Emissions Dataset for MIRAGRODEP

David Laborde. April 4th 2019.

**Abstract:**

*This technical note explains the building of the emissions database coefficients, compatible with FAOSTAT to be connected to MIRAGRODEP*

# Introduction

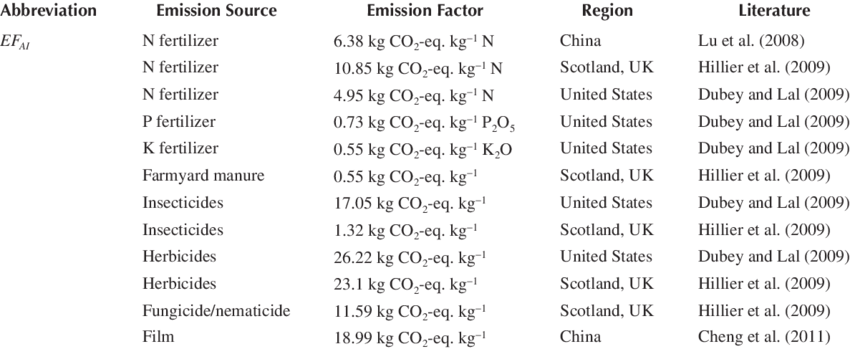
We consider in this note that readers are familiar with key assumptions used in the carbon footprint of agriculture (see for instance Cheng, 2017 or the Tier 1 procedures (IPCC 2006) used in construction of the FAOSTAT database).

Out goal is to produce a dataset of emissions, both for production and land use, based on FAOSTAT, and a few complementary data. An important task is to reverse engineer any aggregated numbers to identify individual coefficients that could be used both in Phase 1 and Phase 2 of the World Bank project to discriminate properly between the 4 drivers of emissions: scale (eg size of herd, cropland), location, composition and technological choice.

While FAOSTAT is a great source of information, and their approach is pretty robust, we will differ on a number of elements to:

* Increase the coverage of emissions (e.g. energy emissions are missing in FAOSTAT aggregated numbers and only synthetic fertilizers are included for chemicals while pesticides have very large emission factors too, see Table 1);
* Update technology of production and consistency between emissions assumption and the IO structure of the CGE (fertilizer coefficients used in the FAOSTAT emissions database are quite outdated);
* Classification of emissions (e.g. burning savannah should be treated as a land use emission in our framework).

Table 1 Emission factors for farm inputs



Source: Cheng, Kun. (2017)

# Emissions from production

The different steps for the dataset processing are listed in the following figure.

## Conceptual framework

Each emission category in FAOSTAT follows a bottom-up approach for computation. It is important to identify this process to understand:

* The data source
* The technological assumption made

Indeed, some of these elements could be endogenous or exogenous to the model, but we also need to make sure that the same data sources are used in the model and the emission computation process.

We decompose each collection in three categories of parameters:

1. The scale of production (area, quantity or head of cattle) in RED in following graphs
2. A set of technological coefficients (emissions per unit, shares), in BLUE in following graphs
3. A set of conversion coefficient (from N to NO2, to NO2 to CO2eq) etc. in GREEN in following graphs.

This allows us to fully reconstruct the database and change coefficients when we need.

Importantly , we map each source of emissions to a key driver, the “origin” of the scale effect (item *i* above).

Table 2 Emissions sources and drivers

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | LAND | ANIMALS | OUTPUT | ENERGY | FERTILIZER | CHEMICALS |
| BurningCR | Burning - Crop residues | x |  |  |  |  |  |
| BurningSA | Burning - Savanna | x |  |  |  |  |  |
| CropRes | Crop Residues |  |  | x |  |  |  |
| OrgSoil | Cultivation of Organic Soils | x |  |  |  |  |  |
| EntFerm | Enteric Fermentation |  | x |  |  |  |  |
| ManureSoils | Manure applied to Soils |  | x |  |  |  |  |
| ManurePast | Manure left on Pasture |  | x |  |  |  |  |
| ManureMgt | Manure Management |  | x |  |  |  |  |
| RiceCult | Rice Cultivation | x |  |  |  |  |  |
| SyntFert | Synthetic Fertilizers |  |  |  |  | x |  |
| Pesti | Pesticides |  |  |  |  |  | x |
| Energy | Energy (Fossil Fuels directly used) |  |  |  | x |  |  |

Also for all the coefficients in category (ii) and (iii) we want to identify any country/time variability.

