

# GHG emission, N balance and Food Availability calculation R calculator

---

*Technical guide*

*R. Frelat, C. Birnholz, A. Notenbaert, R. Summer, B. Paul*

*28/08/2015*



Centro Internacional de Agricultura Tropical  
International Center for Tropical Agriculture  
*Consultative Group on International Agricultural Research*

## Table des matières

Introduction .....	3
Overview .....	3
Calculations .....	3
Organization of the database, the R codes and the parameters .....	4
Key assumptions .....	5
Data Pre-Processing .....	6
Crop .....	6
Livestock .....	7
Feed .....	8
Household .....	9
Region .....	11
Greenhouse gas emissions .....	12
<b>ENTERIC FERMENTATION</b> .....	12
IPCC Tier 1 .....	12
IPCC Tier 2 .....	12
Visual comparison Tier 1 vs Tier 2 .....	13
<b>METHANE EMISSIONS FROM MANURE</b> .....	14
IPCC Tier 1 .....	14
IPCC Tier 2 .....	14
Visual comparison Tier 1 vs Tier 2 .....	15
<b>NITROGEN EXCRETION FROM MANURE</b> .....	16
IPCC Tier 1 .....	16
IPCC Tier 2 .....	16
Visual comparison Tier 1 vs Tier 2 .....	17
<b>DIRECT N<sub>2</sub>O EMISSIONS FROM MANURE</b> .....	17
<b>INDIRECT N<sub>2</sub>O EMISSIONS FROM MANURE</b> .....	18
Visual comparison Tier 1 vs Tier , and direct vs Indirect .....	19
<b>DIRECT N<sub>2</sub>O-N EMISSIONS FROM MANAGED SOILS</b> .....	20

<b>INDIRECT N<sub>2</sub>O-N EMISSIONS FROM MANAGED SOILS .....</b>	<b>22</b>
Visual comparison Tier 1 vs Tier 2, and direct vs Indirect .....	23
<b>RICE - Methane emissions from rice production .....</b>	<b>24</b>
Visual comparison of emission and area .....	25
<b>BURNING .....</b>	<b>26</b>
<b>GHG emissions.....</b>	<b>27</b>
Visualization of the distribution of GHG emission and its sources.....	27
<b>N Balance Calculations .....</b>	<b>29</b>
<b>IN1: Mineral fertilizer .....</b>	<b>29</b>
<b>IN2: Manure .....</b>	<b>29</b>
<b>IN3: Atmospheric deposition .....</b>	<b>29</b>
<b>IN4: Biological N-fixation.....</b>	<b>29</b>
<b>OUT1: Crop yield .....</b>	<b>31</b>
<b>OUT2: Crop residue .....</b>	<b>32</b>
<b>OUT3: Leaching .....</b>	<b>32</b>
<b>Out 4: Gaseous losses .....</b>	<b>33</b>
<b>OUT5: Erosion.....</b>	<b>34</b>
Visualization of the distribution of GHG emission and its sources.....	35
<b>Remarks: .....</b>	<b>37</b>
<b>Way further: .....</b>	<b>37</b>
<b>References.....</b>	<b>38</b>
GHG emission: .....	38
N balance: .....	38

## Introduction

This document provides information about the calculation of the GHG emissions and the N Balance at farm level and how it is implemented in R. It was greatly inspired by the two technical guides 'Soil erosion and nitrogen balance calculator' and 'GHG calculator'.

As a case study, it uses the data from 60 households interviewed in 2015 in Vietnam, following ImpactLite survey scheme. Similar framework could be applied to other datasets with similar information.

## Overview

### Calculations

Most of the GHG emissions calculations follow the Tier 1 guidelines. It uses the herd composition, the crop production and crop residue uses, and the household fertilizer and manure management. In addition, tier 2 calculations were performed for the enteric fermentation and for the manure production using the diet of livestock.

