2.2 Indirect $N_2O$ emissions following N volatilisation

Volatilisation of N as $NH_3$ and $NO_x$ and the subsequent deposition as ammonium and nitrate onto soils represents an indirect way of emission. Deposited N increases the total amount of N in soils and consequently the nitrification/denitrification processes.

Equation 29 $N_2O$ from atmospheric deposition of N volatilised from managed soils

$$N_2O(atd)-N = \left[\sum N_{min}\,\text{applied} \times Frac_{min} + \sum N_{om}\,\text{applied} \times Frac_{om}\right] \times EF(atd)$$

$N_2O(atd)-N$: Amount of $N_2O$-N produced from atmospheric deposition of N volatilised from managed soils, kg $N_2O$-N

$N_{min}\ applied$ Amount of mineral fertiliser applied to soils, kg N

$Frac_{min}$: Fraction of applied mineral fertiliser ($N_{min}\ applied$) that volatilises as $NH_3$ and $NO_x$, kg volatilised (kg N applied or deposited)$^{-1}$

$N_{om}\ applied$ Amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N

$Frac_{om}$ : Fraction of managed animal manure, compost, sewage sludge and other organic N additions applied to soils ($N_{om}\ applied$) that volatilises as $NH_3$ and $NO_x$, kg N volatilised (kg N applied or deposited) $^{-1}$

$EF(atd)$: Emissions factor for $N_2O$ emissions from atmospheric deposition of N on soils and water surfaces, kg $N_2O$-N (kg $NH_3$-N + $NO_x$_N volatilised) $^{-1}$ see table 21

Table 22 Emission volatilisation factor for indirect $N_2O$ emissions for the Carbon Calculator

| | Default value for the Carbon Calculator | Uncertainty range |
|---|---|---|
| $EF(atd)$ - (N volatilisation and redeposition), (kg $N_2O$-N) (kg $NH_3$-N + $NO_x$_N volatilised) $^{-1}$ | 0.010 | 0.002-0.05 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 11 – table 11.3.)

The default emission factor $EF(atd)$ provided by the 2006 IPCC Guideline for N volatilisation and redeposition is 1 %.

**- FRACTION OF APPLIED MINERAL FERTILISER ($N_{min}\ applied$) THAT VOLATILISES AS $NH_3$ AND $NO_x$**

A model provided in the EMEP EAA report (2009), shows that the volatilised fraction of applied mineral fertiliser depends on the mean spring temperature and the soil pH.

Table 23: Volatilisation from synthetic fertiliser $\boldsymbol{Frac_{min}}$ (kg $NH_3$ volatilised/kg N applied or deposited)

| Synthetic fertiliser types | $Frac_{min}$ (kg $NH_3$ volatilised/kg N applied or deposited) | Multiplier if pH> 7 |
|---|---|---|
| Ammoniac anhydride (aa) | 0.0107 + 0.0006 ts[4] | 4 |
| Ammonium nitrate (an) | 0.0080 + 0.0001 ts | 1 |
| Calc.amm. nitrate (can) | 0.0080 + 0.0001 ts | 1 |
| Ammonium sulphate (as) | 0.0107 + 0.0006 ts | 10 |
| Ammonium phosphate (ap) | 0.0107 + 0.0006 ts | 10 |
| NPK compound (npk) | 0.0080 + 0.0001 ts | 1 |
| Nitrogen solutions (ns) | 0.0481 + 0.0025 ts | 1 |
| Urea (ur) | 0.1067 + 0.0035 ts | 1 |

Source: EMEP EAA, 2009 (derived from van der Weerden and Jarvis 1997)

The multipliers are used when these fertilisers are applied to soils with pH > 7.0 (Harrison and Webb, 2001). If users do not know mean pH of their soils, the map below will be used (figure 2).

[4] ts : Mean spring temperature (in °C) - Spring is defined as beginning when the accumulated day degrees above 0°C since 1 January have reached 400 °C (Tsum = 400 °C) and ending three months later.

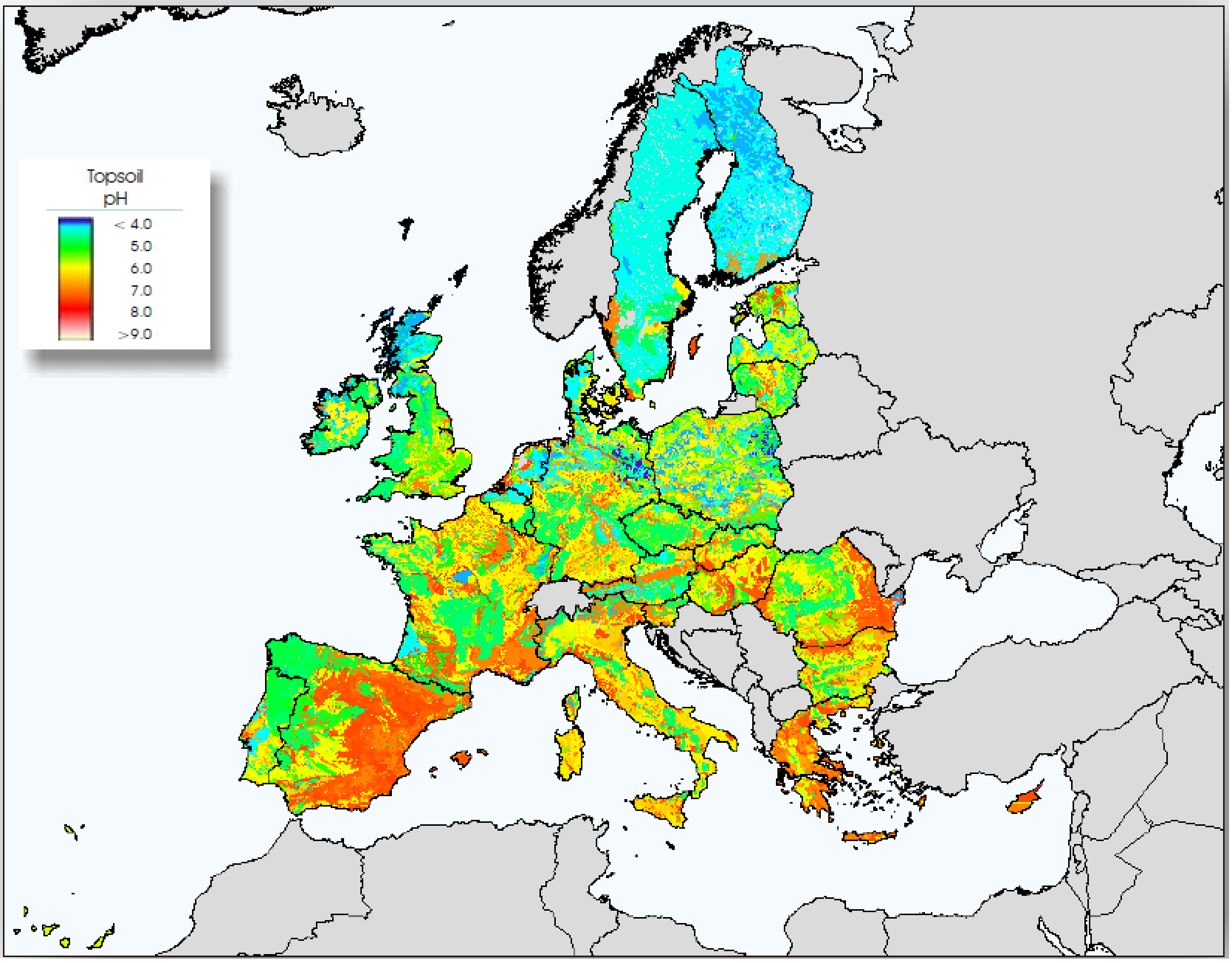



Figure 9: Estimated values of pHCaCl2 for the EU-27 MS and some adjacent countries (JRC).

- **FRACTION OF MANAGED ANIMAL MANURE, COMPOST, SEWAGE SLUDGE AND OTHER ORGANIC N ADDITIONS APPLIED TO SOILS ($N_{om}\ applied$) THAT VOLATILISES AS $NH_3$ AND $NO_x$**

Table 24: Volatilisation from organic fertiliser $\boldsymbol{Frac_{om}}$ (kg $NH_3$ volatilised/kg N applied or deposited)

| Organic fertiliser types | $Frac_{om}$ (kg $NH_3$ volatilised/kg N applied or deposited) |
|---|---|
| Animal manure, compost, sewage sludge and other organic N additions | 0.10 |
| Slurry | 0.20 |
| Buried slurry | |

Source: CORPEN, 2006; Dia'terre®, 2010.

In the Carbon Calculator, data from national inventories are not used because issues have been oriented to EF according to fertiliser types. For organic fertiliser, volatised part $(Frac_{om})$ is either 20 % for slurry or 10 % for other types of manure or organic inputs.

Finally the $N_2O$ emissions from volatilisation are calculated with the following equation:

Equation 30: $N_2O$ emission from atmospheric deposition of N volatised

$$N_2O(atd) = N_2O(atd) - N \times 44/28$$

$N_2O(atd)$: $N_2O$ emission from $NH_3$ atmospheric deposition

$N_2O(atd) - N$: Amount of volatilised N in $N_2O$ based on $NH_3$ depositions

### 2.2.2 $CO_2$ emissions from liming and urea application on soils

The methodology used to evaluate $CO_2$ emissions from liming and urea fertilisation is explained below in order to explain why they are not included in the Carbon Calculator.

#### 2.2.2.1 $CO_2$ emissions from liming

Carbonates application to soils in the form of calcium-containing limestone or dolomite leads to $CO_2$ emissions. Carbonate limes dissolve and release bicarbonate, which evolves into $CO_2$ and water.

Default emission factors provided by the 2006 IPCC Guidelines are 0.12 for limestone and 0.13 for dolomite. The EFs are then multiplied by the quantities of limestone or dolomite applied on soils.

These EF have been determined based on the carbonate carbon contents of these materials (12 % for $CaCO_3$, 13 % for $CaMg(CO_3)_2$). In fact, the carbon is caught during the industrial process and dolomite is then released during farming application.

Emissions are calculated by the Carbon Calculator, but not included in the results since the balance is zero.

#### 2.2.2.2 $CO_2$ emissions from urea fertilization

The addition of urea to soils during fertilisation leads to a loss of $CO_2$. The quantity of $CO_2$ released corresponds to the amount fixed in the industrial process. These emissions are thus not calculated by the Carbon Calculator.

Urea ($CO(NH_2)_2$) is converted to ammonium ($NH_4^+$), hydroxyl ion ($OH^-$) and bicarbonate ($HCO_3^-$) in the presence of water and urease enzymes. Bicarbonate evolves into $CO_2$ and water.

The default EF of urea is 0.20 and it corresponds to the carbon content of urea on an atomic weight basis (20 % for $CO(NH_2)_2$).

In both cases (liming and urea fertilization), the GHG balance from the industrial process to farming applications is null. The Carbon Calculator thus does not include these emissions in its assessment.

## 2.3 Emissions from agricultural inputs processing and transport

This section provides specific data concerning inputs used on the farm. Agricultural inputs presented in this section gather crop (fertilisers, seeds, pesticides) and livestock inputs (e.g. feedstuff).

The 2006 IPCC Guidelines do not provide emission factors (EF) for inputs because a life cycle approach is proposed. Indeed, the emissions attributed to processing, storage and transportation are reported under different sectors (energy, industries, transportation).

Farm inputs do not weight equivalently on GHG emissions. Indeed, the report « Harmonisation of environmental life cycle assessment for agriculture » (Audsley et al., 2003) shows the final inventory for farming system and for wheat production intensive (UK), the main emissions are mineral fertilisers (53 % of the total emission (266.8 kg $CO_2$e/ha) and direct emissions from the field (28.6 % (144 kg $CO_2$e/ha)). Together, pesticides and accessories count for less than 4 % of the total emissions for intensive wheat production (table 24).

Table 25: Emissions for intensive wheat production (UK)

| **Emissions** (mg/ha for wheat production) | **$N_2O$** | **$CO_2$** | **$CH_4$** | **$CO_2$e** | **%** |
|---|---|---|---|---|---|
| Machinery | 2828.6 | 239430486.5 | 462959.5 | 251847396.8 | **5.0** |
| Buildings | 885.4 | 60472575.6 | 102049.8 | 63287669.8 | **1.3** |
| Fuel | 936.1 | 370532595 | 460741.6 | 382330092.8 | **7.6** |
| Mineral fertiliser | 3850766.5 | 1409125106 | 4454029.8 | 2668004268 | **53.0** |
| Seeds | 252240.7 | 62626193.7 | 165630.1 | 141934674.8 | **2.8** |
| Pesticides | 1045.7 | 78186582.8 | 217352 | 83932001.4 | **1.7** |
| Accessories | 16.4 | 1776574.7 | 14251.8 | 2137756.9 | **0.04** |
| Direct origins in the field | 4841477.1 | | | 1442760176 | **28.6** |
| Total | 8950196.5 | 2222150114 | 5877014.6 | 5036234036 | **100.0** |

Source: Audsley et al., 2003

### 2.3.1 Mineral fertilisers ($EF_{min}$)

Mineral fertilisers represent an essential input in cropping systems. Two GHGs are emitted during nitrogen fertiliser production: $CO_2$ from natural gas, used as raw material and energy source for the ammonia ($NH_3$) synthesis, and $N_2O$ from nitric acid production. Most of the natural gas is used to produce hydrogen ($H_2$) that is combined with atmospheric nitrogen ($N_2$) to create the ammonia.

In the Carbon Calculator, emission factors are provided by mineral fertiliser type and are similar throughout the EU-27. No data have been identified at country level. Moreover, the Ecoinvent report no 15a (Nemecek et al., 2007- table 8.12.) notes that inventories are common for all European countries.

Transportation would account for the main difference between countries and weights at a much lower level than manufacturing in GHG emissions. The International industry fertiliser association (IFA, 2009) has estimated that emissions linked to transport of fertilisers is around 37 Tg $CO_2$e, using life cycle analysis methodology. Without considering the $N_2O$ emissions from fertiliser use in agriculture, transport and distribution represent 7.4 % of global emissions linked to fertiliser production and distribution.

#### 2.3.1.1 Mineral fertilisers list

The list of mineral fertilisers provided in the Carbon Calculator is not exhaustive:

- *Ammonium nitrate (N 33.5%),*
- *Ammonium phosphate (N 18%, P 46%),*
- *Ammonium sulphate (N 21%, $SO_3$ 23%),*
- *Calcium ammonium nitrate (N 26.5%),*
- *Dolomite (CaO 30%, MgO 20%)*
- *Lime (CaO 52%),*
- *Nitrogen solution (N 30%),*
- *NPK compound (N 15%, P 15%, K 15%),*
- *Potassium chloride (K 60%),*
- *Urea (N 46%).*

Table 26 shows the most important fertiliser types used in the EU-27. Almost 100 % of N fertilisers, 80 % of P fertilisers and 88.5 % of K fertilisers are covered by this mineral fertilisers list. The table presents European consumptions in 2009 (IFA) (table 26).

Table 26: Mineral fertiliser consumptions in Europe

| Nutrient | Type of fertiliser | Quantity of fertiliser ('000 tonnes nutrients) | % |
|---|---|---|---|
| N | Ammonium nitrate | 2074.6 | 21.3 |
| | Ammonium phosphate | 187.1 | 1.9 |
| | Ammonium sulphate | 305.1 | 3.1 |
| | Calc.amm. nitrate | 2469.6 | 25.3 |
| | Nitrogen solutions | 1159.1 | 11.9 |
| | Urea | 2026.4 | 20.8 |
| | N K compound | 16 | 0.2 |
| | N P K compound | 1515.9 | 15.5 |
| | **Total N** | **9753.8** | **100** |
| P | Ammonium phosphate | 591.9 | 24.6 |
| | Ground rock direct application | 4.9 | 0.2 |
| | Single superphos. | 38.4 | 1.6 |
| | Triple superphos. | 141.7 | 5.9 |
| | N P K compound | 1355.8 | 56.4 |
| | P K compound | 154 | 6.4 |
| | Other P straight | 46.8 | 1.9 |
| | Other NP | 71.7 | 3.0 |

| | | | |
|---|---|---|---|
| | **Total P** | **2405.2** | **100** |
| **K** | N K compound | 2 | 0.1 |
| | N P K compound | 1484 | 57.8 |
| | Other K straight | 42.2 | 1.6 |
| | P K compound | 153.2 | 6.0 |
| | Potassium chloride | 787.1 | 30.7 |
| | Potassium sulphate | 98.5 | 3.8 |
| | **Total K** | **2567** | **100** |

Source: IFA, 2009.

### 2.3.1.2 Emissions from manufacturing and use of mineral fertiliser

Most of the emission factors, presented in table 26, come from the GGELS report (Leip et al., 2010). The GGELS report refers to the publication by Wood and Cowie (2004), a review of GHG factors for fertiliser production. These emission factors include $CO_2$ emissions from ammonia and nitric acid production and from energy use for fertiliser production. Emission factors from GGELS are averages of emission factors, presented as European averages. When data were not available in the publication of Wood and Cowie, emission factors from the CAPRI model (Common agricultural policy regional impact) were used. Transportation from the industry to the farm is not taken into account in GGELS.

No publication covers the entire list of mineral fertilisers, which is why the emissions factors were taken from various references. Emission factors for nitrogen solutions are based on the French GHG methodology called GESTIM (2010). The emission factor for potassium chloride is based on the publication of Brentrup and Pallière (2008). Emission factors for lime and dolomite are based on the IPPC methodology.

Table 27: Emission factors of mineral fertilisers (*$EF_{min}$*)

| Mineral fertilisers | kg eq$CO_2$ / t N | kg eq$CO_2$ / t P | kg eq$CO_2$ / t K | kg eq$CO_2$ / t CaO | SOURCE |
|---|---|---|---|---|---|
| Ammonium nitrate (N 33.5%) | 6854 | | | | Wood and Cowie, 2004 |
| Ammonium phosphate (N 18%, P 46%) | 6047 | | | | CAPRI (GGELS) |
| Ammonium sulphate (N 21%, SO3 23%) | 6047 | | | | CAPRI (GGELS) |
| Calcium ammonium nitrate (N 26.5%) | 7165 | | | | Wood and Cowie, 2004 |
| Dolomite (CaO 30%, MgO 20%) | | | | 860 | IPCC 2006 |
| Lime (CaO 52%) | | | | 750 | IPCC 2006 |
| Nitrogen solution (N 30%) | 5137 | | | | Dia'terre ® (GESTIM) |
| NPK compound (N 15%, P 15%, K 15%) | 5287 | | | | Wood and Cowie, 2004 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium chloride (K 60%) | 0 | | 308 | | Brentrup and Paillière, 2008 |
| Urea (N 46%) | 2351 | | | | Wood and Cowie, 2004 |
| Nitrogen fertilisers | 5120,4 | | | | Wood and Cowie, 2004 |
| Phosphate fertilisers | | 2261 | | | CAPRI |
| Potassium fertilisers | | | 326 | | CAPRI |

### 2.3.2 Feedstuff (processing and transport) ($EF_{feedstuff}$)

In order to determine feedstuff emission factors, two sources could be used: GESTIM (Dia'terre, 2012) and CAPRI (GGELS, 2010). The two methods have been developed into the Carbon Calculator, which means that the user has to choose one or the other of the two methods depending on data availability: detailed quantity of each feedstuff (wheat, oat, soya meal, etc.) or global quantity for cereals, rich protein and rich energy feedstuffs.

#### - Explanation of the GESTIM methodology

GHG emissions from feed mix production are due to different processes.

- Production of the feed ingredients (crop and/or transformation for co-products),
- Transport to the feed processing centre and storage of raw materials.

As is explained in the Ecoinvent report No15a (Nemecek et al., 2007), "transport is by boat for overseas imports and mainly by lorry within Europe and Switzerland".

- Processing of the feedstuff (rolling, milling heat treatment, dosing, mixing, squeezing and pelleting),
- Storage and packaging,
- Transport from factory to farm.

Emissions linked to crop growing are based on a weighted average considering agricultural practices in different regions. $CO_2$ emissions due to raw material production used in feedstuff have been estimated only for the main crops (Arvalis, enquêtes SCEES 2006; AGRESTE, 2008). Transport to the feed processing centre and storage of the raw materials were provided by Institut de l'Elevage and PLANETE (energy and GHG assessment tool and database). It includes transportation by boat and then from the port to the factory. GHG emissions from the processing of feedstuff (including rolling, milling heat treatment, dosing, mixing, squeezing and pelleting) are provided in technical reviews (GESTIM, 2010). Finally, the calculation for the transportation from factory to farm is based on French customs. The methodology is detailed in the GESTIM manual (Fiche FE aliments pour bétail, p129).

Table 28: Emission factors for feedstuff (kg $CO_2$e/ t of feedstuff)

| **Simple feedstuff** | $EF_{feedstuff}$ (kg $CO_2$e/t) |
|---|---|
| Wheat | 353 |

| | |
|---|---|
| Barley | 321 |
| Corn for grain | 296 |
| Triticale | 353 |
| Oat | 321 |
| Soya seed | 59 |
| Peas seed | 122 |
| Rape seed | 810 |
| Sunflower seed | 486 |
| Soya bean meal | 1579 |
| Rapeseed cake | 1552 |
| Sunflower cake | 1122 |
| Flax seed | 295 |
| Milling products | 541 |
| Corn gluten feed | 493 |
| Dry beet flesh | 28.69 |
| Hard wheat | 580.18 |
| | 110 |
| **Herbivorous feedstuff** | $EF_{feedstuff}$ (kg $CO_2$e/t) |
| Dairy cows, 18 % crude protein, pellet form | 616 |
| Dairy cows, 20 % crude protein, pellet form | 655 |
| Dairy cows, 22 % crude protein, pellet form | 694 |
| Dairy cows, 25 % crude protein, pellet form | 753 |
| Dairy cows, 30 % crude protein, pellet form | 850 |
| Dairy cows, 35 % crude protein, pellet form | 948 |
| Dairy cows, 40 % crude protein, pellet form | 1046 |
| Suckler cows, 18 % crude protein, pellet form | 556 |
| Suckler cows, 20 % crude protein, pellet form | 592 |
| Suckler cows, 22 % crude protein, pellet form | 629 |
| Suckler cows, 25 % crude protein, pellet form | 684 |
| Suckler cows, 30% crude protein, pellet form | 775 |
| Suckler cows, 35 % crude protein, pellet form | 866 |
| Suckler cows, 40 % crude protein, pellet form | 958 |
| Mash, pellet form | 513 |
| | |
| **Pigs feedstuff** | $EF_{feedstuff}$ (kg $CO_2$e/t) |
| Piglet, 2nd stage feed, pellet form | 284 |
| Piglet, first stage feed, pellet form | 409 |
| Pigs for fattening, pellet form | 284 |
| Growing-finishing pig, pellet form | 223 |
| Pregnant sow, pellet form | 249 |
| Suckling sow, pellet form | 342 |
| Piglet second stage feed, flour form | 274 |
| Piglet first stage feed, flour form | 399 |

| | |
|---|---|
| Growing-fattening, flour form | 213 |
| Growing-finishing pig, flour form | 239 |
| Suckling sow, flour form | 332 |
| | |
| **Poultries feedstuff** | $EF_{feedstuff}$ (kg $CO_2$e/t) |
| Wheat based, pellet form | 225.6 |
| Maize based, pellet form | 230.5 |
| Wheat based, flour form | 199 |
| Maize based, flour form | 204 |
| | |
| **Other feedstuff** | $EF_{feedstuff}$ (kg $CO_2$e/T) |
| Goat 24% crude protein, pellet form | 753 |
| Meat sheep 16% crude protein, pellet form | 512 |
| Dairy sheep 20% crude protein, pellet form | 655 |
| Horse 14% crude protein, pellet form | 475 |
| Suckler calf, flour form | 616 |

Source: GESTIM, 2011; Guide des valeurs Dia'terre ®, 2012.

## - Explanation of GGELS methodology

The JRC has provided emission factors for simple feedstuffs from the GGELS report (Leip, 2010). Transport is provided at NUTS 2 level.

The perimeter includes:

- direct GHG fluxes from crop activities
- GHG fluxes from land use – cultivated histosols
- indirect GHG fluxes form crop activities
- GHG fluxes from land use change
- GHG fluxes from energy use in crop production

The method is based on the calculated soil-budget approach.

Carbon sequestration has been included in the perimeter, which affects EFs from grass and forage.