### Rice emissions coefficients

FAO uses disaggregated activity data (harvested area (m2) by low land irrigated and rainfed and upland water regimes using IPCC percentages (IPCC, 1997, Vol 3, Ch 4, Table 4.11). However, the emission data doesn’t provide this disaggregation. Reverse engineering of the emission from rice cultivation thus relies on harvested area measured in m2.

FAO then uses seasonally integrated emission coefficient (g CH4/m2/year) for key rice producing countries. These coefficients are modified further by the application of a dimensionless scaling factor for water regime and a dimensionless correction factor for organic amendments.

How FAO is managing dry vs flood rice? Different coefficients by countries or different area?

### Manure management

Emission of CH4 and N2O from manure comes from multiples sources – during storage and treatment, in the application to cropland and when manure is left on pasture by grazing livestock. The stage storage and treatment is referred as manure management and the emission that subsequently arise from the application of the manure to soil are reported as emission from managed soils and these two stages are interlinked.

*Storage and treatment stage*

Total number of heads of livestock is the basis of computation of CH4 and N2O estimation. While CH4 is directly estimated from the number of heads by multiplying emission factor, N2O is computed from manure (N content). Following IPCC 2006 guidelines (Tier 1) manure is computed as number of head of livestock times annual average N excretion per head of livestock times fraction of total annual nitrogen excretion for each livestock that is managed in manure management system.

#Head of livestock

N excretion per head of livestock

Direct emission of N2O

Fraction of N excretion managed in MMS

Indirect emission of N2O

Volatilization coefficient to N

N to N2O coefficient

N2O to CO2 coefficient

N to N2O coefficient

N2O to CO2 coefficient

Leaching coefficient to N

Emission of N2O at this stage depends on the nitrogen and carbon content of manure and on the duration of storage and type of treatment. N2O comes from both direct and indirect sources – volatilization and leaching off.

*Stage of application of manure to cropland*

Significant amount of losses of manure nitrogen in management system, both direct and indirect, is assumed and this loss comes from volatilization, leaching and runoff. The amount remaining is then either applied to cropland or is used for fuel, feed and other purposes. The estimate of managed manure nitrogen available for application to managed soils, or available for use in feed, fuel, or construction purposes is based on the amount of manure net of losses. The amount of manure that is applied to cropland is then estimated by netting of the amount that go to feed, fuel and construction.

#Head of livestock

N excretion per head of livestock

Direct emission of N2O

Fraction of N excretion applied to cropland

Indirect emission of N2O

Volatilization coefficient to N

N to N2O coefficient

N2O to CO2 coefficient

N to N2O coefficient

N2O to CO2 coefficient

Leaching coefficient to N

*Manure that is left on pasture by grazing livestock*

Amount of manure that is left on pasture by grazing livestock is estimated as the number of head of livestock times average N excretion per head of livestock time fraction of total annual N excretion for each livestock that is deposited on pasture, range and paddock.

#Head of livestock

N excretion per head of livestock

Direct emission of N2O

Fraction of N excretion left on pasture

Indirect emission of N2O

Volatilization coefficient to N

N to N2O coefficient

N2O to CO2 coefficient

N to N2O coefficient

N2O to CO2 coefficient

Leaching coefficient to N

Check if [Coefficient % of manure applied to cropland] + [Coefficient % of manure applied to pasture] = 100%.

### Enteric Fermentation

Enteric fermentation, a digestive process, that occurs in livestock animals releases methane. The amount of methane released depends on the type of digestive tract, age and weight of animals and the quality and quantity of the feed consumed (IPCC, 2006). The graph below explains how CH4 and CO2 are estimated directly from number of head of livestock.

### Crop residues

Emission from crop residues comes from two sources – crop residues itself and the crop residue burned. The following graph explain how N2O and CO2 are estimated from crop residues.