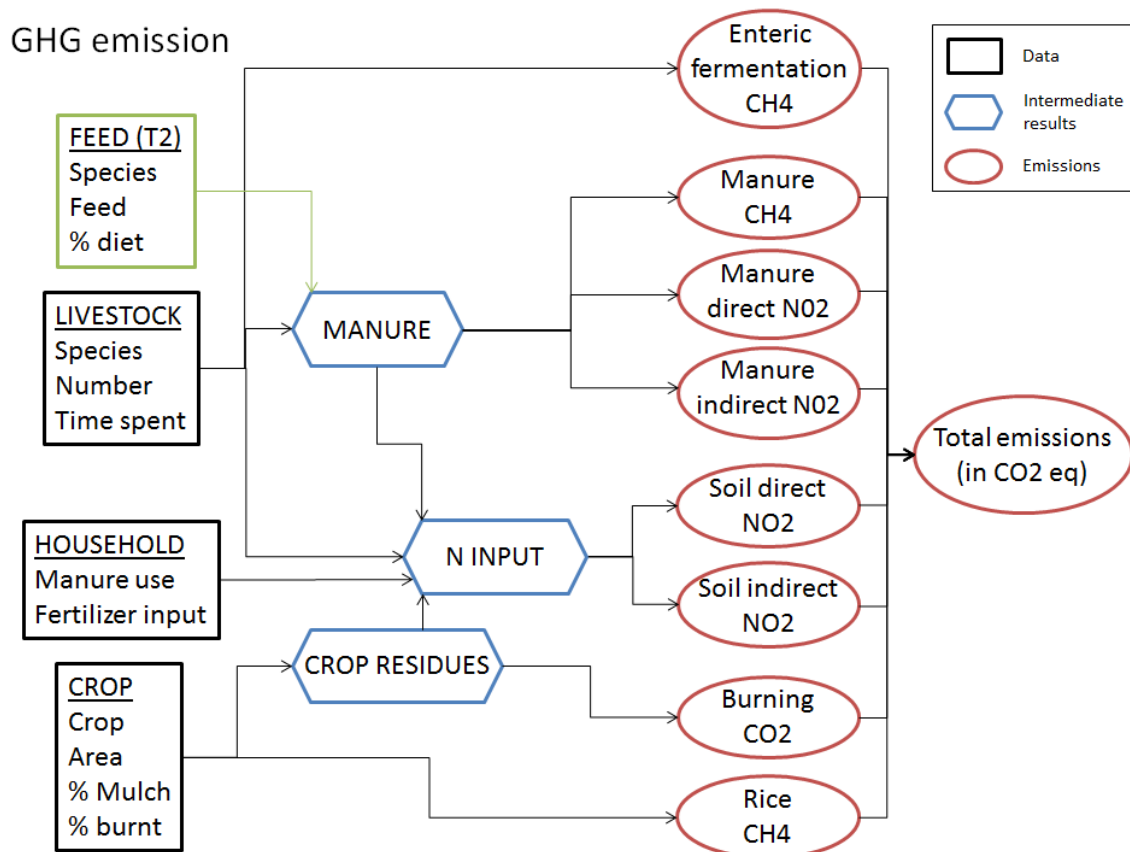
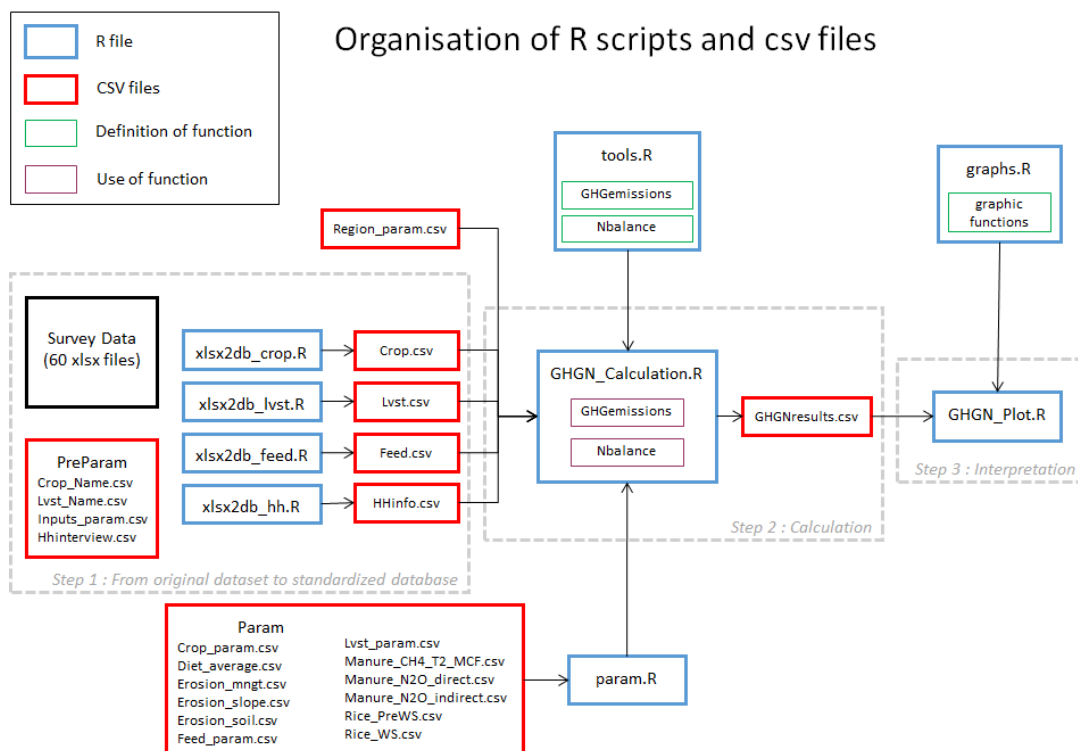


Figure 1: Scheme of the GHG emissions calculation. Most of the calculations follow the Tier1 guidelines, but Tier 2 calculations were performed for the manure production using the diet of livestock.