Table 29: Extract from the emission factors table for feedstuff (grass, fodder and straw)

| By countries | | EF Grass (kg $CO_2$e/kg feedstuff) | EF Fodder other on arable land (kg $CO_2$e/kg feedstuff) | EF Straw (kg $CO_2$e/kg feedstuff) |
|---|---|---|---|---|
| | | FGRA | FOFA | FSTR |
| BL000000 | $CO_2$ | -0.0100049 | 0.0029814 | 0.0932399 |
| BL000000 | $N_2O$ | 0.0452935 | 0.0887033 | 0.0723407 |
| BL000000 | $CH_4$ | | | |
| **BL** | | **0.0352886** | **0.0916847** | **0.1655806** |
| DK000000 | $CO_2$ | -0.0122668 | 0.0015325 | 0.106499 |
| DK000000 | $N_2O$ | 0.0418701 | 0.0783759 | 0.057985 |
| DK000000 | $CH_4$ | | | |
| **DK** | | **0.0296033** | **0.0799084** | **0.164484** |

| | | | | |
|---|---|---|---|---|
| DE000000 | $CO_2$ | -0.0099006 | 0.0172488 | 0.120762 |
| DE000000 | $N_2O$ | 0.0437979 | 0.0552638 | 0.0550377 |
| DE000000 | $CH_4$ | | | |
| **DE** | | **0.0338973** | **0.0725126** | **0.1757997** |
| EL000000 | $CO_2$ | -0.0766971 | -0.0242164 | 0.2854382 |
| EL000000 | $N_2O$ | 0.0447953 | 0.0541849 | 0.0799669 |
| EL000000 | $CH_4$ | | | |
| **EL** | | **-0.0319018** | **0.0299685** | **0.3654051** |

Source: GGELS, 2010.

Table 30: Extract (first 13 lines) from the emission factors table for feedstuff at NUTS 2 level

| Country code | **NUTS2 code** | **code Country, regional** | **FCER** | **FCER-$CO_2$ FTR** | **FCER total** | **FPRO** | **FPRO - $CO_2$FTR** | **FPRO total** | **FENE** | **FENE-$CO_2$ FTR** | **FENE total** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BL | BL40 | BL000000 BL400000 | 1.312 | 0.0738 | 1.386 | 3.577 | 0.1783 | 3.755 | 0.056 | 0.0702 | 0.127 |
| BL | BL21 | BL000000 BL210000 | 1.312 | 0.0974 | 1.410 | 3.577 | 0.1889 | 3.766 | 0.056 | 0.0656 | 0.122 |
| BL | BL22 | BL000000 BL220000 | 1.312 | 0.0844 | 1.397 | 3.577 | 0.1862 | 3.763 | 0.056 | 0.0586 | 0.115 |
| BL | BL23 | BL000000 BL230000 | 1.312 | 0.0834 | 1.396 | 3.577 | 0.2027 | 3.779 | 0.056 | 0.0478 | 0.104 |
| BL | BL24 | BL000000 BL240000 | 1.312 | 0.0906 | 1.403 | 3.577 | 0.1989 | 3.775 | 0.056 | 0.0729 | 0.129 |
| BL | BL25 | BL000000 BL250000 | 1.312 | 0.0725 | 1.385 | 3.577 | 0.1835 | 3.760 | 0.056 | 0.0350 | 0.091 |
| BL | BL31 | BL000000 BL310000 | 1.312 | 0.0688 | 1.381 | 3.577 | 0.1853 | 3.762 | 0.056 | 0.0629 | 0.119 |
| BL | BL32 | BL000000 BL320000 | 1.312 | 0.0758 | 1.388 | 3.577 | 0.1888 | 3.765 | 0.056 | 0.0695 | 0.126 |
| BL | BL33 | BL000000 BL330000 | 1.312 | 0.0834 | 1.396 | 3.577 | 0.1869 | 3.764 | 0.056 | 0.0406 | 0.097 |
| BL | BL34 | BL000000 BL340000 | 1.312 | 0.0822 | 1.394 | 3.577 | 0.1750 | 3.752 | 0.056 | 0.0672 | 0.123 |
| BL | BL35 | BL000000 BL350000 | 1.312 | 0.0647 | 1.377 | 3.577 | 0.1782 | 3.755 | 0.056 | 0.0597 | 0.116 |
| DK | DK00 | DK000000 DK000000 | 0.761 | 0.0313 | 0.792 | 3.652 | 0.2808 | 3.933 | 0.184 | 0.1072 | 0.291 |
| DE | DE40 | DE000000 DE400000 | 1.003 | 0.0256 | 1.029 | 2.470 | 0.1526 | 2.622 | 0.172 | 0.0573 | 0.229 |

FCER: emission factor to produce feed cereals (soft wheat, durum wheat, rye and meslin, barley, oats, maiz, other cereals, paddy rice, rice)
FPRO: emission factor to produce feed rich protein (pulses, rape seed oil, sunflower seed oil, soya oil, olive oil, other oil, rape seed cake, sunflower seed cake, soya cake, olive cake, other cake, destilled dried grains, )
FENE : emission factor to produce feed rich energy (molasse, starch)
FCER-CO2 FTR, FPRO-CO2 FTR, FENE-CO2 FTR : emission factor for transport (at NUTS2) for cereals, rich protein and rich energy feeds
total : total emission factor to produce and transport feed

Source: GGELS, 2010.

### 2.3.3 Pesticides ($EF_{pesticide}$)

Processing and transportation of pesticides are not a major source of GHG. Data is scarce and most of the references base their calculations on the publication of Green (1987). Data used in the Carbon Calculator are provided by the manual and derived from Green (1987) (Table 31). EF factors include production, transportation, storage and transfer to the farm.

Table 31: Emission factors for pesticides

| | $EF_{pesticide}$ (kg $CO_2$e/kg active substances) |
|---|---|
| Herbicides | 8.985 |
| Insecticides | 25.134 |
| Fungicides | 6.009 |

Source: ACCT, Guide des valeurs Dia'terre ®,2012.

GESTIM, 2010. Arvalis based on Green M., 1987. Energy in pesticide manufacture, distribution and use. In B.A. Stout and M.S. Mudahar (Editors), Energy in plant nutrition and pest control. P 165-177.

### 2.3.4 Seeds ($EF_{seeds}$)

Seed emission factors comprise field multiplication, storage, seed conservation, energy consumed by grading and cleaning operations, packaging and transportation.

No data are available for young plants.

The GESTIM methodology has been chosen for the determination of EF. Laboratory steps are considered. By hypothesis, basic and certified seeds multiplication lead to the same level of GHG emissions. EFs for seeds are based on French statistics (GNIS, 2001-2006 and Arvalis 2007). The following equation details the factors considered.

Equation 31: GHG emissions from seeds

$$Seed\ GHG\ emission = \left[\frac{\left(\sum_{Without\ seeding} GHG\ (by\ step) + EF\ seed * seeding\ density\right)}{certified\ seed\ quantity} \times S\ accepted\ for\ certification + firm\ GHG\ for\ certified\ quantities\right] \times (1 - valorised\ sorting\ rate)$$

$GHG\ (by\ step)$: g $CO_2$e $ha^{-1}$

$EF\ seed$ : g $CO_2$e $kg^{-1}$

$seeding\ density$ : kg $ha^{-1}$

$certified\ seed\ quantity$ : kg $ha^{-1}$

$S\ accepted\ for\ certification$: ha

$firm\ GHG\ for\ certified\ quantities$: g $CO_2$e $ha^{-1}$

$valorised\ sorting\ rate$: %

$$S\ accepted\ for\ certification = \frac{surface\ accepted}{(1 - not\ acceepted\ rate)}$$

$surface\ accepted$: ha

$Not\ acceepted\ rate$: %

$$Valorised\ sorting\ rate\ loss = sorting\ loss\ rate \times sorting\ loss\ rate\ valorised$$

Table 32: Emission factors for seeds

| | $EF_{seeds}$ (kg $CO_2$e/kg of seed) |
|---|---|
| Soft wheat | 0.499 |
| Hard wheat | 0.577 |
| Grassland | 0.870 |
| Maize | 0.896 |
| Sunflower | 0.771 |
| Sorghum | 0.870 |
| Pea | 0.149 |
| Rape and others rich oil plants | 1.381 |
| Potatoes | 0.105 |
| Beet (sugar, fodder) | 6.827 |
| Soya | 0.870 |
| Barley | 0.408 |
| Triticale | 0.576 |
| Rye | 0.348 |

Source: GESTIM, 2011; Guide des valeurs Dia'terre®, 2012.

### 2.3.5 Buildings ($EF_{buidlings}$) and materials ($EF_{materials}$)

In the GESTIM methodology, indirect energy emissions from buildings include several steps: material production, transport, implementation, maintenance and recycling.

For each material or building present on the farm, an associated GHG emission is calculated. The method used in the Carbon Calculator is the "digressive depreciation" in order to be as close as possible to the economic depreciation.

The calculation includes digressive rate, age of the material and use rate.

Equation 32 Indirect emissions from material

$$E_{material} = EF_{material} \times (1 - digressive\ rate) \times digressive\ rate^{(age-1)} \times use\ rate$$

$E_{material}$: Indirect emissions from materials

$EF_{material}$ : Emission factor for materials

$age$ : age of the material

Equation 33: Indirect emissions from buildings

$$E_{buidling} = EF_{buidlings} \times (1 - digressive\ rate) \times digressive\ rate^{(age-1)} \times use\ rate$$

$E_{buidling}$: Indirect emissions from buildings

$EF_{buidlings}$ : Emission factor for buildings

$age$ : age of the building

The table 33 and 34 presents the EF linked to the material and building processing. References come mainly from European sources (Ecoinvent, BIO IS (intelligence service) and APME (Association of plastics manufacturers in Europe). Bilan PRODUIT (ADEME, French energy agency) and INIES (French data base for references on environmental and sanitary building materials) are also quoted.

Institutes and organisations have provided emission factors by building type. GESTIM manual (2010) provided detailed calculations for raw materials used on pigs, poultry and dairy cow buildings.

We focus on the main farm buildings at farm level.

Table 33: Emission factors and digressive rate for materials

| **Materials** | **Unit** | $EF_{materials}$ **(kg $CO_2$e/unit)** | **Digressive rate** |
|---|---|---|---|
| Concrete area | $m^2$ | 41.70 | 10% |
| Cement | kg | 0.76 | 10% |
| Concrete | $m^3$ | 207.00 | 10% |
| Steel | kg | 1.22 | 10% |
| Agricultural plastics | kg | 2.59 | 10% |
| Aluminium | kg | 9.09 | 10% |
| Alloy | kg | 3.67 | 10% |
| Stainless steel | kg | 3.67 | 10% |
| Glass | kg | 1;42 | 10% |

Source: GESTIM, 2011; Guide des valeurs Dia'terre®, 2012.

The main farm buildings at farm level have been targeted.

Table 34: Emission factors and digressive rate for farm buildings

| Farm Buildings automatically distributed per production | Unit | $EF_{buidlings}$ (kg $CO_2$e/unit) | Digressive rate |
|---|---|---|---|
| Dairy cow/cubicles, manure (mainly steel) | $m^2$ | 80.14 | 10% |
| Dairy cow/cubicles, manure (mainly timber) | $m^2$ | 26.09 | 10% |
| Dairy cow/cubicles, slurry (mainly steel) | $m^2$ | 80.03 | 10% |
| Dairy cow/cubicles, slurry (mainly timber) | $m^2$ | 25.98 | 10% |
| Dairy cow/straw litter (mainly steel) | $m^2$ | 59.55 | 10% |
| Dairy cow/straw litter (mainly timber) | $m^2$ | 25.87 | 10% |
| Milking parlour + dairy | $m^2$ | 110.94 | 10% |
| Meat cow/straw litter (mainly steel) | $m^2$ | 59.55 | 10% |
| Meat cow/straw litter (mainly timber) | $m^2$ | 25.87 | 10% |

| | | | |
|---|---|---|---|
| Sheep-pen (mainly steel) | $m^2$ | 58.42 | 10% |
| Sheep-pen (mainly timber) | $m^2$ | 21.55 | 10% |
| Poultry house, mechanical ventilation, monolateral extraction, roof and walls in steel , 1750 $m^2$ | $m^2$ | 96.9 | 10% |
| Poultry house, mechanical ventilation, monolateral extraction, steel walls and fiber cement roof, 1020 $m^2$ | $m^2$ | 126 | 10% |
| Poultry house, mechanical ventilation, extraction height, walls in steel and sanswich, fiber cement roof, 1020 m2 | $m^2$ | 128.1 | 10% |
| Poultry house, natural and transverse ventilation (curtain), timber walls, fiber cement roof, 1210 $m^2$ | $m^2$ | 93 | 10% |
| Poultry house, natural ventilation (Lanterneau), walls in steel and sandwich, fiber cement roof, 1020 $m^2$ | $m^2$ | 135 | 10% |
| Poultry house (Louisiane), roof and walls in fiber cement, 400 $m^2$ | $m^2$ | 120 | 10% |
| Duck house, natural ventilation (Lanterneau), slatted floor in concrete, 730 $m^2$ | $m^2$ | 150 | 10% |
| Pighouse without Concentrate feeder with brick walls, plastic slatted floor for Post Weaning | $m^2$ | 135 | 10% |
| Pighouse without Concentrate feeder with brick walls, concrete slatted floor for Post Weaning | $m^2$ | 129 | 10% |
| Pighouse without Concentrate feeder with concrete walls, plastic slatted floor for Post Weaning | $m^2$ | 153 | 10% |
| Pighouse without Concentrate feeder with concrete walls, concrete slatted floor for Post Weaning | $m^2$ | 147 | 10% |
| Pighouse with Concentrate feeder with brick walls, plastic slatted floor for Post Weaning | $m^2$ | 129 | 10% |
| Pighouse with Concentrate feeder with brick walls, concrete slatted floor for Post Weaning | $m^2$ | 123 | 10% |
| Pighouse with Concentrate feeder with concrete walls, plastic slatted floor for Post Weaning | $m^2$ | 141 | 10% |
| Pighouse with Concentrate feeder with concrete walls, concrete slatted floor for Post Weaning | $m^2$ | 135 | 10% |
| Greenhouse/Plastic tunnel, single span (6 years) | $m^2$ | 10.6 | 10% |
| Greenhouse/Plastic tunnel, double spans (6 years) | $m^2$ | 14.7 | 10% |
| Greenhouse/plastic multitunnels, double spans, inflatable | $m^2$ | 38.2 | 10% |
| Glasshouse | $m^2$ | 65.1 | 10% |
| Storage building for potatoes, mainly steel, double skin | $m^2$ | 316 | 10% |
| Storage building for potatoes, concrete walls | $m^2$ | 296 | 10% |
| Storage building for potatoes, mainly steel, simple skin | $m^2$ | 265 | 10% |
| Shed storage (mainly steel, concrete floor) | $m^2$ | 74.91 | 10% |
| Shed storage (mainly timber, concrete floor) | $m^2$ | 26.68 | 10% |
| Shed storage (mainly steel, bare soil) | $m^2$ | 67.26 | 10% |
| Shed storage (mainly timber, bare soil) | $m^2$ | 19.02 | 10% |
| Concrete silo | $m^2$ | 187 | 10% |
| Covered manure storage, with a pit | $m^2$ | 490.7 | 10% |
| Cold room (truck container) | $m^2$ | 160 | 10% |

Source: GESTIM, 2011; Guide des valeurs Dia'terre®, 2012.

### 2.3.6 Machinery ($EF_{machinery}$)

Indirect impacts from the production and assembling of machinery equipment are the impacts of the sum of material component of agricultural equipment. Fluxes from maintenance and repair are not taken into account.

The digressive rate method is the same as for material and buildings.

Equation 34: Indirect emissions from machinery

$$E_{machinery} = EF_{machinery} \times (1 - digressive\ rate) \times digressive\ rate^{(year-1)} \times use\ rate$$

$E_{machinery}$: Indirect emissions from machinery

$EF_{machinery}$: Emission factor for machinery

$year$ : year of the machinery

Table 35: Emission factors for machinery

| Tractors | Standard weight (kg) | $EF_{machinery}$ (kg $CO_2$e/kg) | Total kg $CO_2$e | Degressivity rate |
|---|---|---|---|---|
| tract 2 WD 50 hp | 2 800 kg | 2.033 | 5 692 | 12.5% |
| tract 2 WD 60 hp | 2 900 kg | 2.033 | 5 896 | 12.5% |
| tract 2 WD 70 hp | 3 200 kg | 2.033 | 6 506 | 12.5% |
| tract 2 WD 80 hp | 3 500 kg | 2.033 | 7 116 | 12.5% |
| tract 4 WD 60 hp | 3 200 kg | 2.033 | 6 506 | 12.5% |
| tract 4 WD 70 hp | 3 500 kg | 2.033 | 7 116 | 12.5% |
| tract 4 WD 80 hp | 3 800 kg | 2.033 | 7 725 | 12.5% |
| tract 4WD 90 hp | 4 400 kg | 2.033 | 8 945 | 12.5% |
| tract 4 WD 100 hp | 4 900 kg | 2.033 | 9 962 | 12.5% |
| tract 4 WD 110 hp | 5 100 kg | 2.033 | 10 368 | 12.5% |
| tract 4 WD 120 hp | 5 300 kg | 2.033 | 10 775 | 12.5% |
| tract 4 WD 130 hp | 5 500 kg | 2.033 | 11 182 | 12.5% |
| tract 4 WD 140 hp | 5 700 kg | 2.033 | 11 588 | 12.5% |
| tract 4 WD150 hp | 6 000 kg | 2.033 | 12 198 | 12.5% |
| tract 4 WD 160 hp | 6 250 kg | 2.033 | 12 706 | 12.5% |
| tract 4 WD 170 hp | 6 500 kg | 2.033 | 13 215 | 12.5% |
| tract 4 WD 180 hp | 6 750 kg | 2.033 | 13 723 | 12.5% |
| tract 4 WD 200 hp | 7 000 kg | 2.033 | 14 231 | 12.5% |
| telescopic loader 100 hp | 4 500 kg | 2.033 | 9 149 | 12.5% |
| telescopic loader 120 hp | 5 500 kg | 2.033 | 11 182 | 12.5% |
| vineyard tractor 2 WD 50 hp | 1 800 kg | 2.033 | 3 659 | 12.5% |
| vineyard tractor 2 WD 75 hp | 3 000 kg | 2.033 | 6 099 | 12.5% |
| vineyard tractor 4 WD 90 hp | 3 500 kg | 2.033 | 7 116 | 12.5% |

| Soil tillage | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
|---|---|---|---|---|
| 2 bodies plough | 600 kg | 1.657 | 994 | 10.0% |
| 3 bodies plough | 890 kg | 1.657 | 1 475 | 10.0% |
| 4 bodies plough | 1 140 kg | 1.657 | 1 889 | 10.0% |
| 5 bodies plough | 1 350 kg | 1.657 | 2 237 | 10.0% |
| 6 bodies plough | 3 000 kg | 1.657 | 4 971 | 10.0% |
| 7 and more bodies plough | 3 500 kg | 1.657 | 5 800 | 10.0% |
| 20 disks cover crop | 1 500 kg | 1.657 | 2 486 | 10.0% |
| 24 disks cover crop | 2 200 kg | 1.657 | 3 645 | 10.0% |
| 32 disks cover crop | 3 200 kg | 1.657 | 5 302 | 10.0% |
| 36 disks cover crop | 3 600 kg | 1.657 | 5 965 | 10.0% |
| 2 m cultivator | 390 kg | 1.657 | 646 | 10.0% |
| 2.5 m cultivator | 420 kg | 1.657 | 696 | 10.0% |
| 3 m cultivator | 455 kg | 1.657 | 754 | 10.0% |
| 4.5 m cultivator | 550 kg | 1.657 | 911 | 10.0% |
| 6 m cultivator | 1 000 kg | 1.657 | 1 657 | 10.0% |
| 3 tine subsoiler | 900 kg | 1.657 | 1 491 | 10.0% |
| 5 tine subsoiler | 1 150 kg | 1.657 | 1 906 | 10.0% |
| 7 tine subsoiler | 1 500 kg | 1.657 | 2 486 | 10.0% |
| 2.5 m power harrow | 900 kg | 1.657 | 1 491 | 10.0% |
| 3 m power harrow | 1 100 kg | 1.657 | 1 823 | 10.0% |
| 4 m power harrow | 1 400 kg | 1.657 | 2 320 | 10.0% |
| 4.5 m power harrow | 1 550 kg | 1.657 | 2 568 | 10.0% |
| 4 - 5 m punt harrow | 500 kg | 1.657 | 829 | 10.0% |
| 6 m and + punt harrow | 900 kg | 1.657 | 1 491 | 10.0% |
| 2.5 m rotary harrow | 1 100 kg | 1.657 | 1 823 | 10.0% |
| 3 m rotary harrow | 1 300 kg | 1.657 | 2 154 | 10.0% |
| 4 m rotary harrow | 1 750 kg | 1.657 | 2 900 | 10.0% |
| 4.5 m rotary harrow | 1 900 kg | 1.657 | 3 148 | 10.0% |
| 3 m land roller | 400 kg | 1.657 | 663 | 10.0% |
| 4 m land roller | 600 kg | 1.657 | 994 | 10.0% |
| 6 m land roller | 1 000 kg | 1.657 | 1 657 | 10.0% |
| 2.5 m vibrating tine cultivator | 380 kg | 1.657 | 630 | 10.0% |
| 3 m vibrating tine cultivator | 425 kg | 1.657 | 704 | 10.0% |
| 4 m vibrating tine cultivator | 770 kg | 1.657 | 1 276 | 10.0% |
| 4.5 m vibrating tine cultivator | 900 kg | 1.657 | 1 491 | 10.0% |
| 8 m vibrating tine cultivator | 1 000 kg | 1.657 | 1 657 | 10.0% |
| 6 m chain harrow | 300 kg | 1.657 | 497 | 10.0% |
| 3.3 m cultipacker | 890 kg | 1.657 | 1 475 | 10.0% |
| 1.8-2.3 m disk sprayer | 1 200 kg | 1.657 | 1 988 | 10.0% |
| 12 m chain harrow | 1 020 kg | 1.657 | 1 690 | 10.0% |
| vineyard coil spring tine cultivator (15) | 300 kg | 1.657 | 497 | 10.0% |

| | | | | |
|---|---|---|---|---|
| vineyard 1 tine subsoiler | 250 kg | 1.657 | 414 | 10.0% |
| vineyard light interwinestock | 100 kg | 1.657 | 166 | 10.0% |
| vineyard heavy interwinestock | 250 kg | 1.657 | 414 | 10.0% |
| vineyard disk harrow | 1 200 kg | 1.657 | 1 988 | 10.0% |
| vineyard 1.8 m rotavator | 460 kg | 1.657 | 762 | 10.0% |
| vineyard 5-9 rigid tine cultivator | 400 kg | 1.657 | 663 | 10.0% |
| Seeding and planting | Standard weight (kg) | kg $CO_2e$/kg | Total kg $CO_2e$ | Degressivity rate |
| 2.5 m grain drill | 400 kg | 1.641 | 656 | 12.0% |
| 3 m grain drill | 450 kg | 1.641 | 738 | 12.0% |
| 4 m grain drill | 600 kg | 1.641 | 985 | 12.0% |
| 4.5 m grain drill | 700 kg | 1.641 | 1 149 | 12.0% |
| single seeder 4 rows | 470 kg | 1.641 | 771 | 12.0% |
| single seeder 6 rows | 620 kg | 1.641 | 1 017 | 12.0% |
| single seeder 9 rows | 1 200 kg | 1.641 | 1 969 | 12.0% |
| single seeder 12 rows | 1 490 kg | 1.641 | 2 445 | 12.0% |
| direct seeding 3 m 2.5 tonnes | 2 500 kg | 1.641 | 4 103 | 12.0% |
| Manure spreading | Standard weight (kg) | kg $CO_2e$/kg | Total kg $CO_2e$ | Degressivity rate |
| manure spreader 4 - 5 tonnes | 1 500 kg | 1.678 | 2 517 | 15.0% |
| manure spreader 7 tonnes | 2 500 kg | 1.678 | 4 195 | 15.0% |
| manure spreader 10 tonnes | 3 800 kg | 1.678 | 6 376 | 15.0% |
| field heap spreader with vertical rotor 12 tonnes | 5 000 kg | 1.678 | 8 390 | 15.0% |
| field heap spreader with vertical rotor 15-16 tonnes | 7 000 kg | 1.678 | 11 746 | 15.0% |
| slurry spreader 2000 litres | 1 000 kg | 1.641 | 1 641 | 15.0% |
| slurry spreader 6 000 litres | 1 800 kg | 1.641 | 2 954 | 15.0% |
| slurry spreader 8 000 litres | 2 600 kg | 1.641 | 4 267 | 15.0% |
| slurry spreader 10 000 litres | 4 000 kg | 1.641 | 6 564 | 15.0% |
| slurry spreader 15 000 litres | 6 800 kg | 1.678 | 11 410 | 15.0% |
| slurry spreader 18 000 litres | 7 520 kg | 1.678 | 12 619 | 15.0% |
| Treatments | Standard weight (kg) | kg $CO_2e$/kg | Total kg $CO_2e$ | Degressivity rate |
| sprayer 600 litres | 100 kg | 1.678 | 168 | 15.0% |
| sprayer 800 litres | 150 kg | 1.678 | 252 | 15.0% |
| sprayer 1000 litres | 250 kg | 1.678 | 420 | 15.0% |
| sprayer 1200 litres | 500 kg | 1.678 | 839 | 15.0% |
| trailed sprayer 2500 litres | 800 kg | 1.678 | 1 342 | 15.0% |
| self-propelled sprayer >3000 litres | 4 500 kg | 2.033 | 9 149 | 15.0% |
| vineyard mounted duster 200 litres | 100 kg | 1.678 | 168 | 15.0% |
| vineyard mounted sprayer 400 litres | 150 kg | 1.678 | 252 | 15.0% |
| vineyard trailed sprayer 800 litres | 500 kg | 1.678 | 839 | 15.0% |
| Mineral ferti spreading | Standard weight | kg $CO_2e$/kg | Total kg $CO_2e$ | Degressivity rate |