Crop production

Direct emission

Residue coefficients

Share let on field + share below

Indirect emission

N2O to CO2 coefficient

N to N2O coefficient

N to N2O coefficient

N2O to CO2 coefficient

Leaching coefficient to N

N content of crop residues

Crop residue burned at field releases CH4 and the estimation process is explained in the following graph.

### Organic Soils

Emission associated with the drainage of organic soils under cropland and grazed grassland is explained in the below graph.

### Burning Savannah

Will be treated as land use. CO2 eq coefficients per ha.

## Data processing

NOTE: we use 3 letter iso code countries in all tables. Standard codes for crop and livestock from PRODSTAT will be used.

### Data collection

Datasets to be downloaded and gathered in a unique database for the 2012-2017 period

* <http://www.fao.org/faostat/en/#data/QC> : Crop Area and production
* <http://www.fao.org/faostat/en/#data/QA> : Live animal Stocks
* <http://www.fao.org/faostat/en/#data/RP> Pesticides and Insecticides (total use in Ag.)
* <http://www.fao.org/faostat/en/#data/EI> Emission Intensities
* Emissions – Agriculture :
  + <http://www.fao.org/faostat/en/#data/GT>
  + <http://www.fao.org/faostat/en/#data/GE>
  + <http://www.fao.org/faostat/en/#data/GM>
  + <http://www.fao.org/faostat/en/#data/GR>
  + <http://www.fao.org/faostat/en/#data/GY>
  + <http://www.fao.org/faostat/en/#data/GU>
  + <http://www.fao.org/faostat/en/#data/GP>
  + <http://www.fao.org/faostat/en/#data/GA>
  + <http://www.fao.org/faostat/en/#data/GV>
  + <http://www.fao.org/faostat/en/#data/GH>
  + <http://www.fao.org/faostat/en/#data/GB>
  + <http://www.fao.org/faostat/en/#data/GN>

In these collections we have a sub-number of elements to download, mainly emissions factors and total factors.

Additional data from IFA will be collected for fertilizer use by crop.

## Disaggregation strategy

[…]

Each source of emissions will be allocated to a given sector in the GTAP nomenclature.

Some will require just an “aggregation” procedure e.g. grouping animals by type of GTAP animal sectors.

Others will require an active disaggregation procedure (taking a non-allocated total and distributing accordingly to area or production).

Table 3 Disaggregation space and potential linkages

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [**GTAP Code**](https://www.gtap.agecon.purdue.edu/databases/v6/v6_sectors.asp) | **Label** | Burning - Crop residues | Burning - Savanna | Crop Residues | Cultivation of Organic Soils | Enteric Fermentation | Manure applied to Soils | Manure left on Pasture | Manure Management | Rice Cultivation | Synthetic Fertilizers |
| pdr | Paddy rice | x | x | x | x |  | x |  |  | x | x |
| wht | Wheat | x | x | x | x |  | x |  |  |  | x |
| gro | Cereal grains nec | x | x | x | x |  | x |  |  |  | x |
| v\_f | Vegetables. fruit. nuts | x | x | x | x |  | x |  |  |  | x |
| osd | Oil seeds | x | x | x | x |  | x |  |  |  | x |
| c\_b | Sugar cane. sugar beet | x | x | x | x |  | x |  |  |  | x |
| pfb | Plant-based fibers | x | x | x | x |  | x |  |  |  | x |
| ocr | Crops nec | x | x | x | x |  | x |  |  |  | x |
| ctl | Cattle.sheep.goats.horses |  |  |  |  | x |  | x | x |  | maybe |
| oap | Animal products nec |  |  |  |  |  |  |  | x |  |  |
| rmk | Raw milk |  |  |  |  | x |  | x | x |  | maybe |
| wol | Wool. silk-worm cocoons |  |  |  |  | x |  | x | x |  | maybe |

### Livestock

* Dairy vs non dairy cattle
* Wool vs meat sheep

### Manure Allocation

Manure -stored and treated, applied to soils and left on pasture - is allocated to cattle, milk, wool and other animal products following GTAP nomenclature. The allocation is mainly done for camels, sheep, cattle, buffaloes and goats. Manure from other animals such as swine, chicken, ducks and turkeys are directly mapped to other animal products. Value of production of meat, milk and wool data has been used to get ratio of cattle versus milk by animals (camels, goats, sheep and buffaloes). Manure from buffaloes, camels and goats were split into cattle and milk. Sheep is split into three categories – cattle, milk and wool. Asses, horses, mules, cattle-non-dairy are mapped to cattle. Cattle-dairy is mapped to milk.