## Organization of the database, the R codes and the parameters

The calculations are modular and made in 3 key steps:

1. Preprocessing:  
Loading original data and extract (& clean) the needed information in a new database. This new database is made of 4 tables: one about crop, one about the livestock herd, one with the livestock diet, and one with household information.
2. Calculation:  
From the new database and a regional parameter table, the GHG emissions and N balance are computed. This takes into account numerous parameters that are tables saved in csv files. Regional parameters are parameters that could be different for each site/cluster, but not asked at household level (e.g. rainfall or soil type). The parameters of the calculations in 'param.csv' are parameters similar for all the households (e.g. emission factors, or the conversion factor from CH<sub>4</sub> to CO<sub>2</sub>). The output of both calculations is saved in one table.
3. Interpretation:  
With graphical functions, the interpretation and the validation of the computation is visualized. The distribution of GHG emissions for the whole population, the comparison of sources of GHG for the whole population or per cluster (geography, GHG emission levels, or other clusters).



**Figure 2: Schematic representation of the R scripts and the csv files in the three steps of the process : preprocessing, calculation and interpretation.**

## **Key assumptions**

This is a (not exhaustive) list of assumptions made from the data availability, and the calculations:

- All plots (of the same cluster) have the same slope and soil (defined in 'Region\_param.csv').
- The manure is applied uniformly on all crops.
- Livestock diet is defined per species (no differences of diet intra species). This is quite strong for the cattle species (calves, bull and dairy cows are fed similarly in our model) but more precise information is not available in the data.
- The feed basket is averaged per kg and per season. We compare the feeds with the reported quantity (and not their energy content or DM content). So the assumption is that the feed basket (relative importance of each feed item) is proportional to the quantity of feed. In the GHG emission calculation make the assumption that every animal is fed properly.

(to be completed)

## Data Pre-Processing

The greenhouse gas (GHG) emissions and N balance are calculated at household level from data collected in a household survey. From this dataset, the needed information is extracted and organized in 4 tables.

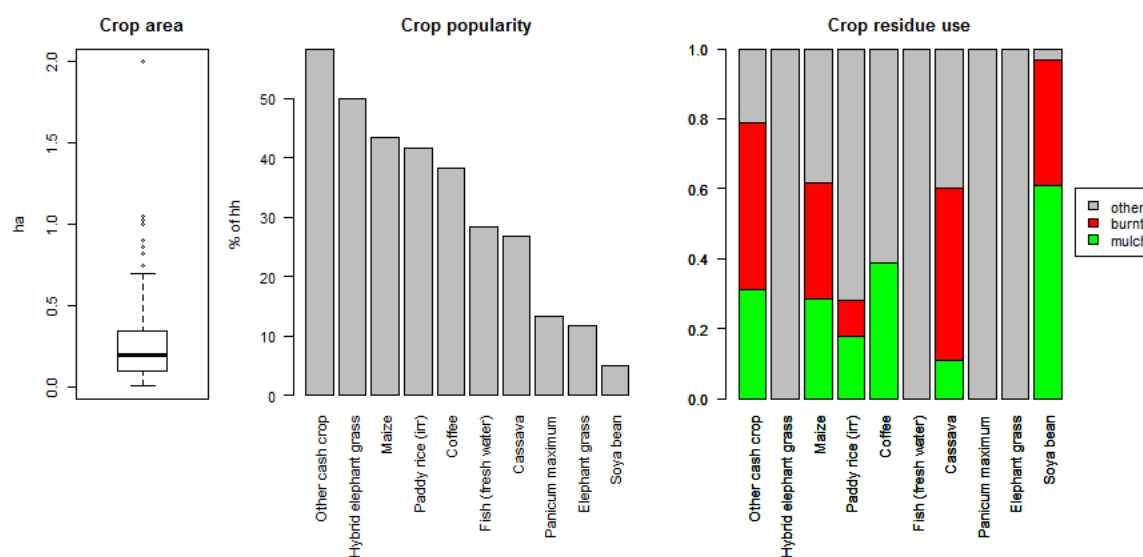
### Crop

The season, the area (converted in ha), the crop code (crops are split if intercropped, area is divided per the number of crops intercropped) are extracted from sheet '03\_SeasonCrop areas'.