| | (kg) | | | |
|---|---|---|---|---|
| fertiliser spreader 12 m | 450 kg | 1.678 | 755 | 15.0% |
| fertiliser spreader 18 m | 500 kg | 1.678 | 839 | 15.0% |
| fertiliser spreader 24 m | 600 kg | 1.678 | 1 007 | 15.0% |
| pneumatic fertiliser spreader 12 m | 650 kg | 1.678 | 1 091 | 15.0% |
| pneumatic fertiliser spreader 18 m | 850 kg | 1.678 | 1 426 | 15.0% |
| vineyard coulter spreader | 250 kg | 1.678 | 420 | 15.0% |
| vineyard disk spreader | 150 kg | 1.678 | 252 | 15.0% |
| **Forage/hay harvest** | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
| 2.5 m hay tedder | 250 kg | 1.641 | 410 | 12.0% |
| 3 m hay tedder | 300 kg | 1.641 | 492 | 12.0% |
| 3.5 m hay tedder | 400 kg | 1.641 | 656 | 12.0% |
| 4 m hay tedder | 500 kg | 1.641 | 821 | 12.0% |
| 6 m hay tedder | 1 600 kg | 1.641 | 2 626 | 12.0% |
| 5.2 m hay tedder | 700 kg | 1.641 | 1 149 | 12.0% |
| 2.5 m mower conditioner | 1 300 kg | 1.641 | 2 133 | 12.0% |
| 2.8 m mower conditioner | 1 500 kg | 1.641 | 2 462 | 12.0% |
| 3 m mower conditioner | 1 700 kg | 1.641 | 2 790 | 12.0% |
| 4.5 m mower conditioner | 2 500 kg | 1.641 | 4 103 | 12.0% |
| 25 m3 self-loading trailer | 1 500 kg | 1.641 | 2 462 | 12.0% |
| 28 m3 self-loading trailer | 2 000 kg | 1.641 | 3 282 | 12.0% |
| 35 m3 self-loading trailer | 2 500 kg | 1.641 | 4 103 | 12.0% |
| 40 m3 self-loading trailer | 3 000 kg | 1.641 | 4 923 | 12.0% |
| 3.4 m side delivery rake | 380 kg | 1.641 | 624 | 12.0% |
| 4-5 m side delivery rake | 700 kg | 1.641 | 1 149 | 12.0% |
| 7.2 m side delivery rake | 1 250 kg | 1.641 | 2 051 | 12.0% |
| taping machine forage. continuous linear | 5 000 kg | 1.641 | 8 205 | 12.0% |
| taping machine forage. transported lift | 800 kg | 1.641 | 1 313 | 12.0% |
| taping machine forage. semi-mounted transported lift | 1 300 kg | 1.641 | 2 133 | 12.0% |
| rectangular big balers 120 x 120 | 8 600 kg | 1.641 | 14 113 | 12.0% |
| rectangular big balers 80 x 80 | 6 200 kg | 1.641 | 10 174 | 12.0% |
| round baler press 1.2 x 1.2 m | 2 400 kg | 1.641 | 3 938 | 12.0% |
| round baler press 1.2 x 1.6 m | 2 600 kg | 1.641 | 4 267 | 12.0% |
| medium density pick up baler | 900 kg | 1.641 | 1 477 | 12.0% |
| **Residues & co-products harvest** | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
| 2.5 m chopper | 960 kg | 1.641 | 1 575 | 12.0% |
| 3 m chopper | 1 200 kg | 1.641 | 1 969 | 12.0% |
| 4 m chopper | 1 600 kg | 1.641 | 2 626 | 12.0% |
| 2 m shredder | 500 kg | 1.641 | 821 | 12.0% |

| | | | | |
|---|---|---|---|---|
| rectangular big balers 120 x 120 | 8 600 kg | 1.641 | 14 113 | 12.0% |
| rectangular big balers 80 x 80 | 6 200 kg | 1.641 | 10 174 | 12.0% |
| round baler press 1.2 x 1.2 m | 2 400 kg | 1.641 | 3 938 | 12.0% |
| round baler press 1.2 x 1.6 m | 2 600 kg | 1.641 | 4 267 | 12.0% |
| medium density pick up baler | 900 kg | 1.641 | 1 477 | 12.0% |
| chopper road margin | 520 kg | 1.641 | 853 | 12.0% |
| shredders raod margin | 500 kg | 1.641 | 821 | 12.0% |
| vineyard windrower for vineshoots | 200 kg | 1.641 | 328 | 12.0% |
| vineyard chopper (vineshoots…) | 380 kg | 1.641 | 624 | 12.0% |
| vineyard topper | 300 kg | 1.641 | 492 | 12.0% |
| vineyard striper | 250 kg | 1.641 | 410 | 12.0% |
| vineyard trunck cleaner | 200 kg | 1.641 | 328 | 12.0% |
| vineyard shredder for grass | 300 kg | 1.641 | 492 | 12.0% |
| vineyard pruner | 350 kg | 1.641 | 574 | 12.0% |
| **Self-propelled machinery for crop harvest** | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
| beet lifter range or drag | 2 500 kg | 1.908 | 4 770 | 12.0% |
| beet striper range or drag | 1 500 kg | 1.908 | 2 862 | 12.0% |
| beet loader range or drag | 2 000 kg | 1.908 | 3 816 | 12.0% |
| beet lifter self propelled | 8 000 kg | 1.908 | 15 264 | 12.0% |
| trailed forage harvester 1 to 1.5 m | 560 kg | 1.908 | 1 068 | 12.0% |
| forage harvester 220 hp | 6 800 kg | 1.908 | 12 974 | 12.0% |
| forage harvester 300 hp | 7 800 kg | 1.908 | 14 882 | 12.0% |
| forage harvester 360 hp | 8 500 kg | 1.908 | 16 218 | 12.0% |
| forage harvester 400 hp | 9 000 kg | 1.908 | 17 172 | 12.0% |
| forage (maize) harvester 220 hp | 7 200 kg | 1.908 | 13 738 | 12.0% |
| forage (maize) harvester 300 hp | 8 200 kg | 1.908 | 15 646 | 12.0% |
| forage (maize) harvester 360 hp | 9 000 kg | 1.908 | 17 172 | 12.0% |
| forage (maize) harvester 450 hp | 12 000 kg | 1.908 | 22 896 | 12.0% |
| combine harvester 120 - 150 hp | 8 500 kg | 1.908 | 16 218 | 12.0% |
| combine harvester 170 - 200 hp | 9 500 kg | 1.908 | 18 126 | 12.0% |
| combine harvester 230 hp | 11 000 kg | 1.908 | 20 988 | 12.0% |
| corn picker | 4 000 kg | 1.908 | 7 632 | 12.0% |
| vineyard. grape harvester 100 hp | 3 000 kg | 1.908 | 5 724 | 12.0% |
| vineyard. grape harvester 150 hp | 4 500 kg | 1.908 | 8 586 | 12.0% |
| vineyard. trailed grape harverster | 2 000 kg | 1.908 | 3 816 | 12.0% |
| **Livestock materials - Others** | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
| grain crusher 200 kg | 200 kg | 1.641 | 328 | 12.0% |
| grain crusher 500 kg | 500 kg | 1.641 | 821 | 10.0% |
| grain storage bin 50 t -1500 kg | 1 500 kg | 1.641 | 2 462 | 12.0% |
| grain storage bin 3 t - 500 kg | 500 kg | 1.641 | 821 | 10.0% |
| Mixing silo unloader 12 m3 | 5 200 kg | 1.641 | 8 533 | 12.0% |

| | | | | |
|---|---|---|---|---|
| Mixing silo unloader 8 m3 | 4 200 kg | 1.641 | 6 892 | 12.0% |
| Strawy silo unloader 3 m3 | 1 400 kg | 1.641 | 2 297 | 12.0% |
| Strawy silo unloader 5 m3 | 1 800 kg | 1.641 | 2 954 | 12.0% |
| Range silo unloader 1.5 m3 | 590 kg | 1.641 | 968 | 12.0% |
| Range silo unloader 1.8 m3 | 650 kg | 1.641 | 1 067 | 12.0% |
| half range silo unloader 3.5 m3 | 1 200 kg | 1.641 | 1 969 | 12.0% |
| half range silo unloader 5 m3 | 1 400 kg | 1.641 | 2 297 | 12.0% |
| milking machine 150 kg | 150 kg | 1.641 | 246 | 10.0% |
| milking machine 500 kg | 500 kg | 1.641 | 821 | 10.0% |
| milk tank 500 lit env | 150 kg | 1.641 | 246 | 10.0% |
| milk tank 1 à 1500 litres | 500 kg | 1.641 | 821 | 10.0% |
| milk tank 3000 litres | 1 000 kg | 1.641 | 1 641 | 10.0% |
| milk tank 7 - 10 000 litres | 1 500 kg | 1.641 | 2 462 | 10.0% |
| cooling fan 25kg | 25 kg | 1.641 | 41 | 10.0% |
| drying fan 250 kg | 250 kg | 1.641 | 410 | 10.0% |
| forage grab | 2 000 kg | 1.641 | 3 282 | 10.0% |
| auger feed | 200 kg | 1.641 | 328 | 10.0% |
| Distribution trailer 12 m3 | 1 500 kg | 1.641 | 2 462 | 10.0% |
| automatic toolthed bar grab | 2 000 kg | 1.641 | 3 282 | 10.0% |
| mobile weighted scales | 800 kg | 1.641 | 1 313 | 10.0% |
| grain bucket elevator + treadmill | 5 000 kg | 1.641 | 8 205 | 10.0% |
| Mobile contention alleys | 1 000 kg | 1.641 | 1 641 | 10.0% |
| Automatic lactation device 100 kg (lambs. calves) | 100 kg | 1.641 | 164 | 10.0% |
| Automatic lactation device 40 kg (calves) | 40 kg | 1.641 | 66 | 10.0% |
| water tank (watering) 2000 liters | 500 kg | 1.641 | 821 | 10.0% |
| **Transportations** | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
| light car | 1 000 kg | 2.033 | 2 033 | 12.0% |
| truck 3-5 tonnes | 2 000 kg | 2.033 | 4 066 | 12.0% |
| truck 10 tonnes | 4 000 kg | 2.033 | 8 132 | 12.0% |
| truck 20 tonnes | 6 000 kg | 2.033 | 12 198 | 12.0% |
| trailer 6 T | 1 400 kg | 1.641 | 2 297 | 10.0% |
| trailer 8 T | 2 200 kg | 1.641 | 3 610 | 10.0% |
| trailer10 T | 2 800 kg | 1.641 | 4 595 | 10.0% |
| trailer12 T | 3 500 kg | 1.641 | 5 744 | 10.0% |
| trailer 18 T | 4 000 kg | 1.641 | 6 564 | 10.0% |
| trailer 21.5 T | 7 460 kg | 1.641 | 12 242 | 10.0% |
| trailer 24 T | 8 510 kg | 1.641 | 13 965 | 10.0% |
| vineyard dumpster 5 T | 1 200 kg | 1.641 | 1 969 | 10.0% |
| livestock trailer | 1 220 kg | 1.641 | 2 002 | 12.0% |
| fodder tray | 1 000 kg | 1.641 | 1 641 | 10.0% |
| tractor front fork | 700 kg | 1.641 | 1 149 | 12.0% |
| motorbike | 200 kg | 2.033 | 407 | 10.0% |

| Quadbike | 300 kg | 2.033 | 610 | 10.0% |
|---|---|---|---|---|
| Others materials and equipements | Standard weight (kg) | kg $CO_2$e/kg | Total kg $CO_2$e | Degressivity rate |
| concrete mixer | 200 kg | 2.033 | 407 | 10.0% |
| air compressor | 50 kg | 2.033 | 102 | 10.0% |
| high pressure cleaner | 70 kg | 2.033 | 142 | 10.0% |
| diverse material (total weight : 100 kg) | 100 kg | 2.033 | 203 | 10.0% |
| welder three-phase | 70 kg | 2.033 | 142 | 10.0% |
| sprinkling irrigation layout 100 kW. 50 m hoses | 1 000 kg | 2.033 | 2 033 | 10.0% |
| hose reel irrigation 250 m | 4 000 kg | 1.641 | 6 564 | 10.0% |
| centre pivot irrigation 250 m | 12 000 kg | 1.641 | 19 692 | 10.0% |

Source: GESTIM, 2011; Guide des valeurs Dia'terre®, 2012.

### 2.3.7 Plastics ($EF_{plastics}$)

The emission factors from plastics come from the French methodology Dia'terre®.

Table 36: Emission factors for plastics and oil

| **Type** | $EF_{plastics}$ (kg $CO_2$e/unit) |
|---|---|
| Big bag fertiliser PP | 1.99 kg |
| Big bag fertiliser PET | 2.47 kg |
| Plastic mulch | 2.59 kg |
| Silage plastic furrow | 2.59 kg |
| Hay plastic furrow | 2.59 kg |
| Strings | 2.59 kg |
| Cardboard packaging | 1.16 kg |
| Pesticides packaging | 2.59 kg |
| Lye can | 2.59 kg |
| Plastic hose, PVC, etc. | 2.55 kg |
| Oils : lubricant, hydraulic | 2.67 kg |
| Oils used for pesticides | 2.67 kg |
| Plastic bags | 0.06 kg |
| Paper bags | 0.04 kg |
| Glass | 1.42 kg |

Source: Guide des valeurs Dia'terre®, 2012.

## 2.4 On-farm energy use

### 2.4.1 Electricity

Emission factors for electricity depend on its origin. As the energy mix (oil, natural gas, hydropower, wind power, nuclear) is very different from a country to another, it is necessary to use specific electricity emission factors.

Electricity emission factors are based on an average of emission intensity for the electricity sector of each country. The GHG emission factors are provided in the Table 37 per kWh of electricity consumed (240 V) for each EU-27 countries.

Table 37: Emission factors for electricity consumed (240 V)

| Countries | | EF (kg $CO_2e$/kWh) |
|---|---|---|
| Belgium | BE | 0.409420446 |
| Bulgaria | BG | 0.908494917 |
| Czech Republic | CZ | 0.81140177 |
| Denmark | DK | 0.789463022 |
| Germany | DE | 0.709087276 |
| Estonia | EE | 1.602304089 |
| Ireland | IE | 0.870514624 |
| Greece | GR | 1.167135347 |
| Spain | ES | 0.670537082 |
| France | FR | 0.153237543 |
| Italy | IT | 0.710450296 |
| Cyprus | CY | 1.019403169 |
| Latvia | LV | 0.584109862 |
| Lithuania | LT | 0.201276566 |
| Luxembourg | LU | 0.598903002 |
| Hungary | HU | 0.680452534 |
| Malta | MT | 1.073195219 |
| Netherlands | NL | 0.730919489 |
| Austria | AT | 0.336253823 |
| Poland | PL | 1.187928488 |
| Portugal | PT | 0.804008324 |
| Romania | RO | 1.08489931 |
| Slovenia | SI | 0.611293928 |
| Slovakia | SK | 0.360718181 |
| Finland | FI | 0.514929201 |
| Sweden | SE | 0.111824333 |
| Great Britain | GB | 0.662918989 |

Source: ELCD, 2001.

### 2.4.2 Fuels

Six categories of fuel are provided. EF for upstream and combustion emissions are separated in Table 38. Total EF for fuels are obtained by adding upstream emissions (for primary energy carriers - cradle to refinery gate) and combustion emissions.

Table 38: Emission factors by fuel type

| FUEL | LPC MJ/kg | $EF_{combustion}$ (kg $CO_2e$/GJ) | Density | | Unit | $EF_{combustion}$ (kg$CO_2e$/unit) | $EF_{upstream}$ (kg $CO_2e$/Unit) (*) |
|---|---|---|---|---|---|---|---|
| Fuel (heating) | 42.0 | 75.5 | 0.84 | kg/litre | L | 2.664 | 0.325 |
| Diesel | 42.0 | 75.5 | 0.84 | kg/litre | L | 2.664 | 0.320 |
| Petrol/Gasoline, regular | 44.0 | 73.1 | 0.76 | kg/litre | L | 2.445 | 0.523 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Propane gas / butane gas (bottle, tank) | 46.0 | 64.6 | 1 | | kg | 2.971 | 0.688 |
| Natural gas | 49.6 | 57.6 | 0.78 | kg/m$^3$ | m$^3$ | 2.228 | 0.328 |
| Coal | 26.0 | 96.0 | 1 | | kg | 2.496 | 0.305 |

Source: OMINEA, CITEPA, février 2012 & (*) ELCD

### 2.4.3 Irrigation

The section 'Irrigation' only touches on collective irrigation. Emission factors for irrigation depend on the country and the electric consumption per m$^3$ of water.

Table 39: Consumption of electricity depending on pumping material

| | kWh/m$^3$ of water |
|---|---|
| Low electric pumping | 0.3 |
| Medium electric pumping | 0.5 |
| High electric pumping | 1 |

Source: ACCT, Guide des valeurs Dia'terre®, 2012.

## 2.5 Renewable energies

This chapter concerns renewable energies that are purchased or produced and consumed on the farm. Also, it concerns renewable energies that are purchased or produced on the farm and sold. Indeed, it is increasingly common that farmers contribute to the production of renewable energies through their farms. The following renewable energies have been included: firewood, wood chips, solar energy, photovoltaic energy, wind energy, biofuels, electricity from biogas, heat from biogas and biogas.

Table 40: Renewable energies and units retained in the Carbon Calculator

| COUNTRY | Unit |
|---|---|
| Firewood | tonnes |
| Wood chips | tonnes |
| Solar energy | m$^2$ |
| Photovoltaic energy | kWh |
| Wind energy | kWh |
| Biofuels | Litres |
| Electricity from biogas | kWh |

| | |
|---|---|
| Heat from biogas | kWh |
| Biogas | $m^3$ $CH_4$ |

The aim is to estimate GHG emissions avoided due to the use of renewable energies in substitution of fossil energies. It is important to note that GHG emissions related to the process of production of renewable energies are not taken into account in the Carbon Calculator.

For example, if a farmer produces renewable electricity from photovoltaic panels the assessment includes avoided emissions (which are evaluated based on regular emissions from the electricity grid of the country). GHG emissions from the processing of the photovoltaic panels are not included. It is the same thing for a farmer that uses biofuel instead of classic fuel. The GHG emissions from crop management and from processing of the biofuel are not included in the assessment.

Table 41 presents the list of fossil energies that are available for substitution by renewable energies.

Table 41: Fossil energies substituted by renewable energies

| **Drop-down list for substituted energy** |
|---|
| Fuel (heating) |
| Diesel |
| Petrol/Gasoline, regular |
| Propane gas / butane gas (bottle, tank) |
| Natural gas |
| Coal |
| Electricity |
| Oil, lubricant |

The methodology used in the Carbon Calculator is:

- first, to convert each type of renewable energies into kWh,
- If the fossil energy substituted is not electricity, the equivalent quantity of energy substituted is calculated into its own unit (litre of fuel, kg of coal, etc.) in order to apply the emission factor for the relevant fossil energies (see Table 38).

For solar panels, a conversion ratio has been retained to convert the surface into kWh. A specific ratio exists for each EU-27 country (see Table below).

Table 42: Conversion ratio of solar panel surface in $m^2$ into kWh (ESTIF, 2011)

| Country | kWh / $m^2$ of solar panel |
|---|---|
| Belgium | 405 |
| Bulgaria | 495 |
| Czech Republic | 420 |
| Denmark | 415 |
| Germany | 430 |
| Estonia | 410 |
| Ireland | 395 |
| Greece | 670 |
| Spain | 685 |
| France | 430 |
| Italy | 650 |
| Cyprus | 750 |
| Latvia | 420 |
| Lithuania | 440 |
| Luxembourg | 415 |
| Hungary | 505 |
| Malta | 795 |
| Netherlands | 405 |
| Austria | 470 |
| Poland | 420 |
| Portugal | 710 |
| Romania | 590 |
| Slovenia | 475 |
| Slovakia | 490 |
| Finland | 405 |
| Sweden | 410 |
| United Kingdom | 390 |

A specific energy ratio is assigned to firewood, wood chips, biofuels and biogas, in order to convert quantities used into energy in kWh (Table 43).

Then, the energy is expressed in MJ by multiplying energy in kWh by 3.6. The Carbon Calculator refers to the primary energy ratio of each fossil fuel in order to calculate the equivalent quantities in their own units (litre of fuel, kg of coal, etc.). Finally, the emission factor from Table 38 in kg$CO_2$e/unit is used to calculate total GHG emissions avoided.

Table 43: Energy conversion ratio

| Resources | Energy ratio | Unit | Details |
|---|---|---|---|
| Firewood | 3500 | kWh/tonnes | 30% humidity |
| Wood chips | 3500 | kWh/tonnes | 30% humidity |
| Biofuels | 9.58 | kWh/litre | |
| Biogas | 11 | kWh/$m^3$ | |

## 2.6 Refrigerant emissions

This chapter concerns refrigerant emissions from different uses on a farm, such as milk tanks in the case of dairy farms, air conditioning in tractors, industrial refrigeration (food processing), retail refrigeration (sale), refrigerated transportation and air conditioning in offices. Emission factors for HFCs correspond to their global warm potential (GWP).

### 2.6.1 Milk tank

A milk tank requires the use of refrigerants, with inevitable gas losses. In cases where the machine is recent, or when maintenance is frequent, it is possible to identify the exact amount of gas lost (based on the quantity used to refill).

But in many cases, exact quantities won't be accessible, for example when there is a lack of maintenance of the equipment. Thus, the Carbon Calculator provides an estimation method to evaluate corresponding losses.

Equation 35: Refrigerant losses from the milk tank

$$Losses_{MT} = Cap \times kgfluid \times AL$$

$Losses_{MT}$: refrigerant losses from the milk tank, in kg

Cap: Capacity of the milk tank, in $m^3$

kgfluid: 2.1 kg of fluid per $m^3$ of storage (ADEME/ARMINES, 2010)

AL: Annual loss, 15% (ADEME/ARMINES, 2010)

Once the refrigerant losses have been quantified or estimated, the quantity is multiplied by the corresponding EF. The most common types of refrigerant for milk tanks are suggested. R134a is used as a default if the type of gas is not known (ADEME/ARMINES, 2010).

Table 44: EF for refrigerant proposed for the milk tank

| Type of refrigerant | EF in $kgCO_2e/kg$ |
|---|---|
| R134a | 1 430 |
| R404a | 3 900 |
| R12* | 0 |

*R12 is not included in the Kyoto Protocol

### 2.6.2 Tractors

Refrigerant emissions from tractors, self-propelled machines and cars are taken into account in the Carbon Calculator. The methodology is similar as the one for milk tanks. An estimation method is used if the amounts of fluid refills are not known.

Equation 36: Refrigerant losses for tractors and vehicles

$$Losses_{cars} = Nb \times kg\ fluid \times AL$$

$Losses_{Cars}$: refrigerant losses from vehicles, in kg
Nb: Number of vehicles
Kgfluid: 0.58 kg of fluid per vehicle (ADEME/ARMINES, 2010)
AL: Annual loss, 10% (ADEME/ARMINES, 2010)

The type of refrigerant is restricted to R134a (ADEME/ARMINES, 2010). Once the refrigerant losses have been quantified or estimated, the quantity is multiplied by the EF of the R134a.

### 2.6.3 Industrial refrigeration

Refrigerant emissions from food processing realised on the farm are taken into account in the Carbon Calculator. The methodology is only based on an estimation method, distinguished by type of equipment (direct or indirect system for industrial refrigeration, low or average temperature). In addition to this, a generic refrigeration group is available.

Table 45: Type of equipment, kg fluid per kW and annual loss percentage for industrial refrigeration

| Type of refrigerant systems | Kg fluid per kW | Annual loss % | Default gas used |
|---|---|---|---|
| Direct system, average temperature | 5.5 | 15% | R134a |
| Direct system, low temperature | 8.8 | 15% | R404a |
| Indirect system, average temperature | 2.0 | 15% | R404a |
| Indirect system, low temperature | 3.0 | 15% | R404a |
| Refrigeration group average | 2.6 | 15% | R404a |

Equation 37: Refrigerant losses for industrial refrigeration

$$Losses_{Ind} = CC \times kgfluid \times AL$$

$Losses_{Ind}$: refrigerant losses from industrial refrigeration, in kg
Carbon Calculator: Cooling capacity, in kW
Kgfluid: kg of fluid per kW (ADEME/ARMINES, 2010)
AL: Annual loss, 15% (ADEME/ARMINES, 2010)

The proposed refrigerant gases (R134a, R404a and R12) are the most common ones (ADEME/ARMINES, 2010). Once the refrigerant losses have been estimated, the quantity is multiplied by the corresponding EF.