[…]

### Fertilizer Allocation

[…]

### Energy Use and Allocation

### Pesticides used and Allocation

<https://www.researchgate.net/publication/276941041_Estimation_of_the_greenhouse_gas_emissions_from_agricultural_pesticide_manufacture_and_use>

*For pesticide emissions in LCA, the most simplified approaches assume that pesticides are entirely emitted in the soil compartment, as it is done in one of the most used LCA databases, i.e. Ecoinvent (Nemecek and Kägi 2007) or that 85% is release to soil, 10% run-off from the soil into the water, 5% to crops, and 10% to air (Margni et al., 2002; Audsley et al., 2003). This last approach has been used in a large number of agricultural LCA studies (see Figure 2). A different approach is considered by PestLCI, a model for estimating field emissions of pesticides based upon fate and exposure modelling principles as applied in relation to risk assessment of single chemical substances (Birkved and Hauschild, 2006). PestLCI and its latest version, PestLCI2.0, estimate emissions to three general environmental compartments: air, surface water and groundwater. PestLCI2.0 considers that after the primary distribution of pesticides over leaves and soil has taken place, then three secondary fate processes on leaves occur: volatilization, degradation and uptake, as explained in details by Dijkman et al. (2012). The use of PestLCI2.0 has recently increased for LCA of cereals, i.e. barley (Niero et al. 2015a,b, Dijkman et al. 2017), wheat and maize (Bacenetti et al. 2014, Fantin et al. 2017).*

<https://www.sciencedirect.com/science/article/pii/S0048969718345583>

<https://www.researchgate.net/publication/222409544_Life_cycle_impact_assessment_of_pesticides_on_human_health_and_ecosystems>

## Quality check procedure

### Stage 0

As stated above, for each individual emissions category listed in 2.1 we check the stability of technological coefficients used across countries and regions.

Also for a given country/year, some coefficients should be identical (e.g. manure production per head of livestock)

Table 4 Summary Table: emissions per unit

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Coefficients - CO2 eq (kg) - per unit of Index (2013-2015)** | | | | | |
| Code | Emissions | Index | *Average (weighted)* | *Simple Average* | *Standard Deviation* | *Median (unweighted)* | *Median (HIC)* | *Median (LMIC)* |
| BurningCR | Burning - Crop residues | *LAND (ha)* | 49.7 | 53.0 | 16.8 | 51.2 | 43.7 | 56.5 |
| BurningSA | Burning - Savanna | *LAND (ha)* | 780.7 | 722.8 | 262.3 | 708.3 | 516.4 | 712.7 |
| CropRes | Crop Residues | *OUTPUT (kg of nutrients)* | 6.0 | 5.9 | 0.4 | 6.0 | 6.0 | 6.0 |
| EntFerm | Enteric Fermentation | *ANIMALS (head)* | 416.1 | 408.2 | 265.8 | 344.1 | 418.8 | 326.5 |
| ManureMgt | Manure Management | *ANIMALS (head)* | 12.3 | 22.0 | 29.8 | 10.6 | 20.5 | 9.8 |
| ManurePast | Manure left on Pasture | *ANIMALS (head)* | 29.7 | 47.7 | 49.0 | 28.2 | 18.1 | 35.4 |
| ManureSoils | Manure applied to Soils | *ANIMALS (head)* | 6.7 | 10.2 | 12.8 | 6.3 | 9.2 | 5.3 |
| OrgSoil | Cultivation of Organic Soils | *LAND (ha)* | 5,238.9 | 5,684.3 | 1853.5 | 5,301.4 | 3,888.1 | 7,645.8 |
| RiceCult | Rice Cultivation | *LAND (m2)* | 0.3 | 0.4 | 0.2 | 0.4 | 0.6 | 0.3 |
| SyntFert | Synthetic Fertilizers | *FERTILIZER (Ton)* | 6,430.3 | 6,430.3 | 0.0 | 6,430.3 | 6430.3 | 6,430.3 |
| Pesti | Pesticides | *CHEMICALS (Ton)* | 20,000.0 | 20,000.0 | 0.0 | 20,000.0 | 20,000.0 | 20,000.0 |
| Energy | Energy (Fossil Fuels directly used) | *ENERGY* |  |  |  |  |  |  |

Note: For synthetic fertilizer and pesticides we have only one year of data (2014). Therefore, average represents number to single year only.