### 2.6.4 Retail refrigeration

Refrigerant emissions from refrigeration at the point of sale realised on the farm are taken into account in the Carbon Calculator. The methodology is only based on two different estimation methods: per type of refrigeration equipment (kW) or per surface ($m^2$) for retail refrigeration.

#### 2.6.4.1 Estimation method per type of equipment (kW)

Table 46: Type of equipment, kg fluid per kW and annual loss percentage for retail refrigeration

| Type of refrigerant systems | Kg fluid per kW | Annual loss % |
|---|---|---|
| Direct system positive refrigeration > 3 years | 2.0 | 30% |
| Direct system positive refrigeration < 3 years | 2.0 | 15% |
| Indirect system positive refrigeration > 3 years | 0.8 | 30% |
| Indirect system positive refrigeration < 3 years | 0.8 | 15% |
| Negative refrigeration > 3 years | 3.5 | 30% |
| Negative refrigeration < 3 years | 3.5 | 15% |

Equation 38: Refrigerant losses for retail refrigeration (per kW)

$$Losses_{Ret} = CC \times kgfluid \times AL$$

$Losses_{Ret}$: refrigerant losses from retail refrigeration, in kg
Carbon Calculator: Cooling capacity, in kW
Kgfluid: kg of fluid per kW (ADEME/ARMINES, 2010)
AL: Annual loss, in % (ADEME/ARMINES, 2010)

The proposed refrigerant gases are the most common ones (ADEME/ARMINES, 2010) and are presented in the table below. The default refrigerant gas used for all equipment is R404a. Once the refrigerant losses have been estimated, the quantity is multiplied by the corresponding EF.

Table 47: EF for refrigerant proposed for retail refrigeration

| Type of refrigerant | EF in kgCO2e/kg |
|---|---|
| R134a | 1 430 |
| R404a | 3 900 |
| R410a | 10 900 |
| R407c | 1 800 |

#### 2.6.4.2 Estimation method per surface

Table 48: Type of equipment, kg fluid per $m^2$ and annual loss percentage for retail refrigeration

| Type of refrigerant systems | Kg fluid per $m^2$ | Annual loss % |
|---|---|---|
| Neighbourhood shop (120-400 $m^2$) | 0.65 | 10% |
| Supermarket direct system (400-2,500 $m^2$) | 0.27 | 22% |
| Hypermarket direct system (2,500-15,000 $m^2$) | 0.29 | 30% |

| | | |
|---|---|---|
| All areas indirect systems (second refrigerant) | 0.12 | 10% |
| Autonomous unit | 0.12 | 10% |

Equation 39: Refrigerant losses for retail refrigeration (per surface)

$$Losses_{Ret} = Surf \times kgfluid \times AL$$

$Losses_{Ret}$: refrigerant losses from retail refrigeration, in kg

Surf: Sales surface, in $m^2$

Kgfluid: kg of fluid per $m^2$ (ADEME/ARMINES, 2010)

AL: Annual loss, in % (ADEME/ARMINES, 2010)

The proposed refrigerant gases are the same ones as for the first estimation method for retail refrigeration per kW. The default refrigerant gas used is R404a, except for the autonomous category (R134a). Once the refrigerant losses have been estimated, the quantity is multiplied by the corresponding EF.

### 2.6.5 Refrigerated transportation

The Carbon Calculator takes refrigerant emissions from refrigerated transportation into account when the farmer owns the vehicle. The methodology is based on an estimation method per type of transportation.

Table 49: Type of transportation, kg fluid item of equipment and annual loss percentage for refrigerated transportation

| Type of transportation | Kg fluid per item of equipment | Annual loss % |
|---|---|---|
| Transport by lorry (“belt-pulley” system) | 2.2 | 22% |
| Transport by semi-trailer (“heat engine” system) | 6.5 | 13% |
| Autonomous containers | 4.6 | 20% |
| Maritime transport | 1 000 | 15% |

Equation 40: Refrigerant losses for refrigerated transportation

$$Losses_{Transp} = Nb \times kg\ fluid \times AL$$

$Losses_{Transp}$: refrigerant losses from refrigerated transportation, in kg

Nb: Number of equipment used

Kgfluid: kg of fluid per item of equipment (ADEME/ARMINES, 2010)

AL: Annual loss, in % (ADEME/ARMINES, 2010)

The proposed refrigerant gases (R134a, R404a and R410a) are the most common ones (ADEME/ARMINES, 2010). The default refrigerant gas used is R134a. Once the refrigerant losses have been estimated, the quantity is multiplied by the corresponding EF.

### 2.6.6 Offices

Refrigerant emissions from air conditioning from buildings equipped on the farm (offices, etc.) are taken into account in the Carbon Calculator. The methodology is only based on an estimation method depending on the air conditioning system.

Table 50: Type of air conditioning system, kg fluid per kW and annual loss percentage for air conditioning

| Type of air conditioning | Kg fluid per kW | Annual loss % |
|---|---|---|
| Water-cooled | 0.25 | 5% |
| Air-cooled | 0.3 | 5% |

Equation 41: Refrigerant losses from air conditioning

$$Losses_{AirCond} = CC \times kg\ fluid \times AL$$

$Losses_{AirCond}$: refrigerant losses from air conditioning, in kg

Carbon Calculator : Cooling capacity, in kW

Kgfluid: kg of fluid per kW (ADEME/ARMINES, 2010)

AL: Annual loss, in % (ADEME/ARMINES, 2010)

The proposed refrigerant gases (R134a, R404a and R410a) are the most common ones (ADEME/ARMINES, 2010). The default refrigerant gas used is R410a. Once the refrigerant losses have been estimated, the quantity is multiplied by the corresponding EF.

## 2.7 Carbon storage

### 2.7.1 Soil carbon storage

#### 2.7.1.1 Soil carbon estimation method

The soil carbon methodology in the Carbon Calculator is based on chapter 2 of volume 4 of NGGI-IPPC-2006 “Generic Methodologies Applicable to Multiple Land-Use categories”.

One advantage of this method is the compatibility with:

- *Commission Decision of 10 June 2010 on guidelines for the calculation of carbon stocks in soils for the purposes of Annex V to Directive 2009/28/EC.*
- *Organisation Environmental Footprint Guide, JRC.*

Soil carbon inventories include estimates of soil organic C stock changes for mineral soils and $CO_2$ emissions from organic soils due to enhanced microbial decomposition caused by drainage and associated management activity.

##### 2.7.1.1.1 Mineral soils

Mineral soils are a carbon pool that is influenced by land-use and management activities.

For mineral soils, the default method evaluates changes in soil carbon stocks over a finite period of time. The change is computed based on C stock after the management change relative to the carbon stock in a reference condition (i.e., native vegetation that is not degraded or improved). The following assumptions are made:

- *Over time, soil organic C reaches a spatially-averaged, stable value specific to the soil, climate, land use and management practices; and*
- *Soil organic C stock changes during the transition to a new SOC equilibrium occur in a linear fashion.*

Equation 42: Organic carbon contents in soils

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I$$

$SOC$: soil content of organic carbon (measured in mass of carbon per ha)

$SOC_{REF}$: reference content of soil organic carbon in the humus layer from 0 to 30 cm (measured in mass of carbon per ha).

$F_{LU}$: stock change factor for land-use systems or sub-systems for a particular land-use

$F_{MG}$: stock change factor for management regime

$F_I$: stock change factor for input or organic matter

Table 51: Default reference (under native vegetation) soil organic C stocks ($SOC_{REF}$) for mineral soils (tonnes C $ha^{-1}$ in 0-30 cm depth).

<table>
<tr><th>Climate region</th><th>HAC soils [1]</th><th>LAC soils [2]</th><th>Sandy soils [3]</th><th>Spodic soils [4]</th><th>Volcanic soils [5]</th><th>Wetland soils [6]</th></tr>
<tr><td>Boreal</td><td>68</td><td>NA</td><td>10[#]</td><td>117</td><td>20[#]</td><td>146</td></tr>
<tr><td>Cold temperate, dry</td><td>50</td><td>33</td><td>34</td><td>NA</td><td>20[#]</td><td rowspan="2">87</td></tr>
<tr><td>Cold temperate, moist</td><td>95</td><td>85</td><td>71</td><td>115</td><td>130</td></tr>
<tr><td>Warm temperate, dry</td><td>38</td><td>24</td><td>19</td><td>NA</td><td>70[#]</td><td rowspan="2">88</td></tr>
<tr><td>Warm temperate, moist</td><td>88</td><td>63</td><td>34</td><td>NA</td><td>80</td></tr>
<tr><td>Tropical, dry</td><td>38</td><td>35</td><td>31</td><td>NA</td><td>50[#]</td><td rowspan="4">86</td></tr>
<tr><td>Tropical, moist</td><td>65</td><td>47</td><td>39</td><td>NA</td><td>70[#]</td></tr>
<tr><td>Tropical, wet</td><td>44</td><td>60</td><td>66</td><td>NA</td><td>130[#]</td></tr>
<tr><td>Tropical montane</td><td>88*</td><td>63</td><td>34</td><td>NA</td><td>80*</td></tr>
</table>

Note: Data are derived from soil databases described by Jobbagy and Jackson (2000) and Bernoux et al. (2002). Mean stocks are shown. A nominal error estimate of ±90% (expressed as 2x standard deviations as percent of the mean) are assumed for soil-climate types. NA denotes 'not applicable' because these soils do not normally occur in some climate zones.

[#] Indicates where no data were available and default values from 1996 IPCC Guidelines were retained.

* Data were not available to directly estimate reference C stocks for these soil types in the tropical montane climate so the stocks were based on estimates derived for the warm temperate, moist region, which has similar mean annual temperatures and precipitation.

[1] Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols).

[2] Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols).

[3] Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psamments).

[4] Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols)

[5] Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols)

[6] Soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; in USDA classification Aquic suborders).

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 5 – table 5.5.)

##### 2.7.1.1.2 Cultivated organic soils

In undrained organic soils, organic matter inputs can exceed decomposition losses and considerable amounts of organic matter can accumulate over time.

Carbon stored in organic soils will readily decompose when conditions become aerobic following soil drainage. Drainage is a practice used in agriculture to improve site conditions for plant growth. Loss rates vary by climate, with drainage under warmer conditions leading to faster decomposition rates.

The basic methodology for estimating C emissions from organic soils is to assign an annual emission factor that estimates C losses following drainage. The area of drained and managed organic soils under each climate type is multiplied by the corresponding emission factor to derive an estimate of annual $CO_2$ emissions:

Equation 43: Carbon loss from drained organic soils

$$L_{Organic} = A \times EF$$

$L_{Organic}$: annual carbon loss from drained organic soils, tonnes C $yr^{-1}$

$A$: land area of drained organic soils in climate type ha

$EF$: emission factor for climate type, tonnes C $ha^{-1}$ $yr^{-1}$

#### 2.7.1.2 Climatic zones

We refer to the delineation of major climatic zones by the IPCC.

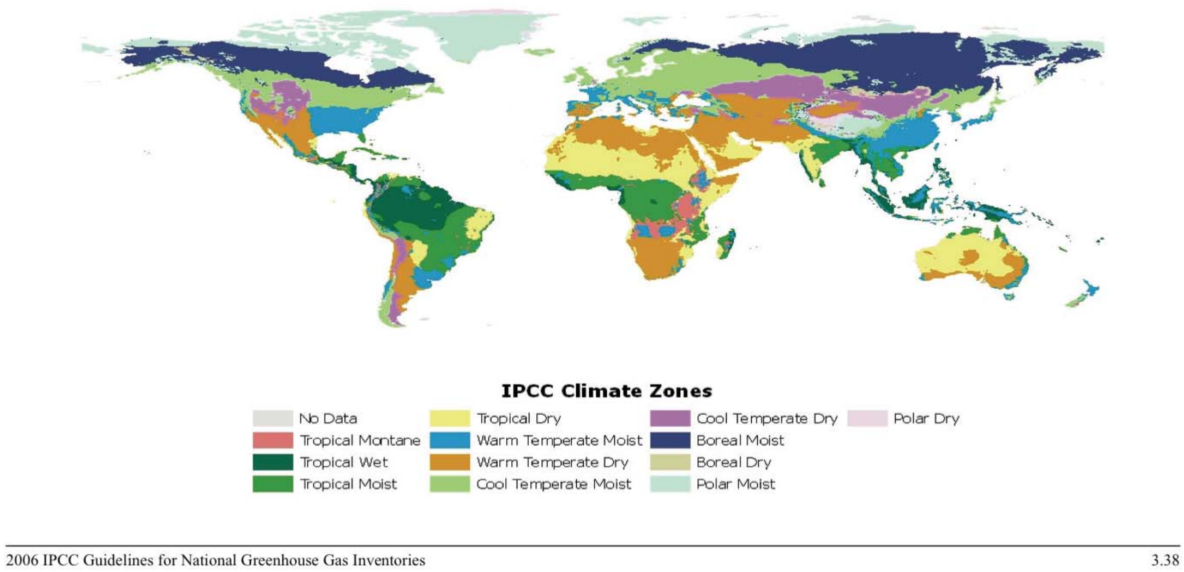



Figure 10: Delineation of major climate zones, updated from the 1996 IPCC Guidelines

5 climate zones are taken into account in the Carbon Calculator:

- *Cool Temperate Moist (most important one)*
- *Cool Temperate Dry (mainly in UK)*
- *Warm Temperate Moist (Mainly in France, Portugal, Italy and Spain)*
- *Warm Temperate Dry (mainly in Spain and Italy)*
- *Boreal Moist (in the north)*

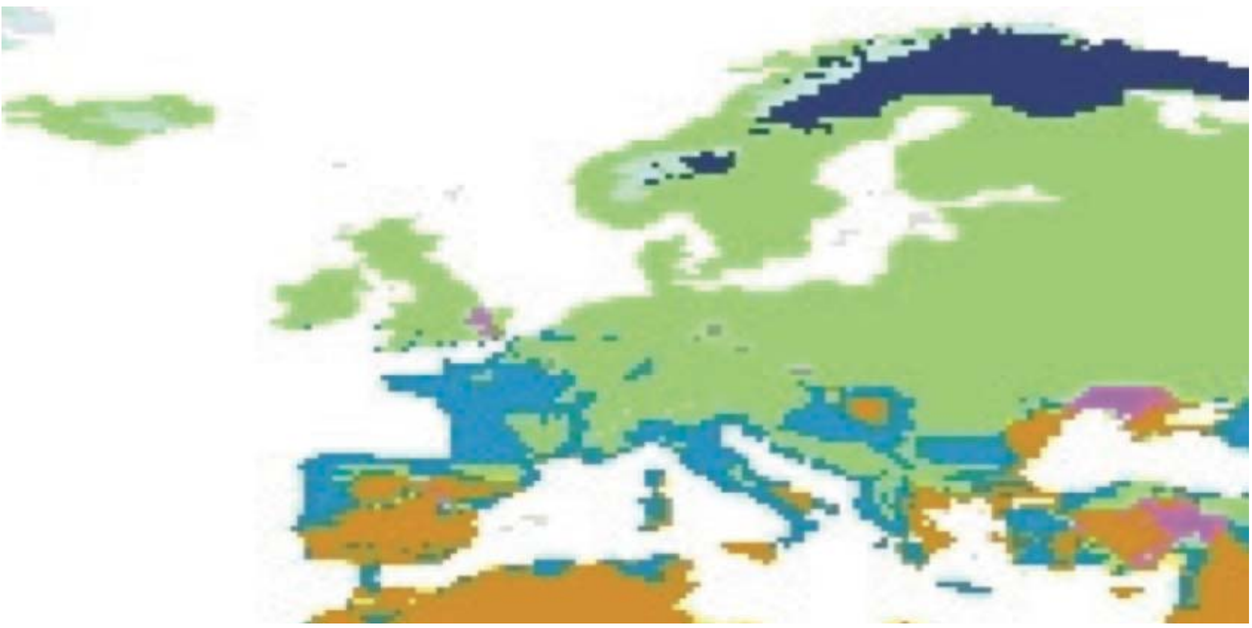


Figure 11: Major climate zones in Europe (see Figure 10 for the definition of the colour codes)

#### 2.7.1.3 Types of soil

We refer to the 2006 IPCC Guidelines (Figure 3A.5.4 in Chapter 3: Consistent Representation of Lands) for the classification scheme for mineral soil types. It is based on the World Reference Base for Soil Resources (WRB) classification.

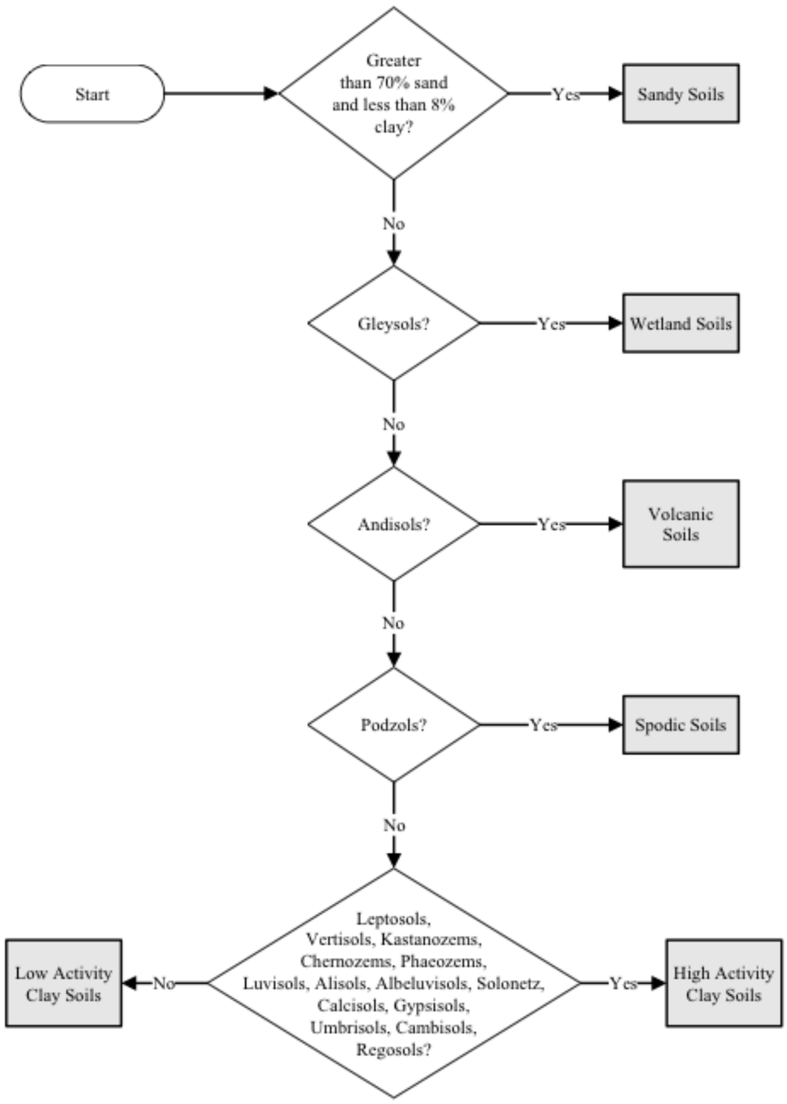



Figure 12 Classification scheme for mineral soil types based on World Reference Base for Soil Resources (WRB) classification

From the JRC website, it's possible to download a Google Earth File (with ".kmz[5]" extension) with maps derived from the European Soil Database v2 (ESDB v2) for EU-27 countries.
http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDBv3/GoogleEarth/index.cfm

[5] The ".kmz" files are zipped ".kml" files and are automatically unzipped when opened by the Google Earth application, which can be freely downloaded. The ".kmz" files are typically 20 MB in size, so it may take some time to download the file and open it with Google Earth.

One of the maps refers to soil reference group code of the STU[6] from the World References Base (WRB) for Soil Resources with 30 available categories.


Figure 13: WRB Major reference Group Legend

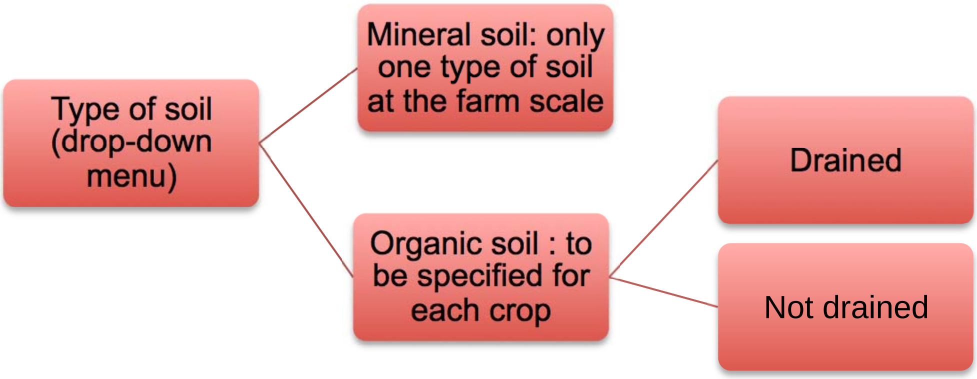
The selection of the type of soil will be based on the WRB major reference groups.

As the methodology for mineral soils is more complex, **only one type of mineral soil can be selected per farm** (the dominant one) in the Carbon Calculator.

If the farm is also concerned by an area of organic soil (histosol), the user will specify it for each crop. In the case of drained organic soils, estimation of C and $N_2O$ emissions will be calculated.

[6] STU: Soil Typological Unit

Figure 14: Soil types for a farm in the Carbon Calculator (mineral and organic)




### 2.7.1.4 Croplands (annual crops and perennial crops)

#### 2.7.1.4.1 Definition

IPCC, definition of cropland:

*Croplands include arable and tillage land, rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category, and is not expected to exceed those thresholds at a later time.*

*Croplands include all annual and perennial crops as well as temporary fallow land (i.e., land set at rest for one or several years before being cultivated again).*

*Annual crops include cereals, oil seeds, vegetables, root crops and annual forages.*

*Perennial crops include all trees and shrubs, in combination with herbaceous or cereal crops (e.g., agroforestry) or as orchards and vineyards.*

*Arable land which is normally used for cultivation of annual crops but which is temporarily used for forage crops or grazing as part of an annual crop-pasture rotation (mixed system) is included under cropland.*

The main management practices that affect soil C stocks in croplands are residue management, tillage management, fertiliser management (both mineral fertilisers and organic amendments), choice of crop and intensity of cropping management (i.e., continuous cropping versus cropping rotations with periods of bare fallow), irrigation management, and mixed systems with cropping and pasture or hay in rotating sequences.

In addition, drainage and cultivation of organic soils reduce soil C stocks.

Carbon Calculator:

We will rely on this global definition of cropland for the Carbon Calculator.

However, as we are working at farm level, we need to specify what temporary grassland is. Thus, all temporary grassland seeded within the last 5 years will be considered as Cropland for the Carbon Calculator.

#### 2.7.1.4.2 Mineral soils

Changes in soil C stocks are computed over an inventory time period. For an inventory time period, soil organic C stocks are estimated for the first and last year based on multiplying the reference C stocks by stock change factors. Annual rates of carbon stock change are estimated as the difference in stocks at two points in time divided by time dependence of stock change factors.

Time dependence of stock change factors, which is the default time period for transition between equilibrium SOC values, yr. Commonly 20 years, but depends on assumptions made in computing the factors $F_{LU}$, $F_{MG}$ and $F_I$. In some inventories, the time period may exceed 20 years. Then, it is recommended to divide the C stock changes by the difference between the initial and final year of the time period.

This methodology is provided to assess C stock changes at the scale of territories. In the Carbon Calculator, we will apply it to calculate the annual rate of change in C stock at the farm level.

**- Land-use factors ($F_{LU}$)**

Table 52: Land-use factors

| Land-use | Temperature regime | Moisture regime[A] | Land use factors |
|---|---|---|---|
| Long term cultivated[7] | Temperate/Boreal | Dry | 0.80 |
| | | Moist | 0.69 |
| | Tropical | Dry | 0.58 |
| | | Moist/Wet | 0.48 |
| | Tropical mountain[B] | n/a | 0.64 |
| Paddy rice[8] | All | Dry and Moist/Wet | 1.10 |
| Perennial/Tree crop[9] | All | Dry and Moist/Wet | 1.00 |
| Set aside (< 20 yrs)[10] | Temperate/Boreal and Tropical | Dry | 0.93 |
| | | Moist/Wet | 0.82 |
| | Tropical mountain[B] | n/a | 0.88 |

[A] Where data were sufficient, separate values were determined for temperate and tropical temperature regimes; and dry, moist, and wet moisture regimes. Temperate and tropical zones correspond to those defined in Chapter 3

[7] Input and tillage factors are also applied to estimate carbon stock changes. Land-use factor was estimated relative to use of full tillage and nominal ("medium") carbon input levels.

[8] Annual cropping of wetlands (paddy rice). Can include double cropping with non-flooded crops. For paddy rice, tillage and input factors are not used.

[9] Long-term perennial tree crops such as fruit and nut trees, coffee and cacao.

[10] Represents temporary set aside of annually cropland (e.g., conservation reserves) or other idle cropland that have been revegetated with perennial grasses.

(Consistent representation of lands); wet moisture regime corresponds to the combined moist and wet zones in the tropics and moist zone in temperate regions.

[B] There were not enough studies to estimate stock change factors for mineral soils in the tropical mountain climate region. As an approximation, the average stock change between the temperate and tropical regions was used to approximate the stock change for the tropical mountain climate.

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 5 – table 5.5.)

Land-use for the Carbon Calculator:

$F_{LU}$ factors from the IPCC methodology are used but the definition of land-use category was adapted because we are working at farm level.

Only the Paddy rice category won't be used as it is out of the perimeter of the Calculator carbon.

- ✓ *The "long-term cultivated" category will be called "**Annual crops/Temporary grassland**" in the Carbon Calculator. Annual crops include cereals, oil seeds, vegetables, root crops, industrial crops (beet, potato, plant fiber) and annual forages. As a reminder, temporary grassland corresponds to grassland seeded within the last 5 years (without ploughing). Input and tillage factors are also applied to estimate carbon stock changes (see next chapter).*
- ✓ *The "perennial/Tree crop" category will be called "**Tree Crop/Vineyard**" in the Carbon Calculator. This includes all perennial tree crops such as fruits (apples, cherries, etc.), nut trees or vineyards.*
- ✓ *The "Set aside" category will be called "**Set aside**" in the Carbon Calculator. This includes all land fallows.*

**- Land management factors ($F_{MG}$)**

Table 53: Land management factors for cropland

| Land-use management | Temperature regime | Moisture regime[A] | Land management factors (IPCC default) |
|---|---|---|---|
| Full tillage[11] | All | Dry and Moist/Wet | 1.00 |
| Reduced tillage[12] | Temperate/Boreal | Dry | 1.02 |
| | | Moist | 1.08 |
| | Tropical | Dry | 1.09 |
| | | Moist/Wet | 1.15 |
| | Tropical montane[B] | n/a | 1.09 |
| No-tillage[13] | Temperate/Boreal | Dry | 1.10 |

[11] Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g., < 30%) of the surface is covered by residues.

[12] Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leave surface with >30% coverage by residues at planting.

[13] Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.

| | | | |
|---|---|---|---|
| | | Moist | 1.15 |
| | Tropical | Dry | 1.17 |
| | | Moist/Wet | 1.22 |
| | Tropical montane[B] | n/a | 1.16 |

[A] Where data were sufficient, separate values were determined for temperate and tropical temperature regimes; and dry, moist, and wet moisture regimes. Temperate and tropical zones correspond to those defined in Chapter 3 (Consistent representation of lands); wet moisture regime corresponds to the combined moist and wet zones in the tropics and moist zone in temperate regions.

[B] There were not enough studies to estimate stock change factors for mineral soils in the tropical montane climate region. As an approximation, the average stock change between the temperate and tropical regions was used to approximate the stock change for the tropical montane climate.

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 5 – table 5.5.)

It is a good practice only to consider reduced and no-tillage if they are used continuously (every year) because even an occasional use of full tillage will significantly reduce the soil organic C storage expected under the reduced or no-tillage regimes.

<u>Land management factors for the Carbon Calculator:</u>

We will use $F_{MG}$ factors of the IPCC methodology only for "Annual crops/temporary grassland" category in the Carbon Calculator.

A land management factor will be affected to each crop depending of the management regime between no-tillage, reduced tillage or full tillage (ploughing).

- ✓ ***Full tillage:*** *substantial soil disturbance with full inversion and/or frequent (within year) tillage operations.*
- ✓ ***Reduced tillage:*** *reduced soil disturbance (usually shallow and without full soil inversion).*
- ✓ ***No tillage:*** *Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone.*

**- Input level factors ($F_I$)**

Table 54: Input level factors for cropland

| Level | Temperature regime | Moisture regime[A] | Input level factors (IPCC default) |
|---|---|---|---|
| Low[14] | Temperate/Boreal | Dry | 0.95 |
| | | Moist | 0.92 |
| | Tropical | Dry | 0.95 |
| | | Moist/Wet | 0.92 |

[14] Low residue return occurs when there is due to removal of residue (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g., vegetables, tobacco, cotton), no mineral fertilisation or N-fixing crops.

| | | | |
|---|---|---|---|
| | Tropical montane[B] | n/a | 0.94 |
| Medium[15] | All | Dry and Moist/Wet | 1.00 |
| High without manure[16] | Temperate/Boreal and Tropical | Dry | 1.04 |
| | | Moist/Wet | 1.11 |
| | Tropical montane[B] | n/a | 1.08 |
| High with manure[17] | Temperate/Boreal and Tropical | Dry | 1.37 |
| | | Moist/Wet | 1.44 |
| | Tropical montane[2] | Not available | 1.41 |

[A] Where data were sufficient, separate values were determined for temperate and tropical temperature regimes; and dry, moist, and wet moisture regimes. Temperate and tropical zones correspond to those defined in Chapter 3 (Consistent representation of lands); wet moisture regime corresponds to the combined moist and wet zones in the tropics and moist zone in temperate regions.

[B] There were not enough studies to estimate stock change factors for mineral soils in the tropical montane climate region. As an approximation, the average stock change between the temperate and tropical regions was used to approximate the stock change for the tropical montane climate.

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 5 – table 5.5.)

<u>Input level factors for the Carbon Calculator:</u>

We will use $F_I$ factors from the IPCC methodology only for the "Annual crops/temporary grassland" category in the Carbon Calculator.

However, we need to adapt the definition of each input category because we are working at farm level.

[15] Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g., manure) is added. Also requires mineral fertilisation or N-fixing crop in rotation.

[16] Represents significantly greater crop residue inputs over medium C input cropping system due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied.

[17] Represents significantly higher C input over medium C input cropping systems due to additional practice of regular addition of animal manure.

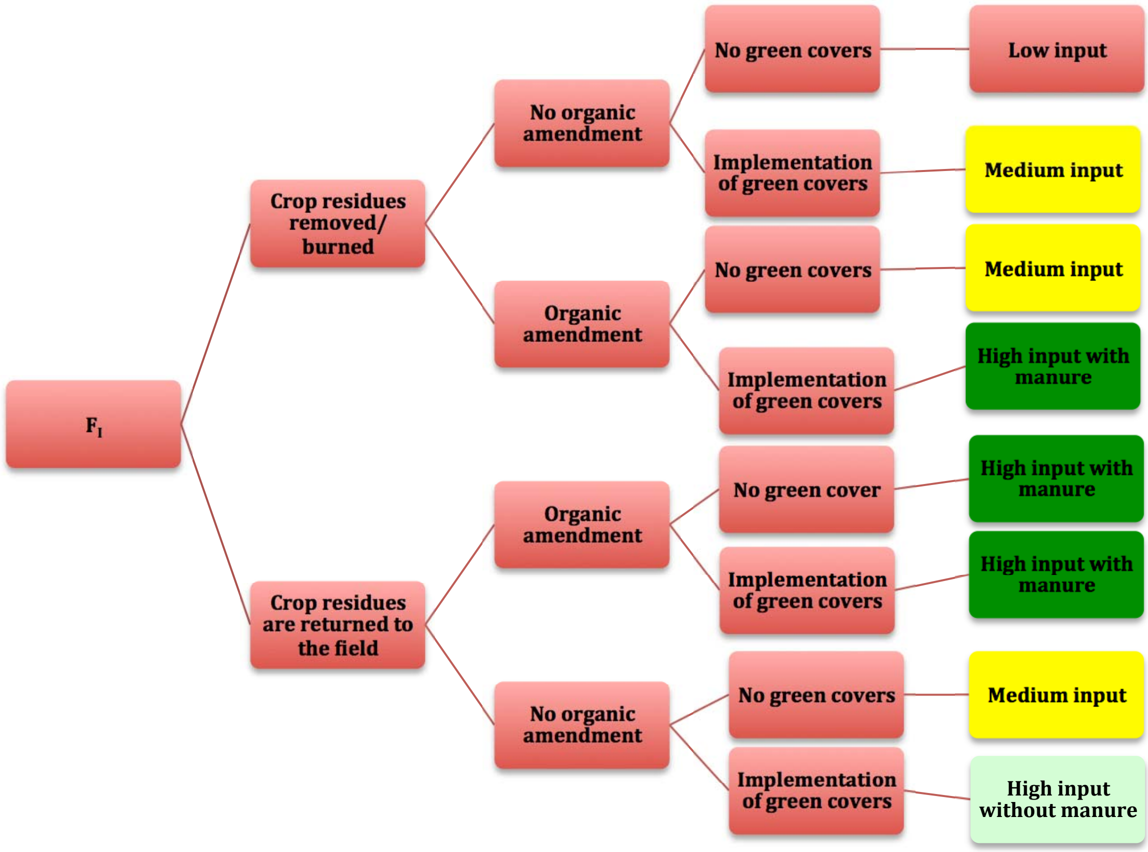



Figure 15: Decision tree for selection of $F_I$ for cultivated land (each crop)

Based on the IPCC methodology, we have chosen to focus on three relevant criteria for increasing carbon storage in the soil. The combination of these three criteria will help to choose the suitable input level factor ($F_I$):

- *First, if the crop residues are removed (or burned) or returned to the field. Export of dry matter on temporary grassland (pasture, hay, silage, etc.) will be equivalent to crop residues removed in the decision tree of the Carbon Calculator.*
- *Secondly, spreading of organic amendment. It can be solid or liquid organic amendment. Pasture of temporary grassland will be equivalent to an organic amendment in the decision tree of the Carbon Calculator.*
- *Finally, if green covers are implemented or not.*

## - Example of calculation

Illustration of the calculation of soil organic carbon content in the Carbon Calculator:

Type of soil: HAC soil, Cambisol
Climate region: Warm temperate moist
Type of crop ($F_{LU}$): wheat, annual crop
$F_{MG}$: reduced tillage
$F_I$: Medium input (crop residues are returned to the field, no organic amendment, no green covers)

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I$$

SOC = 88 x 0.69 x 1.08 x 1 = 65.58 t C/ha

**- C stock changes (cultivated land remaining cultivated land)**

Once the current C stock is calculated for cultivated land in the Carbon Calculator, two simulations will be calculated to estimate the carbon stock changes over a period of 20 years:

- *First step, the Carbon Calculator estimates the difference between the current situation of the farm and the worst combination of tillage factors and input factors for this type of soil and climatic zone. The aim is to highlight the positive results of agricultural practices on the dynamic of carbon sequestration, if any.*
- *Second step, the Carbon Calculator estimates the difference between the current situation of the farm and the best combination of tillage factors and input factors for this type of soil and climatic zone[18]. This calculation of C stock changes will help the user to quantify how much good agricultural practices can increase C stock in the soil. Margins of progress in C storage will be highlighted with this calculation.*

Example:

Current situation of the farm:

Type of soil: HAC soil, Cambisol

Climate region: Warm temperate moist

Type of crop ($F_{LU}$): wheat, annual crop

$F_{MG}$: reduced tillage

$F_I$: Medium input (crop resides are returned to the field, no organic amendment, no green covers)

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I$$

SOC = 88 x 0.69 x 1.08 x 1 = 65.58 t C/ha

Worst combination of $F_{MG}$ and $F_I$ for this type of soil and climatic zone:

$F_{MG}$: full tillage

$F_I$: Low input (crops residues are removed, no organic amendment, no green covers)

SOC = 88 x 0.69 x 1 x 0.92 = 55.86 t C/ha

**Dynamic of increase in carbon stock in the soil by current agricultural practices = (65.58-65.58) / 20 = 0.48 t C/ha/year**

Best combination of $F_{MG}$ and $F_I$ for this type of soil and climatic zone:

$F_{MG}$: no tillage

$F_I$: High input with manure

SOC = 88 x 0.69 x 1.15 x 1.44 = 100.55 t C/ha

**Possible margin of progress in carbon stock in the soil = (100.55 – 65.58) / 20 = 1.75 t C/ha/year**

[18] In the Carbon Calculator, a list of mitigation actions will be suggested once the assessment will be done. One of them will deal with the increase of the carbon storage in the soil.

#### 2.7.1.4.3 Cultivated organic soils

Cropland on organic soils are not differentiated based on management systems, as it is assumed that drainage associated with any type of management stimulates oxidation of organic matter previously built up under a largely anoxic environment.

Table 55: Annual emission factors for cultivated organic soils

| Climatic temperature regime | IPCC default (t C $ha^{-1}$ $yr^{-1}$) |
|---|---|
| Boreal/Cool Temperate | 5.0 |
| Warm Temperate | 10.0 |
| Tropical/Sub-Tropical | 20.0 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 5 – table 5.6.)

For the Carbon Calculator, two emission factors are suitable for Europe (Boreal/Cool Temperate and Warm Temperate climatic zone).

Example:

Current situation of the farm:

Type of soil: Organic soil

Climate region: Cool Temperate

Land area of drained organic soils: 15 ha

$L_{Organic}$: annual carbon loss from drained organic soils, tonnes C $yr^{-1}$

$$L_{Organic} = A \times EF$$

$L_{Organic}$ = 15 x 5 = 75 t C $yr^{-1}$

However, the calculated emissions are very important in comparison to references we have got at farm level. For example, the climate impact is around 2 $tCO_2e$ /ha for wheat, for a farm with dairy cows it is around 6 $tCO_2e$ /ha (RefPLANETE 2010).

GHG emissions taken into account reach 18 $tCO_2e$/ha for Boreal/Cool temperate climatic zone and 36 $tCO_2e$ /ha for a Warm temperate climatic zone.

### 2.7.1.5 Grasslands

#### 2.7.1.5.1 Definition

IPCC definition of grassland:

Grasslands generally have vegetation dominated by perennial grasses, and grazing is the predominant land use.

For mineral soils, soil C stocks in grassland are influenced by fire, grazing intensity, fertiliser management, liming, irrigation, re-seeding with more or less productive grass species and mixed swards with N fixing legumes.

In addition, drainage of organic soils for grassland management causes losses of soil organic C.

Carbon Calculator:

The methodology described for grassland will be applied only to grasslands that no longer fit into a rotation and that have been in place for over five years. Grasslands that have been ploughed less than five years ago will be managed as croplands.

Moreover, in the European Union we have to take into account that grasslands are very likely to receive mineral fertilisers and be grazed as well as mechanically harvested.

#### 2.7.1.5.2 Mineral soils

For mineral soils, the estimation method is based on changes in soil organic C stocks over a finite period following changes in management practices.

After a finite transition period, one can assume a steady state for this stock.

Grassland systems are classified by practices that influence soil C storage. In general, practices that are known to increase C input to the soil and thus soil organic stocks, such as irrigation, fertilisation, liming, organic amendments, more productive grass varieties, are given an improved status, with medium or high inputs depending on the level of improvement.

Practices that decrease C input and soil organic C storage, such as long-term heavy grazing, are given a degraded status relative to nominally-managed seeded pastures or native grassland that are neither improved nor degraded.

These practices are used to categorise management systems and then estimate the change in soil organic C stocks.

**- Land-use factors ($F_{LU}$)**

Table 56: Land-use factor for grassland

| Land-use | Climate regime | IPCC default |
|---|---|---|
| Permanent grassland | All | 1.0 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 6 – table 6.2.)

Carbon Calculator:

Land use factor of 1.0 is assigned to all permanent grasslands.

**- Land management factors ($F_{MG}$)**

Table 57: Land management factors for grassland

| Land-use management | Climate regime | IPCC default |
|---|---|---|
| Nominally managed (non-degraded)[19] | All | 1.00 |
| Moderately degraded[20] | Temperate/Boreal | 0.95 |
| | Tropical | 0.97 |
| | Tropical Montane[A] | 0.96 |
| Severely degraded[21] | All | 0.70 |
| Improved grassland[22] | Temperate/Boreal | 1.14 |
| | Tropical | 1.17 |
| | Tropical Montane[A] | 1.16 |

[A] There were not enough studies to estimate stock change factors for mineral soils in the tropical montane climate region. As an approximation, the average stock change between the temperate and tropical regions was used to approximate the stock change for the tropical montane climate.

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 6 – table 6.2.)

Land management factors for the Carbon Calculator:

The four land-use management categories and $F_{MG}$ factors from the IPCC methodology are used in the Carbon Calculator.

It will be possible to assign different land management factors for each grassland type present on the farm.

[19] Represents non-degraded and sustainably managed grasslands, but without significant management improvements.

[20] Represents overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) and receiving no management inputs.

[21] Implies major long-term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and/or severe soil erosion.

[22] Represents grassland which is sustainably managed with moderate grazing pressure and that receive at least one improvement (e.g., fertilisation, species improvement, irrigation).

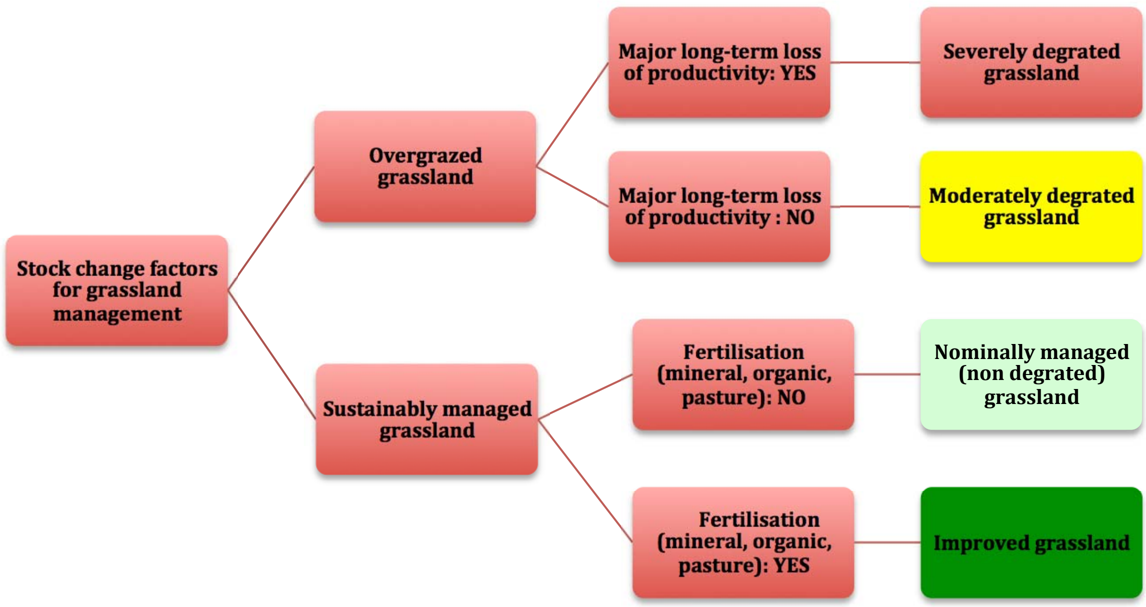



Figure 16: Decision tree for selection of stock change factors for grassland management

Carbon Calculator:

Based on the IPCC methodology, the Carbon Calculator focuses on three criteria to select the suitable stock change factors for grasslands:

- ✓ *First, is the grassland overgrazed or sustainably managed? Overgrazing may be the result of excessive loading of livestock or a time of insufficient rest of the grass (especially in autumn). Grasses are establishing energy reserves in their roots and base of their stems. Thus, overgrazing leads inexorably to a more or less pronounced degradation of the grassland as these reserves are important for regrowth of the grass when weather conditions are favourable. It is recommended to leave a grass height of between 5 and 6 cm in late season to avoid prejudicing the next spring regrowth. Overgrazed grassland can take three to five times longer to regrow and dry matter production is generally twice lower. For the Carbon Calculator, overgrazed grassland will be characterised by a low density of grasses, a longer time to regrow and a loss of productivity.*
- ✓ *For overgrazed grassland, is there major long-term loss of productivity? If the loss of productivity is recurrent in recent years, then we will put it in the "Severely degraded grassland" category. If it's the first year that there is an overgrazing, then we will put it in "Moderately degraded grassland" category.*
- ✓ *Sustainably managed grassland corresponds to grassland that is not overgrazed. We will consider fertilisation as a relevant management improvement. Both mineral fertilisers and organic amendment (solid, liquid or pasture) will correspond to the fertilisation choice.*

**- Input level factors ($F_I$)**

Two input levels are available in the IPCC methodology but only for improved grassland.

Table 58: Input level for improved grassland

| Land-use management | Level | Climate regime | IPCC default |
|---|---|---|---|
| Improved grassland | Medium[23] | All | 1.0 |
| | High[24] | All | 1.11 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 6 – table 6.2.)

Carbon Calculator:

Based on a list of possible improvements (including irrigation, liming and implementation of more productive grass varieties or seeding legumes in recent years), the Carbon Calculator differentiates grassland management between "high input level" and "medium input level".

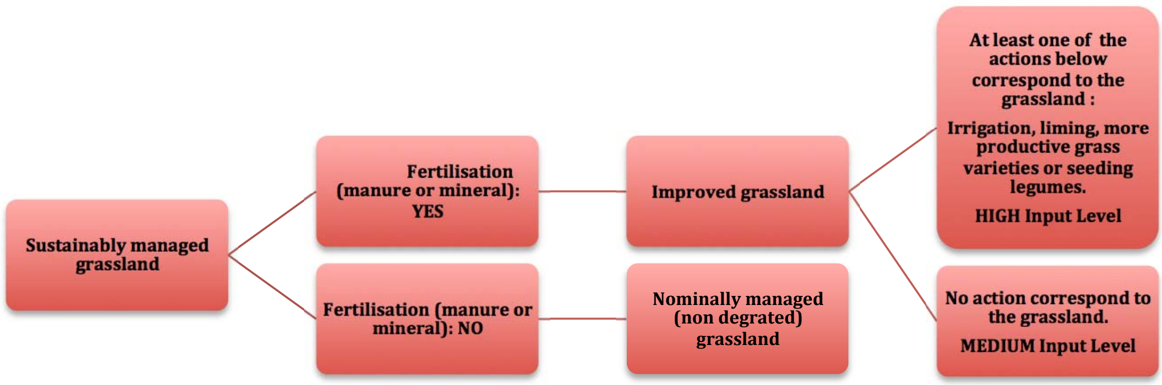



Figure 17: Decision tree for selection of input level factors

**- Example of calculation**

Illustration of the calculation of soil organic carbon content:

Type of soil: HAC soil, Cambisol

Climate region: Warm temperate moist

Type of crop ($F_{LU}$): permanent grassland, 8 year-old (never ploughed during this period).

$F_{MG}$: sustainably managed grassland with no fertilisation (non-degraded grassland)

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I$$

SOC = 88 x 1 x 1 = 88 t C/ha

**- C stock changes (grassland remaining grassland)**

[23] Applied to improved grassland where no additional management inputs have been used.

[24] Applies to improved grassland where one or more additional management inputs/improvements have been used (beyond that is required to be classified as improved grassland).

Once the current C stock is calculated for grassland in the Carbon Calculator, two simulations will be calculated to estimate the carbon stock changes over a period of 20 years:

- *First step, we will make the difference between the current situation of the farm and the worst combination of land management factors and input factors for this type of soil and climatic zone. The aim is to highlight the positive results of agricultural practices on the dynamic of carbon sequestration, if any.*
- *Second step, we will make the difference between the current situation of the farm and the best combination of land management factors and input factors for this type of soil and climatic zone[25]. This calculation of C stock changes will help the user to quantify how good agriculture practices can increase C stock in the soil. Margins of progress in C storage will be highlighted with this calculation.*

<u>Example:</u>

Current situation of the farm:

Type of soil: HAC soil, Cambisol

Climate region: Warm temperate moist

Type of crop ($F_{LU}$): permanent grassland, 8 years old (never ploughed during this period).

$F_{MG}$: sustainably managed grassland with no fertilisation (non-degraded grassland)

SOC = 88 x 1 x 1 = 88 t C/ha

Worst combination of $F_{MG}$ and $F_I$ for this type of soil and climatic zone:

$F_{MG}$: severally degraded grassland (overgrazed and long-term loss of productivity)

$F_I$: no factor

SOC = 88 x 1 x 0.70 = 61.60 t C/ha

**Dynamic of increase in carbon stock in the soil by current agricultural practices = (88 – 61.60) / 20 = 1.32 t C/ha/year**

Best combination of $F_{MG}$ and $F_I$ for this type of soil and climatic zone:

$F_{MG}$: sustainably managed grassland with mineral fertilisation (Improved grassland)

$F_I$: implementation of seeding legumes in recent years give the grassland a High input level.

SOC = 88 x 1 x 1.14 x 1.11 = 110.35 t C/ha

**Possible margin of progress in carbon stock in the soil = (100.35 – 88) / 20 = 1.12 t C/ha/year**

#### 2.7.1.5.3 Organic soils

The methodology is to stratify managed organic soils by climate region and assign a climate-specific annual emission rate. Surfaces are multiplied by the emission factor and then added up to derive annual C emissions.

---

[25] In the Carbon Calculator, a list of mitigation actions will be suggested once the assessment will be done. One of them will deal with the increase of the carbon storage in the soil.