### Stage 1

After stage 1, we need to check if adding up all the elements listed in this section allows us to reproduce total agricultural emissions by country as given in <http://www.fao.org/faostat/en/#data/GT>.

Any discrepancies should be tracked down.

NOTE: The total agricultural emissions from FAOSTAT does not include the Energy emissions, while we do.

### Stage 2

After stage 2, we compare our crop specific emissions factor with <http://www.fao.org/faostat/en/#data/EI> Differences by more than 20 percent for OECD countries will be identified and investigated.

# Land Use emissions

**[to be added in Phase 2]**

# Outputs

## Final nomenclature

Country : ISO3

Sector: GTAP nomenclature

## Aggregation procedure

## Format of outputs for GAMS

Table 5 Fields for output format

|  |  |
| --- | --- |
| **Dimension** | **Description** |
| COUNTRY | {ISO3 code} |
| YEAR | {2013-2014-2015} |
| SECTOR | {GTAP SECTOR} |
| EMISSIONSSOURCE | {BurningCR, BurningSA, CropRes, OrgSoil, EntFerm, ManureSoils, ManurePast, ManureMgt, RiceCult, SyntFert, Pesti, Energy} |
| INDEX | {“LAND”, “ANIMALS”,”OUTPUT”,”ENERGY”,”FERTILIZER”, “CHEMICALS” |
| INDEXVALUE | The base value for computation |
| GHG\_TYPE | {CH4,NO2,CO2} |
| VALUE | Value in CO2eq |

References

Cheng, K. Ming Yan, Genxing Pan, Ting Luo, and Qian Yue (2015), *Methodology for Carbon Footprint Calculation in Crop and Livestock Production* in Muthu, S. ed. The Carbon Footprint Handbook, CRC Press, Boca Raton.

IPCC (2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Institute for Global Environmental Strategies, Japan. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

**Appendix**

**Reconstructing emission database of FAO**

Steps in re-computing emission data from different sources are described in the following table. The sources include burning crop residues and savanna, crop residues, manure management, manure applied to soils, manure left on pasture, rice cultivation, cultivation of organic soils, enteric fermentation and synthetic fertilizers. This note describes the three step procedures in computing emission of greenhouse gas from all these sources – first recompute emission coefficient (EC) for N2O and CH4, second recompute emission of N2O and CH4 and finally recompute CO2 equivalent from N2O and CH4. The default value for CO2 from N2O is 310 and for CO2 from CH4 is 21.

FAO emission database provides implied emission factors for various activities at emission source such as area harvested in rice cultivation, manure N contents in manure production. The database in some cases provides the base activity data, e.g. area in the cultivation of organic soil, stocks (number of heads of livestock) in manure management etc., while in other cases only provide computed activity data, not the underlying data, such as biomass burned (dry mater) in burning crop. In such cases we import base activity data from crop and livestock production database. For synthetic nitrogen fertilizer there is activity data and thus we relied on the FAO numbers instead. In our final database we keep the base activity data (we call index data) to get average emission value per index type (land, animals, output, fertilizer and energy).

In the case of enteric fermentation and manure management (during storing and treatment, application to soils and left on pasture) we have disaggregated emission numbers for the following animals – buffaloes, camels, goats and sheep – by use of products – meat, milk and wool (sheep). We have made the split on number of heads of these animals by constructing ratio of value of production of the meat, milk and wool to the total value. This helps us to be consistent with GTAP nomenclature and the IO structure of CGE. In the final step we have produced emissions data by country, emission source and sector. Individual sector is mapped to GTAP sector.