Table 59: Annual emission factors for drained grassland on organic soils

| Climatic temperature regime | IPCC default (tonne C $ha^{-1}$ $yr^{-1}$) |
|---|---|
| Boreal/Cold Temperate | 0.25 |
| Warm Temperate | 2.5 |
| Tropical/Sub-Tropical | 5.0 |

Source: 2006 IPCC Guidelines for national greenhouse gas inventories (chapter 6 – table 6.3.)

For the Carbon Calculator two emission factors are suitable for Europe (Boreal/Cold Temperate and Warm Temperate climatic zones).

<u>Example:</u>

Current situation of the farm:

Type of soil: Organic soil

Climate region: Cold Temperate

Surface of drained organic soils: 10 ha

$L_{Organic}$: annual carbon loss from drained organic soils, tonnes C $yr^{-1}$

$$L_{Organic} = 10 \times 0.25 = 2.5 \text{ t C yr}^{-1}$$

As emission factors for grasslands on drained organic soils are lower than for cropland, the climate impact calculated is lower.

#### 2.7.1.6 Land-use changes

Land-use changes that occurred over the past 20 years are taken into account in the Carbon Calculator.

Type of conversions included:

Conversion of forest to cropland

Conversion of forest to grassland

Conversion of grassland to cropland

Conversion of cropland to grassland

Conversion of cropland to forest

The calculation of C stock change due to land-use changes will highlight whether the farmer's decision had an impact or not on total GHG emissions.

Equation 44: Change in organic carbon stocks in mineral soils

$$\Delta C_{mineral} = \frac{SCO_0 - SOC_{(o-T)}}{D}$$

$\Delta C_{mineral}$: Change in carbon stocks in mineral soils, tonnes C.yr$^{-1}$

$SCO_0$: Soil organic carbon stock in the last year of the time period, tonnes C

$SOC_{(o-T)}$: Soil organic carbon stock at the beginning of the time period, tonnes C

$T$: duration of time period, in years (with T = 5 yrs in the Carbon Calculator)

$D$: Time dependence of stock change factors (default time period for transition between equilibrium SOC values, Commonly 20 years).

### 2.7.2 Carbon storage in natural infrastructures

The aim of this chapter is to list the natural infrastructures of the farm. Carbon stock in trees, hedgerows, vineyards or orchards is taken into account as well as the annual increase of carbon storage in each category.

Woods and forests are outside the boundaries of the natural infrastructures category.

Natural infrastructures are divided in three categories:

- Tree natural elements (more than 5 meters high)
- Shrubby natural elements (1 to 5 meters high)
- Low natural elements (less than 1 meter high)

#### 2.7.2.1 Total carbon stock

For each category, the Carbon Calculator evaluates a total C stock, which corresponds to the surface of each natural infrastructure multiplied by the ratio of tC per ha.

Note that for forestry statistics, the surface is counted by projection on the ground of the tree crown.

Table 60: Carbon storage by tree natural elements

| Tree natural elements (> 5 m high) | Characteristics | Current C stock (soil + wood) |
|---|---|---|
| Grove < 0.5 ha | | 120 tC/ha |
| Maintained hedge row 3 stratum | More than 3 trees for 25 m linear | 120 tC/ha |
| Damaged hedgerow (L basis <1.5 m) | | 100 tC/ha |
| Tree line | Road side. Standard width = 5 m | 100 tC/ha |
| Scattered tree (adult) | 100 m$^2$/ tree | 100 tC/ha |
| Riverine | Along the stream | 120 tC/ha |
| Wood edges | Wood> 0.5ha, take 10m width and count the wood edges length | 0 tC/ha |

Source: IFN (Agreste - Chiffres et données n°137 de nov. 2001, statistiques forestières en 2000)

Table 61: Carbon storage by shrubby natural elements

| Shrubby natural elements (1 to 5 m high) | Characteristics | Current C stock (soil + wood) |
|---|---|---|
| Shrubby hedgerow | Less than 3 trees for 25 metres | 94 tC/ha |
| Bank with shrub | | 94 tC/ha |
| Wildland, heath | Less than 3 trees for 0.5 ha | 94 tC/ha |
| Orchards | Carbon storage at the end of their lives, except for yearly trimming (vine shoots, etc.) = trunk and branches with the exception of stumps. | |
| Vineyards | Carbon storage at the end of their lives, except for yearly trimming (small branches, etc.) = vine trunk (with the exception of stumps). | |

Source: IFN (Agreste - Chiffres et données n°137 de nov. 2001, statistiques forestières en 2000)

Table 62: Carbon storage by low natural elements

| Low natural elements (< 1 m high) | Characteristics | Current C stock (soil + wood) |
|---|---|---|
| Grass strips | | 50 tC/ha |
| Green cover bank | | 70 tC/ha |
| Dry lawn | Not used by agriculture | 70 tC/ha |
| Wet natural meadow | Not used by agriculture | 90 tC/ha |
| Young hedgerow (0-3 years) | Hedgerow recently planted | 50 tC/ha |
| Young hedgerow (4-7 years) | | 59 tC/ha |
| Stone low wall | | 0 tC/ha |
| Ponds < 1000 $m^2$ | | 0 tC/ha |

Source: IFN (Agreste - Chiffres et données n°137 de nov. 2001, statistiques forestières en 2000)

#### 2.7.2.2 Increase of Carbon stock

In addition to the total C stock, an annual increase of C stock is calculated for each category depending of the quality of the station. The user can choose the rate of increase from three possible levels: favourable, average and unfavourable.

Default data for forestry annual increase ($m^3$ per year) are based on French data (IFN (Agreste - Chiffres et données n°137 de nov. 2001, statistiques forestières en 2000). However, users can customize the data by country in the Carbon Calculator if they want to implement national data.

Table 63: Wood and carbon storage depending on yield class

| Woodland yield class/ wood and carbon storage | $F_{IV}$: Forestry increase in volume | $C_C$: Carbon content of dry wood (tC/tDM wood) | $C_{CONV}$: Conversion of cubic meter of roundwood into tC | $F_{IC}$: Forestry increase in tC/year |
|---|---|---|---|---|
| Favourable | 7.5 $m^3$/year | 0.475 | 0.502 | 1.79 |
| Average | 6.0 $m^3$/year | 0.475 | 0.502 | 1.43 |
| Unfavourable | 4.5 $m^3$/year | 0.475 | 0.502 | 1.07 |

Source: IFN (Agreste - Chiffres et données n°137 de nov. 2001, statistiques forestières en 2000)

Equation 45: Forestry increase in carbon

$$F_{IC} = F_{IV} \times C_C \times C_{CONV}$$

$F_{IC}$: Forestry increase in carbon (tC/year)

$F_{IV}$: Forestry increase in volume ($m^3$/year)

$C_C$: Carbon content of dry wood (tC/tDM wood)

$C_{CONV}$: Conversion of cubic meter of roundwood into tC

#### 2.7.2.3 Vineyards and orchards

Default data for the annual increase of carbon storage (0.1 tC/ha) are from France (INRA, expertise collective 2002). However, users can customise the data by country in the Carbon Calculator if they want to implement national data.

The annual increase of carbon storage (tC) for vineyards and orchards corresponds to the surface of orchards and vineyards (in ha) multiplied by 0.1 tC/ha.

## 2.8 End of life

The end-of-life of organic matter outputs of the farm and of plastics used on the farm are taken into account in the assessment.

### 2.8.1 Manure exported

For the end of life of manure, two possibilities are considered:

- The manure exported is spread on other farmland,
- The manure exported is treated as waste.

If an off-farm waste management service provider manages the manure as waste, its emissions are included under the indirect activities section. Emission factors for treatment have not been found at this time (no such data could be found in the literature but the table is ready to be completed).

If the manure is spread on another farm, the Carbon Calculator considers a direct substitution of the equivalent amount of nitrogen from a mineral fertiliser and the farm is "credited" of those avoided emissions[26].

In all cases, the transportation of the organic manure output to the "client" is taken into account here when it is not done with the farm-owned machinery or operated vehicles. Different types of transport are included: with farm-type machinery or by trucks. These emissions are added to the indirect activities section.

All these emissions are reported in the "mineral and organic fertilisers" purchases.

### 2.8.2 Plastics end-of-life

The Carbon Calculator takes into account the end-of-life of the plastics used by the farm, on the basis of what the farmer does with its plastics:

- If the plastics are recycled, the specific emission factor for recycling is applied,
- If the plastics are re-used (e.g. by returning the plastic containers back to the supplier), no emission factor is applied as this is seen as a zero balance.
- If the plastics are burnt, the specific emission factor for burning in the air is applied.

The emission factors for treatment have not been found at this time but the table is ready to be completed.

Once the calculation is operational, results will be aggregated under "secondary inputs" purchased.

## 2.9 Attribution and allocation rules

### 2.9.1 Production and product

#### 2.9.1.1.1 Definition

The first step in the Carbon Calculator is to define and quantify the total amount of relevant products at farm level. What is considered to be a product corresponds to its physical form beyond farm gate (before processing, if there is).

Tableau 64: Available productions in the Carbon Calculator and corresponding products

| Productions | Products |
|---|---|
| Dairy cattle | Cow milk + meat |
| Dairy sheep herd | Sheep milk + meat |
| Meat sheep herd | Sheep meat |
| Dairy goat herd | Goat milk + meat |
| Beef herd | Beef meat |

[26] See Organisational Environmental Footprint Guide p61.

| | |
|---|---|
| Other ruminants | Other meat |
| Pigs | Pork meat |
| Poultry | Poultry meat |
| Laying hens | Eggs + laying hens meat |
| ***Cereals*** | ***All cereal grains*** |
| Barley | Barley grain |
| Maize | Maize grain |
| Sorghum | Sorghum grain |
| Hard wheat | Hard wheat grain |
| Soft wheat | Soft wheat grain |
| Lupine | Lupine grain |
| Millet | Millet grain |
| Oat | Oat grain |
| Peas | Peas grain |
| Rape | Rape grain |
| Rice | Rice grain |
| Rye | Rye grain |
| Soya | Soya beans |
| Sunflower | Sunflower grain |
| Triticale | Triticale grain |
| Spring field bean | Spring field bean grain |
| Winter field bean | Winter field bean grain |
| ***Industrial crops*** | ***All industrial crop grains*** |
| Potatoes | Potatoes |
| Tobacco | Tobacco |
| Sugar beet | Sugar beet |
| Wine | Wine |
| Grapefruit | Grapefruit |
| Fruits | Fruits |
| Vegetables | Vegetables |
| Fodder | Fodder plants |

Table 64 above presents the list gathering the main products for European farms. The user can select up to five different product categories from the list (see Carbon Calculator -User Guidance Manual page 20), which can be single products or groups of products. As an example, for cereals (the same for industrial crops, or fruits or vegetables), two options are available:

- The Carbon Calculator can analyse them all together under a unique product category,
- Or the Carbon Calculator can analyse them separately, e.g.: barley, black wheat, corn for grain, grain sorghum, hard wheat, lupine, millet, oat, peas, rape, rice, rye, soft wheat, soya, sunflower, triticale, spring field bean and winter field bean.

The user cannot create two categories for the same product. For example, soft wheat can appear only once among the five products of the farm.

A sixth category called “Other products” is always available in the Carbon Calculator (useful for farms with more than 5 products).

Some products have co-products. In the Carbon Calculator, these products are milk (always associated with meat: cow, sheep and goat), and eggs (associated with meat). The user cannot select these co-products, as they are automatically created.

If the user selects as its two main products cereals and milk, the Carbon Calculator automatically creates “dairy meat” as the third product of the farm. In the case where the user had already selected five main products, the “dairy meat” product is not created and related emissions are reported under “other products”.

Solagro’s experience in energy and GHG emissions assessment at farm level has shown that five products per farm was a good compromise and in many cases was enough to take into account all the different activities of the farm.

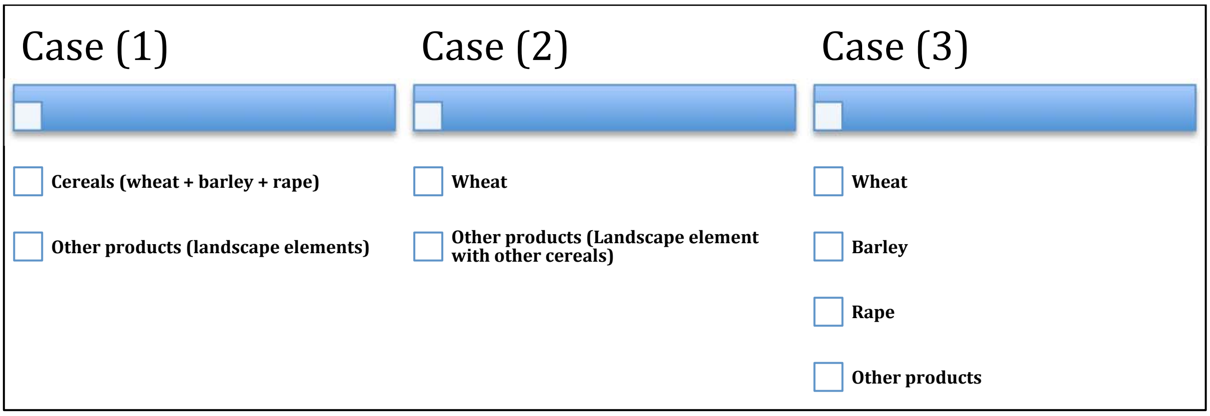
Examples of possible selections for products of different farming systems:

Farm type 1:

100 ha of cereals with wheat (40 ha), barley (30 ha), seed rape (25 ha) and landscape elements (5 ha).

Available options include: analysing cereals all together in a same production (1) or analysing some of them separately (2 and 3).

Figure 18: Example 1 for possible section of production or products

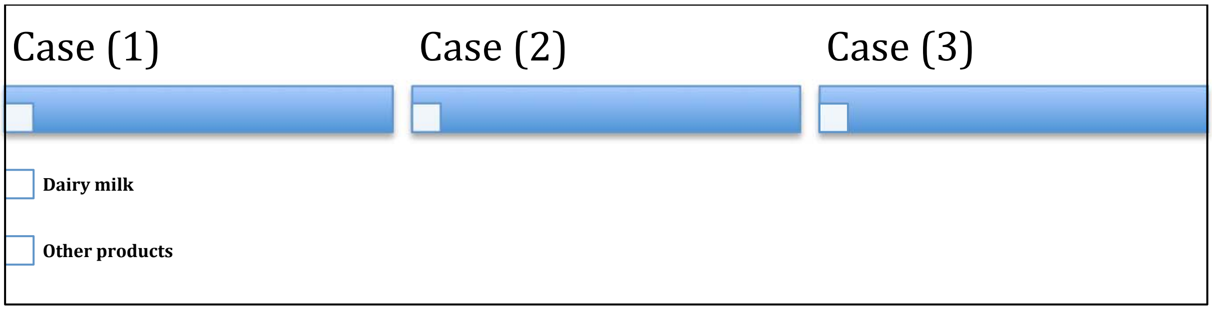



Farm type 2:

Dairy farm with only milk and meat from dairy cattle.

In this case, meat from dairy cows is considered as a compulsory product of the farm. The user only has to select cow milk. While only one production has been selected, the Carbon Calculator creates two products for the final results report: milk and dairy cow meat.

Figure 19: Example 2 for possible section of productions or products



#### 2.9.1.2 Functional unit

The Carbon Calculator reports GHG emissions as total GHG emissions as $tCO_2e$ by functional unit.

For the results at farm level, the functional unit is the “ha UAA”.

For the results by production or product, the Carbon Calculator uses:

- ✓ Tonnes of milk: for cow milk, sheep milk and goat milk. The farm’s milk production is converted to Fat and Protein Corrected Milk (FPCM) with 4% fat (cow milk) or 7% (sheep and goat milk) and 3.3% protein, using GGELS methodology.

Equation 46: Fat and protein corrected milk calculation

$$FPCM = raw\ milk\ (kg) \times (0.337 + 0.116 \times Fat\ content(\%) + \ 0.06 \times Protein\ content\ (\%))$$

- ✓ Tonnes of meat (live weight): for meat from dairy cows, beef, pork meat, poultry meat, goat meat and sheep meat.
- ✓ Tonnes of dry matter: for cereals (including oil and protein crops) and fodder (such as hay and silage).
- ✓ Tonnes of fresh matter: suitable for eggs, vegetables, fruits, wine and industrial crops (potatoes, tobacco, flax fibre, *Miscanthus*).

#### 2.9.1.3 Multiple outputs (Co-products)

In cases of multiple outputs from one production activity (like milk and beef), an allocation key has to be defined. Several allocation techniques exist in the literature and are summarised below:

- ✓ Economic allocation
- ✓ Mass allocation
- ✓ Allocation according to the production cycle
- ✓ Protein or energy allocation

Each method has advantages and disadvantages. The Carbon Calculator systematically uses the **protein or energy** allocation key to distribute GHG emissions between:

- Milk and meat from dairy animals (cow, sheep, goat)
- Eggs and poultry meat for laying hens.

As processing is outside the boundaries of the Carbon Calculator, the possibility to allocate GHG emissions between co-products resulting from processing is not available. For example, if a farmer grows sunflower in order to make oil and sunflower cake, the Carbon Calculator only calculates GHG emissions from sunflower grains (no result for oil and sunflower cake).

#### 2.9.1.4 Attribution and allocation of GHG emissions per product

##### 2.9.1.4.1 General rules

The tool relies above all on the traceability of the inputs used. There are many situations where it is possible to make a direct link between the source of emissions and the final product. For example, the GHG emissions (manufacturing) of mineral fertilisers applied on a crop will be directly attributed to this product.

As it is not always the case, the Carbon Calculator also relies on automatic allocations for some sources of emissions. For example, on a dairy farm (two products = milk and meat) an automatic allocation rule based on energy content in milk and meat is implemented.

Finally, as it's impossible to predict allocation rules for all the situations on farms, the Carbon Calculator sometimes asks the user to distribute the percentage of use of an input between different available products. For example, for propane gas used on a farm, the user has to distribute the percentage of use between the different available products (see the table below).

Table 65: Attribution by the user himself of input use between products

| | Product 1 | Product 2 | Product 3 | Product 4 | Product 5 | Other products |
|---|---|---|---|---|---|---|
| **Petrol** | % | % | % | % | % | % |
| **Propane or butane gas** | % | % | % | % | % | % |
| **Natural gas** | % | % | % | % | % | % |
| **Coal** | % | % | % | % | % | % |

The three available types of attribution rules in the Carbon Calculator are:

- ✓ Type 1: Direct attribution
- • Type 2: Automatic allocation between the source of emission and the products (protein or energy allocation, restricted to milk and meat from dairy animals and eggs and poultry meat for laying hens).
- ✓ Type 3: attribution by the user himself.

#### 2.9.1.5 Crops case

In the Carbon Calculator, GHG emissions of a crop are distributed based on the end-use of the crop production.

Example:

In the case of a wheat crop on a dairy farm, the user notifies (by entering the information in the Carbon Calculator) that they grow wheat.

As a first step, the user enters the data concerning the wheat-related inputs he uses (quantity). The Carbon Calculator will then add the GHG emissions from the different inputs to calculate the wheat-related GHG emissions (type 1 attribution rule).

In a second step, an open question (type 3 attribution rule) allows the user to identify how their wheat is used. GHG emissions are in the end distributed according to the end-use of the wheat indicated by the user, e.g. 50% for animal feed and 50% sold.

### 2.9.2 Direct sources

#### 2.9.2.1 Fuel/Diesel emissions

The data collection step allows identifying several uses of fuel/diesel on the farm. The Carbon Calculator uses a Type 2 attribution rule for consumptions by tractors and other machinery, whereas it uses a Type 3 attribution rule for other uses.

Table 66: Type of attribution rules for fuel and diesel use

| | |
|---|---|
| Tractors and other machinery | Type 2 and Type 3 |
| Heating | Type 3 |
| Pumping: | |
| Other use | |
| Cars and trucks | |

**- Tractor and other machinery ($C_T$)**

$C_T$ corresponds to the total consumption of the farm for tractor and other machinery + fuel consumption by third parties (contractors)– fuel consumption for third parties.

$C_T$ can be due to field operations ($C_{CROPS}$) for grain or forage, or to consumption inside buildings for animals ($C_{ANIMALS}$) (feeding, bedding, etc.).

Equation 47: Tractor and other machinery emissions

$$C_T = C_{CROPS} + C_{ANIMALS}$$

$C_{CROPS}$: corresponds to total consumption of fuel per crop (Data list: fuel consumption per ha for each crop). As the crops are linked to a production or product by a type 3 attribution, $C_{CROPS}$ impacts are easily affected.

$C_{ANIMALS}$ : is calculated by difference between $C_T$ and $C_{CROPS}$. Then, the Carbon Calculator uses a type 3 attribution to distribute GHG emissions per production or product.

In summary:

Step 1: Calculation of $C_T$

Step 2: Calculation of $C_{CROPS}$. GHG emissions are then associated to each crop and crops are associated to products.

Step 3: Calculation of $C_{ANIMALS}$. GHG emissions are associated to products depending on indications by the user.

Example:

Annual fuel consumption of the farm for tractor and other machinery: 8 000 litres
Annual fuel consumption by third parties: 1 000 litres
Annual fuel consumption for third parties: none
Fuel consumption for crop 1: 4 000 litres
Fuel consumption for crop 2: 1 000 litres

Calculations:

$C_T$ = 8 000 + 1 000 = 9 000 litres
$C_{CROPS}$ = 4 000 + 1 000 = 5 000 litres
$C_{ANIMALS}$: 9 000 – 5 000 = 4 000 litres

GHG emissions from $C_{ANIMALS}$ are then distributed according to the percentage of use indicated by the user.

### 2.9.2.2 Petrol, propane or butane gas, natural gas, coal

As the consumption of fuels (excluding diesel for machinery) can be considered as specific to the farm, the Carbon Calculator uses a Type 3 attribution rule.

Table 67: Manual user attribution (type 3) for petrol, gas and coal

| | Product 1 | Product 2 | Product 3 | Product 4 | Product 5 | Other products |
|---|---|---|---|---|---|---|
| **Petrol** | % | % | % | % | % | % |
| **Propane or butane gas** | % | % | % | % | % | % |
| **Natural gas** | % | % | % | % | % | % |
| **Coal** | % | % | % | % | % | % |

### 2.9.2.3 Enteric fermentation

Each livestock is automatically linked to a product in the Carbon Calculator (see below): for instance, all the enteric fermentation emissions from animals in the "dairy cattle" section are reported on the product (milk) and the co-product (meat). In the same way, all emissions from purchased inputs (feed, young animals, etc.) are reported on these two products by direct attribution.

Table 68: Attribution rules for enteric fermentation and manure management

| | | |
|---|---|---|
| Dairy cattle | Cow milk and heifers from/to dairy cows | Milk and meat |
| Meat cattle | Sucker cows, heifers, bullocks and bulls | Only meat |
| Dairy sheep | Milk ewes, strain female and lambs from these ewes | Milk and meat |
| Meat sheep | Meat ewes, lambs from these ewes | Only meat |
| Goats (milk and meat) | Milk and meat goats | Milk and meat |
| Pig | Sows, piglets and pigs | Meat |
| Poultry and other | Broilers chickens, turkeys, ducks, geese … and rabbits | Only meat |
| Laying hens | Laying hens | Eggs (kg) and meat |

Step 1: The Carbon Calculator calculates the emissions from enteric fermentation for each animal subspecies.

Step 2: Emissions from each animal subspecies are linked to pre-defined productions (type 1 attribution rule). The enteric fermentation emissions for each subspecies of “meat cattle” section, for example, are cumulated. Then that amount is divided by the quantity of meat sold.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between product and co-product (for example, milk and meat). The gross energy values for milk, meat and egg are calculated. Then, emissions are attributed to one or the other product based on their relative energy contents (percentage of total energy value).

#### 2.9.2.4 Manure management

Step 1: the Carbon Calculator calculates emissions from manure management for each animal subspecies.

Step 2: Emissions from each animal subspecies are linked to pre-defined productions (type 1 attribution rule).

Step 3 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between product and co-product (for example, milk and meat).

#### 2.9.2.5 Direct emissions from soil

<u>Emissions related to mineral fertilisers applied in fields:</u>

Step 1: the Carbon Calculator uses a type 1 attribution rule for emissions related to mineral fertilisers applied in fields as the amount of mineral nitrogen per crop is exactly known.

Step 2: the Carbon Calculator distributes the GHG emissions per product depending on the end-use of the crops indicated by the user.

Step 3 (only in cases of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between product and co-product (for example, milk and meat).

<u>Emissions related to manure applied in fields:</u>

Step 1: the Carbon Calculator identifies the crops receiving manure and sums up the surfaces.

Step 2: the Carbon Calculator calculates the total amount of organic nitrogen from manure and the GHG emissions.

Step 3: the Carbon Calculator uses a type 2 attribution rule for emissions related to manure applied in fields in proportion of the surfaces receiving manure.

Step 4: the Carbon Calculator distributes GHG emissions per production or product depending on the end-use of the crops indicated by the user.

Step 5 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between product and co-product (for example, milk and meat).

<u>Emissions related to grazing:</u>

Step 1: The Carbon Calculator calculates the amount of nitrogen from grazing and the GHG emissions for each animal subspecies.

Step 2: the Carbon Calculator makes automatic links as the emissions from each animal subspecies are linked to pre-defined product (type 1 attribution rule).

Step 3 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between product and co-product (for example, milk and meat).

Emissions related to crops residues:

Step 1: the Carbon Calculator calculates emissions from crop residues per crop, as crop residues are burnt, incorporated or exported from the field (type 1 attribution rule).

Step 2: Carbon Calculator distributes the GHG emissions per production or product depending on the end-use of the crops indicated by the user.

Step 3 (only in cases of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

### 2.9.3 Indirect sources

#### 2.9.3.1 Electricity purchased

Electricity consumption (without irrigation):

Step 1: the Carbon Calculator uses a type 3 attribution rule to distribute the emissions.

Step 2 (only in cases of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

Electricity for irrigation, individual pumping system:

Step 1: the Carbon Calculator calculates the total GHG emissions from irrigation

Step 2: the Carbon Calculator calculates total water consumption ($m^3$) from an individual pumping system.

Step 3: the Carbon Calculator uses a type 2 attribution rule to distribute GHG emissions in proportion to the quantity of water consumed per crop.

Step 4: the Carbon Calculator distributes the GHG emissions per production or product depending on the end-use of the crops indicated by the user.

Step 5 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

#### 2.9.3.2 Collective irrigation (electric pumping)

Electricity for irrigation, collective pumping system:

Step 1: the Carbon Calculator calculates the total GHG emissions separately for low, medium and high electric pumping system.

Step 2: the Carbon Calculator calculates the total water consumption ($m^3$) separately for low, medium and high electric pumping system.

Step 3: the Carbon Calculator uses a type 2 attribution rule to distribute the GHG emissions in proportion to the quantity of water consumed per crop and separately for low, medium and high electric pumping system.

Step 4: the Carbon Calculator distributes GHG emissions per production or product depending on the end-use of the crop indicated by the user.

Step 5 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

#### 2.9.3.3 Water from network

Step 1: the Carbon Calculator calculates the GHG emissions.

Step 2: the Carbon Calculator uses a type 3 attribution rule to distribute GHG emissions.

Step 3 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

#### 2.9.3.4 Mineral fertilisation (manufacturing)

Step 1: the Carbon Calculator uses a type 1 attribution rule for emissions related to mineral fertilisers (manufacturing), as the quantity of mineral fertilisers applied per crop is exactly known.

Step 2: the Carbon Calculator distributes GHG emissions per production or product depending on the end-use of the crops indicated by the user.

Step 3 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

#### 2.9.3.5 Pesticides (manufacturing)

Step 1: the Carbon Calculator uses a type 1 attribution rule for emissions related to pesticides (manufacturing), as the number of treatments per crop is known.

Step 2: the Carbon Calculator distributes the GHG emissions per production or product depending of the end-use of the crops indicated by the user.

Step 3 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

#### 2.9.3.6 Seeds

Step 1: the Carbon Calculator uses a type 1 attribution rule for emissions related to seeds, as the quantity of seeds purchased per crop is known.

Step 2: GHG emissions are then distributed per production or product depending of the end-use of the crop indicated by the user.

Step 3 (only in the case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

#### 2.9.3.7 Materials and farm buildings

Materials:

Step 1: the Carbon Calculator calculates GHG emissions for each material.

Step 2: the Carbon Calculator uses a type 3 attribution rule to distribute GHG emissions.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

Farm building (automatically linked to products):

Step 1: First, the Carbon Calculator calculates GHG emissions for each building. Secondly, GHG emissions are automatically distributed to production (type 1 attribution rule) as these buildings are linked to specific agricultural activities (see table below).

Step 2 (only in case of milk production or laying hens): Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

Farm building (not linked to production):

Step 1: the Carbon Calculator calculates the GHG emissions for each building.

Step 2: the Carbon Calculator uses a type 3 attribution rule to distribute the GHG emissions.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

#### 2.9.3.8 Farming machinery

Tractors, livestock materials and other equipment:

Step 1: the Carbon Calculator calculates GHG emissions of production of all farming machinery.

Step 2: the Carbon Calculator uses a type 3 attribution rule to distribute the GHG emissions.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide the emissions between co-products (for example, milk and meat).

Soil tillage, seeding and planting, manure spreading, treatments, mineral fertilisation spreading, forage/hay harvest, self-propelled machinery for crop harvest, residues and co-products harvest:

Step 1: the Carbon Calculator calculates total GHG emissions for each category of farming machinery.

Step 2: Depending on the crop surface and the number of operations, the Carbon Calculator calculates a cumulative surface for each category of farming machinery.

Step 3: the Carbon Calculator distributes GHG emissions per crop (type 2 attribution rule) in proportion of the aggregated surface.

Step 4: the Carbon Calculator distributes GHG emissions per production or product depending on the end-use of the crops indicated by the user.

Step 5 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

#### 2.9.3.9 Indirect emissions from soils

$NH_3$ atmospheric deposits:

Step 1: the Carbon Calculator calculates GHG emissions at farm level and distributes them to the crops in proportion of the surface of each crop (type 2 allocation rule).

Step 2: the Carbon Calculator distributes GHG emissions per product depending on the end-use of the crops indicated by the user.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

<u>Run-off and leaching:</u>

Step 1: the Carbon Calculator uses a type 1 attribution rule for run-off and leaching, as the nitrogen surplus is calculated for each crop.

Step 2: the Carbon Calculator distributes GHG emissions of the crop per production or product depending of the end-use of the crops indicated by the user.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

#### 2.9.3.10 Plastics, cardboard, oils, other animal inputs

Step 1: the Carbon Calculator calculates GHG emissions for each input.

Step 2: the Carbon Calculator uses a type 3 attribution rule to distribute GHG emissions.

Step 3 (only in case of milk production or laying hens): the Carbon Calculator uses an energy attribution key to divide emissions between co-products (for example, milk and meat).

## 2.10 Mitigation and sequestration actions

In order to highlight opportunities to improve the GHG profile of the farm, the Carbon Calculator recommends mitigation and sequestration actions.

The tool includes 16 mitigation or sequestration actions. They concern agronomical practices (A), livestock management (B), direct energy consumption (C) or carbon storage (D). The Carbon Calculator provides an estimation of the impact of each measure on the GHG profile of the farm. The Carbon Calculator provides cost estimations, based on the reduction of purchases, for six mitigation actions: adjust N fertiliser balance, soils covered all the year, reduction of electricity consumption of the milking system, reduce engines fuel consumption, heat water with solar panel and wood boiler.

Table 69: List of mitigation and sequestration actions available in the Carbon Calculator

| Code | Actions | A – Agronomics | B – Livestock | C – Energy (direct energy) | D – Carbon storage (soils and hedges) |
|---|---|---|---|---|---|
| A1 | Adjust N fertiliser balance | X | | | |
| A2 | Soils covered all the year | X | | | X |
| A3 | Introduction of legumes in the rotation | X | | | |
| A4 | Introduction of legumes in grasslands | X | | | |
| A5 | No-tillage | X | | | X |
| A6 | Agroforestry | | | | X |
| A8 | Avoid burning residues | X | | | |
| B1 | Reduce methane from enteric fermentation | | X | | |
| B2 | Change in slurry management system: cover/crust | | X | | |
| B4 | Biogas production | | X | X | |
| C1 | Reduction of electricity consumption of the milking system | | X | X | |
| C5 | Reduce engines fuel consumption (test and eco driving) | | | X | |
| C6 | Solar panel on suitable buildings | | | X | |
| C7 | Heat water with solar panel | | | X | |
| C8 | Wood boiler | | | X | |
| D1 | Implementation of hedges and Other landscape elements | | | | X |

Each action is described with a fact sheet and by using a codification of mitigation or sequestration actions by themes and by GHG concerned:

<u>Themes:</u>
A: Agronomics
B: Livestock
C: Energy (direct energy)
D: Carbon storage (soils, hedges)

<u>GHG concerned:</u>
$CO_2$ (direct or indirect)
$CH_4$
$N_2O$
C (storage variation more/less)

| | |
|---|---|
| Action Number | A-1 |
| Action | **Adjust N fertiliser balance (in case of a nitrogen surplus above 50 kg N/ha)** |
| Theme | Agronomical practices |
| Type | **A (basic)** |
| GHG concerned | **$N_2O$, $CO_2$** |
| Type of farm | Crops, grassland<br>Other crops |
| Conditions to propose the action | - *At least 1 crop has to be registered in the data entry*<br>- *Fertiliser purchase >0*<br>- *1: calculate N fertiliser balance at farm scale (inputs – outputs)*<br>- *2: If the surplus is high: for example: >* ***50 kg N/ha*** *(target value)* |
| Calculation in the tool (detailed method) | 3: Calculate N balance – target (kgN/ha)<br>4: Calculate N mineral / chemical fertiliser in excess<br>5. Select the most important N mineral fertiliser on the farm and the N purchase reduction<br>5: Calculate GHG mitigation potential:<br>• N production avoided<br>• $N_2O$ emissions from soils avoided by direct emission and indirect emissions by N-$NH_3$ and N leaching / run-off |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level in t$CO_2$e / year and in %* |
| Indirect effects | - Split application will increase labour and machinery use[1] |
| Public Costs | - *Cost = 0 €*<br>- *(increase labour demand if split applications)* |
| Benefit for the farmer | - *Reduction of expenses linked to fertiliser excess cost (not yet implemented)*<br>- *→ Saved amount of fertiliser * mean price of fertiliser in €* |
| Other environmental aspects | - *Soil:*<br>- *Biodiversity: Reduction of N pressure / ha*<br>- *Water Quality: Reduction of N leaching*[1]<br>- *Water quantity: /*<br>- *Air Quality: Reduction of $NH_3$ emissions* |
| How to | Be more efficient in fertiliser application by:<br>- *Adapting quantities for each crop*<br>- *Applying at the right time of crop growth (e.g. split applications)*<br>- *Applying under the most optimal weather and soil conditions*<br>- *Applying precisely (precision farming)* |
| References | Standard value: - 206 kg $CO_2$e/ha/yr ($N_2O$ form) — Lesschen J.P. et al, PICCMAT deliverable 7: European quantification results, 2008 |

Fertiliser surplus may be due to various reasons. First, there is a trend in some European countries to increase fertiliser applications (more than crops need) as a preventive method to reach potential yields. Moreover, non-optimised application techniques may lead to higher rates of nitrogen spread on fields.

Balanced fertilisation, i.e. fertiliser application tuned to crop demand, allow reducing $N_2O$ emissions as well as fertiliser rates.

In order to optimise the use of fertilisers, application rates have to be calculated based on the requirements of each crop. A farmer may need the help of a technical advisor.

Also, fertiliser application can be optimized through timing (avoid wet conditions, target growing phases that require nitrogen) and split applications.

The $N_2O$ mitigation potential for EU-27 is about 4.2 Mton $CO_2$-eq/year[2] (Lesschen et al., 2008).

The action implemented in the Carbon Calculator also includes $CO_2$ mitigation linked to the reduction of fertiliser purchases (e.g. emissions from processing and transport).
Precision farming is not taken into account.

**References:**

[1] Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 3 Practices description and analysis report, page 14-16/69, 2007

[2] Lesschen J.P.,Schils R, Kuikman P, Smth P, Oudendag D, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 7 European quantification results, page 26/42, 2008

| | |
|---|---|
| Action Number | A-2 |
| Action | **Soils covered all the year (cover crops or catch crops)** |
| Theme | Agronomical practices<br>Carbon storage |
| Type | **Type A (basic)** |
| GHG concerned | **$N_2O$, $CO_2$, Soil carbon storage** |
| Type of farm | Cropland (temporary grasslands and vegetables included)<br>Permanent crops (vineyards, orchards, etc.) |
| Conditions to propose the action | - *At least 1 crop has to be registered in the data entry*<br>- *% of covered soil all the year < 100%*<br>Target value: **100% of covered soil for cropland** |
| Intermediary calculation in the tool (detailed method) | 1) Area with "bare land in winter" is calculated (in ha and % of UAA)<br>2) Calculation of $N_2O$ emissions of the farm if 100% of covered soil, then $N_2O$ emissions saved between current farm situation and 100% of soil covered. $N_2O$ emissions are then converted into $CO_2$e.<br>3) Calculate N mineral fertiliser reduction<br>• Calculation of the amount of saved nitrogen from leaching and run-off.<br>• This amount is then converted into indirect $CO_2$ emissions avoided by fertiliser that is not processed (based on the farm ratio of t$CO_2$e/t mineral nitrogen)<br>4) Calculate $CO_2$ emissions from additional fuel for engines<br>• At least, 2 field operations (sowing and destruction or harvest), which represent an additional fuel consumption of 9 litres/ha<br>• Theoretical fuel consumption is calculated by multiplying 9 litres/ha by the additional surface needed to reach 100% of covered soil. This amount of fuel is then converted into additional $CO_2$ emissions. |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level (more $N_2O$ and more carbon storage)* |
| Indirect effects | |
| Public Costs | - *Costs are low*[4]<br>- *Subsidy?* |
| Benefit / charges for the farmer | - *Increased costs for seed and harvest/destruction (fuel and inputs)*<br>- *Specific equipment for sowing: investment subsidy?*<br>- *Money is saved through decreased nitrogen fertiliser requirements*[4] |
| Other environmental aspects | - *Soil: less erosion and more fertility (organic matter)*<br>- *Biodiversity: soil biodiversity is higher*<br>- *Water Quality: leaching and run-off of nutrients and soils*<br>- *Water quantity: better water retention*<br>- *Air Quality: no* |
| How to | - *Select the right species /plants (to be adapted according to the soil and local climate and the crop rotation)*<br>- *Harvest (if livestock) or mechanical destruction of the covered crops.* |

| | |
|---|---|
| | Reference values:<br>• *-306 kg $CO_2$e/ha/year ($CO_2$)*[1]<br>*+120 kg$CO_2$e/ha/year ($N_2O$)*[1]<br>• *Increases in SOC of around 7-11% over 20 years*[2]<br>• *C Storage: +0.15 tC/ha/yr*[3]<br><br>Intercropping may reduce the nitrogen amount by more than 40% (Brentrup 2000). |

[1] Lesschen J.P.,Schils R, Kuikman P, Smth P, Oudendag D, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 7 European quantification results, page 21/42 table 16, 2008

[2] Ogle S, Breidt, F, Paustian, K (2005) Agricultural management impacts on soil organic carbon storage under moist and dry climatic conditions of temperate and tropical regions. Biogeochemistry 72(1), 87-121 *find in* Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 3 Practices description and analysis report, page 8/69, 2007

[3] Arrouays D., Balesdent J., Germon J.C., Jayet P.A., Soussana J.F., Stengel P., 2002. Increasing carbon stocks in French agricultural soils? B. Seguin et al. (Eds) Moderating the impact of agriculture on climate. INRA *find in* Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 3 Practices description and analysis report, page 8/69, 2007

[4] Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 3 Practices description and analysis report, page 8/69, 2007

| | |
|---|---|
| Action Number | A-3 |
| Action | **Introduction of legumes in the annual crop rotation (cropland)** |
| Theme | Agronomical practices |
| Type | **Type A (basic)** |
| GHG concerned | **$N_2O$, $CO_2$, Soil carbon storage** |
| Type of farm | With annual cropland (cereals, vegetables, industrial crops, annual forages)<br>Temporary grasslands not included here (see next action) |
| Conditions to propose the action | - *At least one crop has to be registered in the data entry*<br>- *1) Calculate % of legumes already on farm*<br>- *2) Calculate the action if % of legumes* ***< target value***<br>Target value: 20% of legumes on cropland |
| Intermediary calculation in the tool (detailed method) | **<u>Carbon Calculator</u>**<br>- *3) Calculate the potential of implementation of the action on the farm: delta surface*<br>- *5) Select which crop will be substituted (proposal = % of the three main crops) and calculate a new quantity of vegetal production with a yield of legumes set at 3.0 tDM/ha (modifiable by administrator)*<br><br>• ***Reduction of $N_2O$ and $CO_2$ emissions from replacing fertilised crops by legumes***<br>- *6) Calculate new quantity of fertiliser application on cropland*<br>- *7) Calculate by difference the reduction of $N_2O$ and $CO_2$ emissions linked to soil emissions as well as fabrication and transport of fertilisers*<br><br>• ***Reduction of $N_2O$ and $CO_2$ emissions on following crop due to legumes***<br>- *8) Legumes permit the reduction of 40 kg N/ha[1] on following crops. Calculation by difference of the reduction of $N_2O$ and $CO_2$ emissions linked to soil emissions as well as processing and transportation of fertilisers* |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level in $tCO_2e$ / year and in %* |
| Indirect effects | - *Increase or decrease crop production, depending on the productivity of the cropland before including legumes.* |
| Public Costs | - *Low cost practice* |
| Benefit for the farmer | - *Decrease fertiliser charges: mineral N fertiliser avoided.* |
| Other environmental aspects | • *Soil: Increase in SOC content*<br>- *Biodiversity: increase crop diversity*<br>- *Water Quality: less leaching and run-off of nutrients due to the decrease of fertiliser use*<br>- *Water quantity:*<br>- *Air Quality:* |

| | |
|---|---|
| How to | - *Introduce legumes on 20% of the cropland area*<br>- *Manage N fertiliser taking into account the nitrogen-fixing property of legumes*<br>- *Reduce fertiliser purchases* |
| Bibliography | Reference values:<br>-307 kg $CO_2$e/ha/year ($CO_2$)[2]<br>-1.6 kg$CO_2$e/ha/year ($N_2O$)[2] |

[1] COMIFER Groupe azote, Calcul de la fertilisation azotée, Guide méthodologique pour l'établissement des prescriptions locales, Cultures annuelles et prairie, mars 2012

[2] Lesschen J.P.,Schils R, Kuikman P, Smth P, Oudendag D, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 7 European quantification results, page 21/42 table 16, 2008

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|---|---|
| Action Number | A-4 |
| Action | **Introduction of legumes in grassland (chemically fertilised)** |
| Theme | Agronomical practices |
| Type | **Type A (basic)** |
| GHG concerned | **$N_2O$, $CO_2$** |
| Type of farm | With grassland: temporary and permanent |
| Conditions to propose the action | - *At least 1 ha of grassland is captured*<br>- *At least 1 ha of grassland is chemically fertilised* |
| Intermediary calculation in the tool (detailed method) | - *1) In grassland set an objective of surface with legumes inside.*<br>Target value: 20% of legume in grasslands<br><br>- *2) Determine % of legumes in existing grassland on the farm*<br>- *3) Calculate the potential of implementation of the legumes on the farm*<br><br>• ***Reduction of $N_2O$ and $CO_2$ emissions from reducing fertilisation on mixed grassland***<br><br>- *6) The quantity of biomass produced is unchanged*<br>- *7) We consider that mineral fertilisation on grassland should be limited to the target value: 60 kg N/ha*<br>- *8) Implement the reduction of mineral fertilisation on potential surfaces*<br>9) Reduction of $N_2O$ and $CO_2$ emissions on field and from transport and processing of inputs is calculated |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level in $tCO_2e$ / year and in %* |
| Indirect effects | - |
| Public Costs | - *Low cost practice* |
| Benefit for the farmer | - *Decrease fertiliser charges* |
| Other environmental aspects | - *Soil:*<br>- *Biodiversity: increase diversity*<br>- *Water Quality: less leaching and run-off of nutrients due to the decrease of fertiliser use*<br>- *Water quantity:*<br>- *Air Quality:* |
| How to | - *Introduce legumes on (target value)% of the grassland area*<br>- *Manage N fertiliser taking into account the nitrogen-fixing property of legumes* |

| | | |
|---|---|---|
| References | - *Cavailles E., 2009, La reliance des légumineuses dans le cadre d'un plan proteine : quels benefices environnementaux ? Commissariat general au developpement durable CGDD,44 p* | |

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|---|---|---|
| Action Number | A-5 | |
| Action | **No tillage** | |
| Theme | Agronomical practices | |
| Type | **A (basic)** | |
| GHG concerned | **$N_2O$, $CO_2$, C storage** | |
| Type of farm | With cropland and grassland | |
| Conditions to propose the action | - *Climatic zone: all*<br>- *Type of soil: all*<br>- *At least one crop is captured*<br>- *Ploughed surface > 0 ha* | |
| Calculation in the tool (detailed method) | - *1) Calculate the % of ploughed soil on farm*<br>- *2) With the objective =100% (target value) of no tillage, calculate the potential of implementation on the farm → surfaces to run the action*<br><br>• ***C storage***<br>- *3) Change of $F_{MG}$ factor in the calculation of soil carbon (No tillage for all crops and grasslands)*<br>• ***Modification of $N_2O$ soil emissions***<br>- *4) Additional $N_2O$ emissions: +1 kg N-$N_2O$ / ha (default value)*<br>• ***Reduction of $CO_2$ emissions from fuel consumption***<br>- *5) Calculate actual fuel consumption avoided per ha (default value: 40 litres/ha with no tillage) compare with actual fuel consumption*<br>6) Calculate $CO_2$ emissions avoided linked to saved quantities of fuel | |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level in t$CO_2$e / year and in %* | |
| Indirect effects | - *Increase of herbicides costs (often the case)*<br>- *Smaller yields in some cases* | |
| Public Costs | - *Cost of new direct drill machinery (indicative value: 30 to 50,000 € HT)* | |
| Benefit for the farmer | - *Reduce fuel cost* | |
| Other environmental aspects | - *Soil: increase SOC, improve soil structure, no sealing*<br>- *Biodiversity: improve soil biodiversity*<br>- *Water Quality:*<br>- *Water quantity: /*<br>- *Air Quality: /* | |
| How to | - *Adapt the rotation, choose new inter-crops* | |
| Bibliography | Reference values:<br>- 958 kg $CO_2$e /ha/year ($CO_2$)[3]<br>+20 kg $CO_2$e/ha/year ($N_2O$)[3]<br><br>- | |

[1]Marland, G., McCarl, B.A. & Schneider, U.A. 2001 Soil carbon: policy and economics. Climatic Change 51,101-117 find in Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 3 Practices description and analysis report, page 9-10/69, 2007

[2] Hypothesis of data set with the help of the bibliographic review

Nicolardot B., Germon J.C., **Emissions de methane (CH4) et d'oxydes d'azote (N2O et NOx) par les sols cultivés, aspects généraux et effet du non travail du sol**. Etude et Gestion des sols, Volume 15,3,2008 – pages 171 à 182.