**Table: Computations of emission coefficient, N2O, CH4 and CO2eq**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Emission Source** | **Emission type** | **Steps in recompute** | | |
| *Step 1*  Recompute emission coefficient (EC) | *Step 2*  Recompute emission of N2O, CH4 | *Step 3*  Recompute emission of CO2 equivalent from N2O, CH4 |
| Burning - crop residues | CH4, N2O | EC\_CH4 = CH4\*10e5/Biomass burned (tons)  EC\_N2O = N2O\*10e5/Biomass burned (tons)  Unit: kg CH4/ton, kg N2O/ton | CH4\_RC = Biomass burned\*EC\_CH4/10e5  N2O\_RC = Biomass burned\*EC\_N2O/10e5  Unit: gigagrams | **Conversion factor**:  EC\_CH4\_CO2 = CO2 from CH4 (CO2\_fCH4)/ CH4\_RC  **CO2eq**:  CO2\_fCH4\_RC = CH4\_RC\* EC\_CH4\_CO2  **Conversion factor**:  EC\_N2O\_CO2 = CO2 from N2O (CO2\_fN2O)/ N2O\_RC  **CO2eq**:  CO2\_fN2O\_RC = CH4\_RC\* EC\_N2O\_CO2 |
| Burning - savanna | CH4, N2O | EC\_CH4 = CH4\*10e5/Burned area (ha)  EC\_N2O = N2O\*10e5/burned area (ha)  Unit: kg CH4/ha, kg N2O/ha | CH4\_RC = Burned area\*EC\_CH4/10e5  N2O\_RC = Burned area\*EC\_N2O/10e5  Unit: gigagrams | Same as above for from CH4 to CO2 and from N2O to CO2 |
| Crop residues | N2O | **Direct**  EC\_N2O = N2O\_DR\*10e5/Crop residues (kg of nutrients)  Unit: kg N2O/kg N  **Indirect (**through leaching**)**  *Fraction leaching (kg N)*  N\_LCH\_f = Crop residues\*0.3  *Kg N2O-N*  N2ON\_LCH = N\_LCH\_f\*0.0075 (EF)  *Kg N2O-N to kg N2O*  N2O\_KG\_LCH = N2ON\_LCH\*44/28 | **Direct**  N2O\_DR\_RC = Crop residues\*EC\_N2O/10e5  **Indirect**  N2O\_INDR\_RC=N2O\_KG\_LCH/10e5  Unit: gigagrams N2O per year | Same as above for from N2O to CO2 |
| Enteric fermentation | CH4 | EC\_CH4 = CH4\*10e5/Stocks (head of livestock)  Unit: kg CH4/head | CH4\_RC = Stocks\*EC\_CH4/10e5  Unit: gigagrams CH4 per year | Same as above for from CH4 to CO2 |
| Manure management | CH4, N2O | EC\_CH4 = CH4\*10e5/Stocks (head)  **Direct**  kg\_N2O = N2O\_DR\*10e5/Manure (N content)  EC\_N2O = kg\_N2O\*28/44  **Indirect**  Coefficient for indirect (through volatilization by animal and manure management system (MMS)) couldn’t be computed, as it involves identifying MMS in different geographical areas.  Unit: kg CH4/head, kg N2O/N | CH4\_RC = Stocks\*EC\_CH4/10e5  N2O\_DR\_RC = Manure\*EC\_N2O/10e5  N2O\_INDR (taken from database)  N2O\_RC = N2O\_DR\_RC + N2O\_INDR  Unit:  Gigagrams CH4 per year  gigagrams N2O per year | Same as above for from CH4 to CO2 and from N2O to CO2 |
| Manure applied to soils | N2O | **Direct**  EC\_N2O = N2O\_DR\*10e5/Manure (N-content) applied  N2O\_DR\_RC = Crop residues \* EC\_N2O  **Indirect (**through volatilization and leaching**)**  *Fraction leaching (kg N)*  N\_VOL\_f = Manure\*0.2  N\_LCH\_f = Manure\*0.3  *Kg N2O-N*  N2ON\_VOL\_RC = N\_VOL\_f\*0.01 (EF)  N2ON\_LCH\_RC = N\_LCH\_f\*0.0075 (EF)  *Kg N2O-N to kg N2O*  N2O\_KG\_VOL = N2ON\_VOL\_RC\*44/28  N2O\_KG\_LCH = N2ON\_LCH\_RC\*44/28 | **Direct**  N2O\_DR\_RC = Manure (N-content) applied\*EC\_N2O/10e5  **Indirect**  N2O\_VOL\_RC=N2O\_KG\_VOL/10e5  N2O\_LCH\_RC=N2O\_KG\_LCH/10e5  *Total N2O from indirect source*  N2O\_INDR\_RC = N2O\_VOL\_RC + N2O\_LCH\_RC  *Total N2O*  N2O\_RC = N2O\_DR\_RC + N2O\_INDR\_RC  Unit: gigagrams N2O per year | Same as above for from N2O to CO2 |
| Manure left on pasture | N2O | **Direct**  EC\_N2O = N2O\_DR\*10e5/Manure on pasture (N-content) on pasture  N2O\_DR\_RC = Crop residues \* EC\_N2O  **Indirect (**through volatilization and leaching**)**  *Fraction volatilization and leaching (kg N)*  N\_VOL, N\_LCH (given in database). Checked the ratio of N from leaching to total N and same for volatilization. The ratio remains same as seen in manure applied section.  *Kg N2O-N*  N2ON\_VOL\_RC = N\_VOL\*0.01 (EF)  N2ON\_LCH\_RC = N\_LCH\*0.0075 (EF)  *Kg N2O-N to kg N2O*  N2O\_KG\_VOL = N2ON\_VOL\_RC\*44/28  N2O\_KG\_LCH = N2ON\_LCH\_RC\*44/28 | **Direct**  N2O\_DR\_RC = Manure on pasture (N-content) applied\*EC\_N2O/10e5  **Indirect**  N2O\_VOL\_RC=N2O\_KG\_VOL/10e5  N2O\_LCH\_RC=N2O\_KG\_LCH/10e5  *Total N2O from indirect source*  N2O\_INDR\_RC = N2O\_VOL\_RC + N2O\_LCH\_RC  *Total N2O*  N2O\_RC = N2O\_DR\_RC + N2O\_INDR\_RC  Unit: gigagrams N2O per year | Same as above for from N2O to CO2 |
| Rice cultivation | CH4 | *Conversion from ha to m2*  Harvested area (m2) = Area harvested (ha) \*10e3  EC\_CH4 = CH4\*10e5/harvested area (m2)\*1000  Unit: g CH4/m2 | CH4\_RC = Harvested area (m2) \*EC\_CH4/10e8  Unit: gigagrams CH4 per year | Same as above for from CH4 to CO2 |
| Synthetic fertilizers | N2O | Here activity is Agriculture use in Nutrients.  For synthetic nitrogen fertilizer there is no activity data available. Therefore, just simply aggregate N2O from direct and indirect source.  Unit: kg N2O/kg of nutrients | N2O\_RC = N2O\_DR + N2O\_INDR  Unit: gigagrams N2O per year | Same as above for from N2O to CO2 |
| Cultivation of organic soils | N2O | *Compute kg N2O*  Kg\_N2O = N2O\*10e5/Area (ha)  From kg N2O/ha to kg N2O-N/h  EC\_N2O = kg\_N2O\*28/44  Note: This EC\_N2O is consistent with EF\_N2O given in database  Unit: kg N2O-N/ha | N2O\_RC = Area\*kg\_N2O /10e5  Note: used kg\_N2O instead of EC\_N2O.  Unit: gigagrams N2O per year | Same as above for from N2O to CO2 |
| Energy | CH4, N2O | Activity: Consumption of energy in agriculture (Terajoule)  EC\_N2O = N2O\*10e5/Activity  EC\_CH4 = N2O\*10e5/Activity  Unit: kg/TJ | N2O\_RC = Activity \* EC\_N2O  CH4\_RC = Activity \* EC\_CH4  Unit: gigagrams per year | Same as above for from CH4 to CO2 and from N2O to CO2 |

Note: EC – emission coefficient. Please note that FAO data provides implied emission factor (EF). Suffix RC means recomputed. The rest are self-explanatory.