[3] Lesschen J.P.,Schils R, Kuikman P, Smth P, Oudendag D, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 7 European quantification results, page 26/42, 2008

| | | |
|---|---|---|
| Action Number | A-6 | |
| Action | **Agroforestry in cropland** | |
| Theme | Agronomical practices | |
| Type | **A (basic)** | |
| GHG concerned | **C storage** | |
| Type of farm | With cropland: annual crops and temporary grasslands | |
| Conditions to propose the action | **-** *At least one ha of crop is present on the farm* | |
| Calculation in the tool (detailed method) | ***<u>Carbon Calculator</u>***<br>*1) Objective =* ***5% of agroforestry of the cropped field area (target value)***<br>*2) Calculate the cropped field area in ha*<br>*3) Calculate the potential of implementation on the farm (= X ha)*<br>***C storage:***<br>*4) On X ha, calculate an increase of C storage of* ***3 tC/ha/yr (default value)*** | **<u>Bibliography</u>**<br><br>-196 kgCO2e/ha/y ($CO_2$) [3]<br>-6.7 kgCO2e/ha/y ($N_2O$) [3]<br><br>Increase of C storage of 3.9 tC/ha/y[1] or 1 to 4 tC/ha/yr[2] on 30 years |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* | |
| Indirect effects | **-** Reduce arable land | |
| Public Costs | - *Investment for planting the trees* | |
| Benefit for the farmer | - *Wood production (pellets with annual growth of the trees, and at the end of tree life: timber production)* | |
| Other environmental aspects | - *Soil: reduce soil erosion*<br>- *Biodiversity: food and cover for wildlife*<br>- *Water Quality: reduce N leakage*<br>- *Water quantity: improve water use efficiency*<br>- *Air Quality:*<br>- *Landscape: diversity* | |
| How to | Delimit the line to implement trees<br>Choose species | |
| Other impacts on productions: | *Not taken into account: revised crop production, wood production*<br>*Density of plantation =* ***50 trees/ha***<br>*Area dedicated to wood production =**12%** of the area. Thus, a decrease of the crop production is observed (yield x 12% of the surface) compared to a situation without agroforestry on a plot.*<br>*Calculate the revised crop production (impact of agroforestry on crop production is 12%)*<br>*Calculate a new wood production:* ***2.18 tDM/ha of X/yr*** *or* ***4 $m^3$ of wood/ha of X/yr*** | |

[1] Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 3 Practices description and analysis report, page 22-23/69, 2007

[2] Hamon X, Dupraz C, Liagre F, **L'agroforesterie, outil de séquestration du carbone en agriculture**, 2009

[3] Lesschen J.P.,Schils R, Kuikman P, Smth P, Oudendag D, **Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT),** Deliverable 7 European quantification results, page 26/42, 2008

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|---|---|
| Action Number | A-8 |
| Action | **Avoid burning residues** |
| Theme | Agronomical practices |
| Type | **A (basic)** |
| GHG concerned | **$N_2O$ and $CH_4$** |
| Type of farm | All farms with croplands or grasslands |
| Conditions to propose the action | - *GHG emissions from the burning of crop residues appear in the assessment* |
| Calculation in the tool (detailed method) | ***<u>Carbon Calculator</u>***<br>*1) Objective =* ***0% of crop residues burnt***<br>*2) Calculate the current GHG emissions from the burning of crop residues*<br>*3) This emission is considered as a potential for mitigation if these crop residues are not burnt* |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* |
| Indirect effects | / |
| Public Costs | / |
| Benefit for the farmer | - *Preserve its soil fertility (organic matter content)* |
| Other environmental aspects | - *Soil: preserve soil organic matter content*<br>- *Biodiversity: improved (side effects from fire could be the destruction of animals and plants)*<br>- *Water Quality: /*<br>- *Water quantity: /*<br>- *Air Quality: preserve air quality*<br>- *Landscape: /* |
| How to | *1 The burning of crop residues is quite limited by law, but exemptions sometimes exist. The burning of crop residues can help the farmer fight against pest or improve the sowing (improve the contact between the seed and the soil) in case of huge quantities of crop residues.*<br>*2 Alternatives could include exporting these residues from the plots for other uses (for example, as a fodder for animals, as biomass to produce energy…).* |
| Other impacts on productions: | / |

| | |
|---|---|
| Action Number | B-1 |
| Action | **Reduce $CH_4$ from enteric fermentation** |
| Theme | Livestock management |
| Type | **B (Complex)** |
| GHG concerned | **$CH_4$** |
| Type of farm | Livestock farms with ruminants (cattle, sheep, goats) |
| Conditions to propose the action | - One ruminant is input in the tool |
| Qualitative description of the aspects of the action | - *Cattle breeding for minimising methane production:*<br>*Calculate the enteric fermentation based on a target value for the digestibility of the diet: 80% of DE for all the ruminants*<br>- *New calculation of the methane enteric fermentation with that value*<br>- *Calculate gain between before / after* |
| Potential of reduction of GHG emissions | *- Overall technical potential between -5% and -10% GHG from enteric fermentation*[1] |
| Indirect effects | - *Effect on milk production*<br>- *Indirect emissions from maize cultivation* |
| Public Costs | - |
| Benefit for the farmer | - *Better digestibility of the forages will allow reducing the quantity or increasing production* |
| Other environmental aspects | - *Soil:*<br>- *Biodiversity: /*<br>- *Water Quality: /*<br>- *Water quantity: /*<br>- *Air Quality: /* |
| How to | - *Analysis of the quality of forages, especially for grass (hay, old pastures etc.)* |
| Literature: | Actions on animal diet:<br>- *Optimising diets: diet components can be changed significantly (crude fibre, N-free extract, crude protein and other extract)*<br>- *Actions focusing on alteration of bacterial flora, including removal of ruminant protozoa, reduction of bacterial flora*<br>- *Additives in feed (their use is currently limited by negative effects on milk production)*<br>- *Increase maize share in diet (up to a maximum of 75% of needed energy intake from grass)* |

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| | Actions on herd management:<br>- *Cattle breeding for minimizing methane production*<br>- *An increase of lactations per cow has the potential to reduce methane emissions by -10%, because heifers emit greenhouse gases without producing milk* |

[1] Leip A., Weiss F., Wassenaar T., Perez I., Fellmann T., Loudjani P. ,Tubiello F., Grandgirard D. ,Monni S. ,Biala K., **Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS)**, European Commission, Joint Research Centre, 2010. P194/323

<table>
<tr><td>Action Number</td><td colspan="2">B-2</td></tr>
<tr><td>Action</td><td colspan="2">Change in slurry management system: cover/crust</td></tr>
<tr><td>Theme</td><td colspan="2">Manure management</td></tr>
<tr><td>GHG concerned</td><td colspan="2">$CH_4$, $N_2O$</td></tr>
<tr><td>Type of farm</td><td colspan="2">Livestock farms</td></tr>
<tr><td>Conditions to propose the action</td><td colspan="2">- Presence of livestock: YES<br>- Presence of slurry as a manure management: YES<br>- Storage of the slurry on farm: YES<br>- Is the slurry mixed: YES</td></tr>
<tr><td>Calculation in the tool (detailed method)</td><td><u>C Calculator</u><br>- Identify type of slurry (liquid manure) on farm with and without natural crust cover and N losses due to $NH_3$ emissions.<br>- Simulation of covering or making natural crust on slurry by changing from “without natural crust cover” to “with natural crust cover”[2]:<br>Calculate N-$NH_3$ emissions avoided: cut by 50% of $NH_3$ emissions from slurry without natural crust cover (see table 14).<br>This amount of N permits to reduce mineral N purchased, and so manufacturing and transport of fertiliser.<br>No change in the $N_2O$ emissions from soils.<br>→ New $N_2O$ emissions</td><td><u>Bibliography</u><br><br>Between -20 to -80% of $CH_4$[1]<br>May increase $N_2O$[1] but values are -50% of $NH_3$ losses<br><br>Default value: cut by 50% of N-NH3 losses during the storage.</td></tr>
<tr><td>Potential of reduction of GHG emissions</td><td colspan="2">- GHG mitigation at farm level</td></tr>
<tr><td>Indirect effects</td><td colspan="2">- Reduced $NH_3$ emissions by up to 80% (default value: 50%)</td></tr>
<tr><td>Public Costs</td><td colspan="2">- Low cost practices</td></tr>
<tr><td>Benefit for the farmer</td><td colspan="2">-</td></tr>
<tr><td>Other environmental aspects</td><td colspan="2">- Soil:<br>- Biodiversity<br>- Water Quality:<br>- Water quantity:<br>- Air Quality: improved through a decrease of $NH_3$ emissions</td></tr>
</table>

| | |
|---|---|
| How to | - *Natural crust or artificial cover → wood cover / plastic sheet* |

[1] Leip A., Weiss F., Wassenaar T., Perez I., Fellmann T., Loudjani P., Tubiello F., Grandgirard D. ,Monni S. ,Biala K., **Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS)**, European Commission, Joint Research Centre, 2010. P194/323

[2] IPCC

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|---|---|
| Action Number | B-4 |
| Action | **Biogas production** |
| Theme | Manure management and energy production |
| GHG concerned | **$CH_4$, $N_2O$, $N_2$, $NH_3$** |
| Type of farm | Livestock farms |
| Conditions to propose the action | - *Presence of livestock: YES*<br>- *Presence of manure storage (solid or liquid) on the farm: YES* |
| Calculation in the tool (detailed method) | ***<u>Carbon Calculator</u>***<br>*1) Calculation of $NH_3$ emissions avoided from manure storage by the implementation of a biogas plant*<br>Calculation of the amount of N-$NH_3$ from manure (solid and liquid) storage.<br>This amount is then converted to an amount of mineral nitrogen fertiliser saved.<br>Conversion of this amount of mineral nitrogen fertilisers into saved GHG emissions due to the manufacturing of these fertilisers (current ratio of the farm from t$CO_2$e/tonne of mineral fertiliser purchased).<br>*2) Calculation of $N_2O$ emissions avoided and the amounts of N mineral fertilisers savings*<br>Calculation of the amount of N-$N_2$ from manure (solid and liquid) storage.<br>Conversion of this amount of mineral nitrogen fertilisers into saved GHG emissions due to the manufacturing of these fertilisers (current ratio of the farm from t$CO_2$e/tonne of mineral fertiliser purchased).<br>*3) Calculation of $N_2O$ emissions avoided by the implementation of a biogas plant*<br>Calculation of the current $N_2O$ emissions from the manure storage (liquid and solid).<br>Conversion into GHG emissions avoided in t$CO_2$e.<br>*4) Calculation of $CH_4$ emissions avoided by the implementation of a biogas plant*<br>Calculation of $CH_4$ emissions from manure storage (liquid and solid).<br>Conversion into GHG emissions avoided in t$CO_2$e. |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* |
| Indirect effects | - *Improvements of crop fertilisation (nitrogen under a mineral form)*<br>- *Energy produced (electricity and heat) can be used on the farm (replacement of fossil energy) or sold* |
| Public Costs | - *Public money is often required in addition to income from the sale of energy (electricity and heat). The total investment is very high.* |
| Benefit for the farmer | - *Reduction of mineral nitrogen fertiliser purchases* |

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| Other environmental aspects | - *Soil: in case of energetic crops to feed the biogas plant, a risk of decrease of organic matter exist if humus exports are higher than humus inputs*<br>- *Biodiversity: /*<br>- *Water Quality: improved as the digestate produced from the biogas processing contains nitrogen only in mineral form. The nitrogen is more easily available to crops than in untreated manure (solid or liquid) in which nitrogen is mainly in organic form. Thus, the use of digestate can help to reduce the nitrogen surplus if the quantities applied correspond to the nitrogen needs of the plants.*<br>- *Water quantity: /*<br>- *Air Quality: improved through a decrease of* $NH_3$ *emissions* |
| How to | - |

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|---|---|---|
| Action Number | C1 | |
| Action | **Reduction of electricity consumption of the milking systems** | |
| Theme | Direct energy | |
| GHG concerned | **$CO_2$** | |
| Type of farm | Farms with milk production | |
| Conditions to propose the action | One milk product is chosen (dairy, sheep or goat)<br>Electricity for farm and attribution to milk product are properly evaluated | |
| Intermediary calculation in the tool (detailed method) | 1) Identify and select milk products and electricity consumption on farm for these products<br>2) Default values for milking system and energy saving:<br>- Part of electricity for milking system: 75% (default value) of dairy electricity<br>- Target of avoided electricity consumption: 10% (default value)<br><br>3) Calculate the amount of electricity (kWh) and the $CO_2$ emissions avoided | |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level (more $N_2O$ and more carbon storage)* | |
| Indirect effects | | |
| Public Costs | - *Cost= ?*<br>- *Subsidy?*<br>- | |
| Benefit for the farmer | - *Saving energy and charges for electricity*<br>- *Investment in technology* | |
| Other environmental aspects | - *Soil:*<br>- *Biodiversity:*<br>- *Water Quality: beneficial effects*<br>- *Water quantity:  beneficial effects*<br>- *Air Quality: reduced emissions due to electricity production* | |
| How to | - | |
| References | | - |

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|---|---|---|
| Action Number | C5 | |
| Action | **Reduce engines fuel consumption (test and eco driving)** | |
| Theme | Energy (direct) | |
| GHG concern | **$CO_2$** | |
| Type of farm | Farms with fuel for tractors | |
| Conditions to propose the action | - *At least fuels consumption for tractors is captured*<br>- *Fuels by third parties: not take into account* | |
| Intermediary calculation in the tool (detailed method) | Estimate energy savings: 10% (default value)<br>- *Emissions of $CO_2$ linked to the fuel consumption* | |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level (more $N_2O$ and more carbon storage)* | |
| Indirect effects | | |
| Public Costs | - *Information about test and training session* | |
| Benefit for the farmer | - *Reduced fuel charges* | |
| Others environmental aspects | - *Soil*<br>- *Biodiversity:*<br>- *Water Quality:*<br>- *Water quantity:*<br>- *Air Quality: air pollution reduced* | |
| How to | - | |
| References | | - |

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|---|---|
| Action Number | C6 |
| Action | **Solar panels on suitable buildings** |
| Theme | Energy (direct) |
| GHG concerned | **$CO_2$** |
| Type of farm | All the farms with farm buildings |
| Conditions to propose the action | - *The farm should have farm building facing south* |
| Intermediary calculation in the tool (detailed method) | Estimate GHG emissions saved<br>1) The user indicates a roof surface in $m^2$ facing south.<br>2) This surface is multiplied by a global yearly irradiation ($kWh/m^2$) (national average per country, EU-27)<br>3) The potential annual renewable electricity production is calculated and multiplied by the EF of electricity from the grid of the country to obtain the total GHG emissions avoided by the use of this renewable energy. |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* |
| Indirect effects | |
| Public Costs | - |
| Benefit for the farmer | - *Additional income to the sales of agricultural products or savings from the electricity expenditure if this renewable electricity is used on the farm.* |
| Others environmental aspects | - *Soil:/*<br>- *Biodiversity: /*<br>- *Water Quality: /*<br>- *Water quantity: /*<br>- *Air Quality: air pollution reduced* |
| How to | |
| References | |

[1]Šúri M., Huld T.A., Dunlop E.D. Ossenbrink H.A., 2007. **Potential of solar electricity generation in the European Union member states and candidate countries**. Solar Energy, 81, 1295–1305.

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|---|---|---|
| Action Number | C7 | |
| Action | **Heat water with solar panels** | |
| Theme | Energy (direct) | |
| GHG concerned | **$CO_2$** | |
| Type of farm | All farms that need hot water: dairy farms (milking parlour), processing that requires hot water, veal calves | |
| Conditions to propose the action | - *The farms should have daily needs of hot water* | |
| Intermediary calculation in the tool (detailed method) | Estimate GHG emissions saved:<br>1) Daily needs of hot water in litres, percentage of heat needs covered by solar energy (standard suggested value = 50%) and energy substituted<br>2) Calculation of the energy consumption (in kWh) to heat the water to 65°C<br>3) Calculation of the amount of fossil energy substituted for hot water production<br>4) Calculation of GHG emissions avoided | |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* | |
| Indirect effects | | |
| Public Costs | - | |
| Benefit for the farmer | - *Reduction in fossil fuel expenses* | |
| Other environmental aspects | - *Soil:/*<br>- *Biodiversity: /*<br>- *Water Quality: /*<br>- *Water quantity: /*<br>- *Air Quality: air pollution reduced (renewable energies)* | |
| How to | | |
| References | | |

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|---|---|
| Action Number | C8 |
| Action | **Wood boiler** |
| Theme | Energy (direct) |
| GHG concern | **$CO_2$** |
| Type of farm | All farms with needs of heating (pigs, poultry, greenhouse…) |
| Conditions to propose the action | - *The farms should have heating needs* |
| Intermediary calculation in the tool (detailed method) | Estimate GHG emissions saved<br>1) Identification of existing fossil energies (fuel, diesel, petrol, gasoline, regular, propane gas, butane gas, natural gas, coal) used for heating.<br>2) Calculation of GHG emissions avoided |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* |
| Indirect effects | |
| Public Costs | - |
| Benefit for the farmer | - *Savings from the expenditure of the fossil energies replacement by wood* |
| Other environmental aspects | - *Soil:/*<br>- *Biodiversity: /*<br>- *Water Quality: /*<br>- *Water quantity: /*<br>- *Air Quality: air pollution reduced (renewable energies)* |
| How to | |
| References | |

| | | |
|---|---|---|
| Action Number | D1 | |
| Action | **Implementation of hedges and other landscape elements** | |
| Theme | Carbon storage | |
| GHG concerned | **C** | |
| Type of farm | All farm types | |
| Conditions to propose the action | - *The action is proposed if the farm has less than 5% of its total UAA in natural elements* | |
| Intermediary calculation in the tool (detailed method) | Estimate GHG emissions saved<br>1) Calculation of the number of ha needed to reach 5% of the UAA of the farm in natural elements<br>2) This surface is multiplied by the annual increase of C stock for an average quality of the station | |
| Potential of reduction of GHG emissions | - *GHG mitigation at farm level* | |
| Indirect effects | | |
| Public Costs | - | |
| Benefit for the farmer | | |
| Other environmental aspects | - *Soil:/*<br>- *Biodiversity: increase the natural infrastructures*<br>- *Water Quality: /*<br>- *Water quantity: /*<br>- *Air Quality:* | |
| How to | | |
| References | | |

# 3 References

**For the entire document**

ACCT, Agriclimate change combating climate change through farming. http://www.agriclimatechange.eu/

ADEME, 2012. Guide de la methode Dia'terre®. Synthèse.

ADEME, 2012. Guide des valeurs Dia'terre®. Version 1.13. 177p.

Audsley E et al., 2003. Harmonisation of environmental life cycle assessment for agriculture.

Economic and social council. 2012.

Revision of the annexes to the 1999 Gotenburg Protocol to abate acidification, eutrophication and ground-level. ECE/EB.AIR/2012/11

GESTIM. 2010. Guide méthodologique pour l'estimation des impacts des activités agricoles sur l'effet de serre. Version 1.2. Institut de l'élevage, Paris.

IPCC, 1997. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual, Vol. 3, Paris.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.4, Japan.

Leip A., Weiss F., Wassenaar T., Perez I., Fellmann T., Loudjani P. ,Tubiello F., Grandgirard D. ,Monni S. ,Biala K., 2010. Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS), European Commission, Joint Research Centre.

Pelletier N. et al., 2012, Organisation environmental Footprint (OEF) guide, European Commission, Joint Research Center (JRC / IES).

**CHAP 1. THE CARBON CALCULATOR PROJECT**

Rusell S, 2011. Corporate greenhouse gas inventrories for the agricultural sector: proposed accounting and reporting steps. WRI Working paper. World ressources institute, Washington, DC 29p.

**CHAP 2. QUANTIFICATION OF GHG EMISSIONS AND SEQUESTRATIONS AT FARM SCALE**

**Chap 2.1. Livestock and manure**

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.4, Japan. Chapter 10 "Livestock and manure management".

**Chap 2.2. Emissions from soils**

Bouwman AF, 1996. Direct emissions of nitrous oxide from agricultural soils. Nutr. Cycl. Agroecosyst., 46, 53-710.

Bouwman AF, Boumans LJM and Batjes NH, 2002. Emission of N2O and NO from fertilised fields : Summary of available measurement data. Glob. Biogeochem. Cycles, 16 (4), art. No. 1058.

Bouwman AF, Boumans LJM and Batjes NH, 2002. Modeling global annual N2O and NO emissions from fertilised fields. Glob. Biogeochem. Cycles, 16 (4), art. No. 1080.

Brentrup F et al., 2000. Methods to estimate on-field nitrogen emissions from crop production as an input to LCA studies in the agricultural sector. International Journal of Life Cycle Assessment 5 (6) 349-357.

CORPEN, 2006. Les emissions d'ammoniac et de gaz azotés à effet de serre en agriculture.

EMEP/EAA/ CORINAIR Emission Inventory Guidebook-3rd edition October 2002

EMEP/EAA air pollutant emission inventory guidebook, 2009. Technical guidance to prepare national emission inventories

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.4, Japan. Chapter 11 "$N_2O$ emissions from managed soils and $CO_2$ emissions from liming and urea".

Schröder JJ, 1996. Long term reduction of nitrate leaching by cover crops : duration, December 1994-December 1997 : first progress report of EU concerted action (AIR3) 2108, reporting period, December 1994-December 1995.

**Chap 2.3. Emissions from agricultural inputs production and transport**

Audsley E et al., 2009. Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University

CITEPA, 2012. Organisation et methods des inventaires nationaux des emissions atmosphériques en France/ National inventories of air emissions in France: organisation and methodology. 9ème edition. Rapport national d'inventaire.

Ecoinvent report No15. V2, 2007. Life cycle inventories of agricultural production systems.

ELCD, European references life cycle database of the LCI (life cycle inventory).

Energy Information Administration U.S., based on data from the following sources: International Energy Agency (IEA), Electricity Information Database 2007 and CO2 Emissions from Fuel Combustion Database 2006, http://www.iea.org, October 2007

FAO, Ex-ANTE Carbon-balance Tool (Ex-ACT) – Guide technique pour la version 3. EasyPol

GNIS, 2007. Statistique annuelle Semences et plants, 2005-2006. Céréales et protéagineux/Maïs et Sorgho/Pommes de terre.

GNIS, 2005-2006, données disponibles sur : www.gnis.fr

IFA, Climate change, Sources of fertiliser related GHG emissions. http://www.fertilizer.org/ifa/HomePage/SUSTAINABILITY/Climate-change/Facts-figures.html

http://www.fertilizer.org/ifa/ifadata/search

IFA, 2009, Fertilizers, climate change and enhancing agricultural productivity sustainably, IFA, Paris, 30p.

IFS proceedings no 639, Brentrup F and Pallière C, 2008. GHG Emissions and Energy Efficiency in European Nitrogen Fertilizer Production.

Jenssen TK and Kongshaug G, 2003. Energy consumption and greenhouse gas emissions in fertiliser production. Proceedings No. 509. International Fertiliser Society. York. UK

Lal R 2004, Carbon emission from farm operations. Environmental International 30: 981-990.

SALCAo61, 2006. Regular update and enlargement of ecoinvent (2003) agricultural inventories including the impact assessment factors (not published). Agroscope ART Reckenholz, Zuerich.

Wood S and Cowie A, 2004. A review of Greenhouse gas Emission Factors for Fertiliser Production. For IEA Bioenergy Task 38.

**Chap 2.4. On-farm energy use**

ELCD, European references life cycle database of the LCI (life cycle inventory).

Leip A., Weiss F., Wassenaar T., Perez I., Fellmann T., Loudjani P. ,Tubiello F., Grandgirard D. ,Monni S. ,Biala K., 2010. Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS), European Commission, Joint Research Centre.

**Chap 2.5. Renewable energies**

Nielsen J.E., March 2011. Simple method for Converting Installed Solar Collector Area to Annual Collector Ouput, ESTIF (European Solar thermal Industry Federation).

Šúri M., Huld T.A., Dunlop E.D. Ossenbrink H.A., 2007. Potential of solar electricity generation in the European Union member states and candidate countries. Solar Energy, 81, 1295–1305.

**Chap 2.6. Refrigerant emissions**

ADEME/ARMINES Agreeement 0874C0147 – Extracts from the Final Report – April 2010. Global inventories of the worldwide fleets of refrigerating and air-conditioning equipment in order to determine refrigerant emissions. The 1990 to 2006 updating. Mise à jour des banques, marches et emissions de fluids frigorigènes dans la base de données RIEP au niveau mondial.

ADEME/ARMINES, Année 2010. Inventaire des emissions de fluides frigorigènes et de leurs emissions.

**Chap 2.7. Carbon storage**

Arrouays D., Balesdent J., Germon J.C., Jayet P.A., Soussana J.F., Stengel P., 2002. Increasing carbon stocks in French agricultural soils? INRA.

IFN (Agreste - Chiffres et données n°137 de nov. 2001, statistiques forestières en 2000)

INRA, 2002. Expertise collective.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.4, Japan. Chapter 2 "generic methodologies applicable to multiple land-use categories"

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.4, Japan. Chapter 5 "Cropland".

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.4, Japan. Chapter 6 "Grassland".

JO, 2010. Décision de la commission du 10 juin 2010 relative aux lignes directrices pour le calcul des stocks de carbone dans les sols aux fins de l'annexe V de la directive 2009/28/CE

**Chap 2.8. End of Life**

Pelletier N. et al., 2012, Organisation environmental Footprint (OEF) guide, European Commission, Joint Research Center (JRC / IES).

**Chap 2.10. Mitigation and sequestration actions**

Arrouays D., Balesdent J., Germon J.C., Jayet P.A., Soussana J.F., Stengel P., 2002. Increasing carbon stocks in French agricultural soils? B. Seguin et al. (Eds) Moderating the impact of agriculture on climate. INRA *find in* Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT), Deliverable 3 Practices description and analysis report, page 8/69, 2007

COMIFER Groupe azote, Calcul de la fertilisation azotée, Guide méthodologique pour l'établissement des prescriptions locales, Cultures annuelles et prairie, mars 2012

Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT), Deliverable 3 Practices description and analysis report, page 22-23/69, 2007

Hamon X, Dupraz C, Liagre F, L'agroforesterie, outil de séquestration du carbone en agriculture, 2009

Lal, R. and Bruce, J.P. 1999. The potential of world cropland soils to sequester C and mitigate the greenhouse effect. Environmental Science and Policy 2: 177-185 find in Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT), Deliverable 3 Practices description and analysis report, page 24/69, 2007

Lesschen J.P.,Schils R, Kuikman P, Smth P, Oudendag D, Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT), Deliverable 7 European quantification results, page 26/42, 2008

Marland, G., McCarl, B.A. & Schneider, U.A. 2001 Soil carbon: policy and economics. Climatic Change 51,101-117 find in Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT), Deliverable 3 Practices description and analysis report, page 9-10/69, 2007

Nicolardot B., Germon J.C., Emissions de methane (CH4) et d'oxydes d'azote (N2O et NOx) par les sols cultivés, aspects généraux et effet du non travail du sol. Etude et Gestion des sols, Volume 15,3,2008 – pages 171 à 182.

Ogle S, Breidt, F, Paustian, K (2005) Agricultural management impacts on soil organic carbon storage under moist and dry climatic conditions of temperate and tropical regions. Biogeochemistry 72(1), 87-121 *find in* Flynn H., Smith P, Bindi M, Trombi G, Oudendag D, Rousseva S, Policy Incentives for Climate Change Mitigation Agricultural Techniques (PICCMAT), Deliverable 3 Practices description and analysis report, page 8/69, 2007