The uses of crop residue (in %) are extracted from sheet '05\_Crop residues'. The sum of the 5 categories of CR uses is equal to 100%. If the information is not available for a given crop, the CR uses are filled with 'NA'.

The script 'xlsx2db\_crop.R' extracts the information from crops and organizes it in 11 variables, as explained below.

Name	Description
hhid	ID of household
season	Season (1 or 2)
intercrop	Intercrop code or NA if not intercropped
cropcode	Crop code (as given in the 'Crop_Name.csv' file)
crop	Name of the crop grown
area	Area grown (in ha). <i>If intercropped, the area is divided per the number of crops.</i>
CRmulch	% of CR used as mulch
CRburnt	% of CR burnt
CRsale	% of CR sold
CRfeed	% of CR given as feed for livestock
CRother	% of CR used as fuel or other.



**Figure 3: Crop characteristics for the 60 households in Vietnam. Left: distribution of crop area (in ha); middle: the 10 most popular crop (in % of household growing each species); right: average CR uses for the 10 most popular crops.**

The most common crop (Figure 3, middle) is ‘other cash crop’ (code 109) which is cashew or pepper. This crop will have the characteristics of the pepper (since cashew characteristics are difficult to get).

There are 60% of crops (on 429 reported crops) without information on their residue uses (% burnt and % kept as mulch). If not available, the assumption will be to use the average CR uses per crop (Figure 3, right). If the average is not available (e.g. Elephant Grass), we consider that none is burnt and none is kept as mulch.

## Livestock

The number of livestock and the species are extracted from sheets ‘07\_Livestock’ and ‘08\_Herd Structure’. The cattle are divided in four categories:

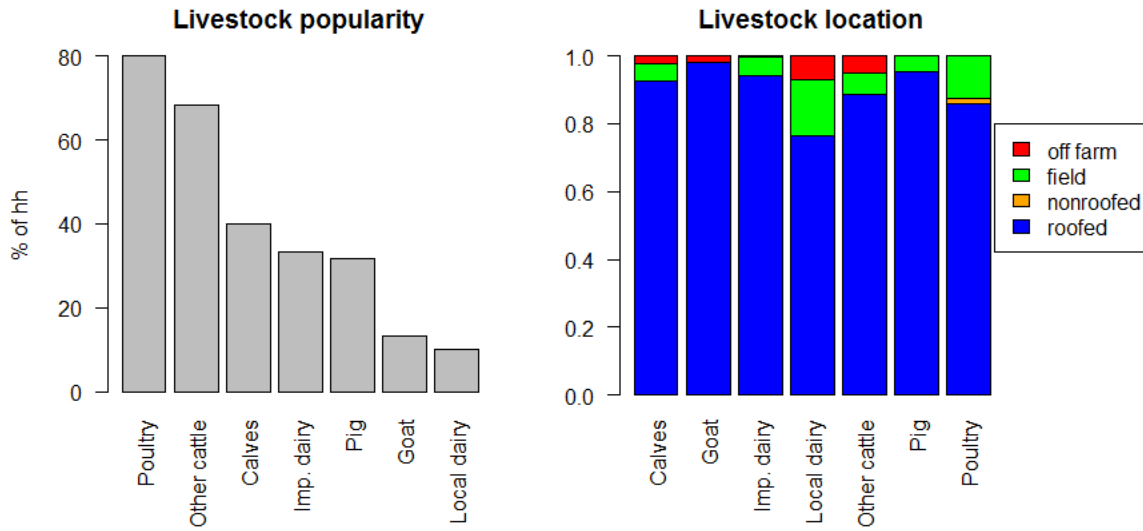
- if the age is equal to category 1 (<6months), then it is a ‘Calve’
- else, if the sex is not 2 (Female) or the age is different from category 3, then it is an ‘Other adult cattle’
- else, if the breed is 1 (Local), it is a ‘Local dairy cows’; else an ‘Improved dairy cows’.

The ‘location’ of the livestock are extracted from sheet ‘12\_New\_Dung utilization.csv’.

The script ‘xlsx2db\_lvst.R’ extracts the information from livestock herd and organizes it in 10 variables, as explained below.

Name	Description
hhid	ID of household
id	ID of the livestock (0 if non ruminant)
code	Livestock code
lvst	Livestock species (8 categories: Local dairy cows, improved dairy cows, other adult cattle, calves, sheep, goat, pig and poultry)
num	Number of livestock
roofed.p	Percentage of annual time spent in a roofed building
nonroofed.p	Percentage of annual time spent in a non-roofed enclosure
field.p	Percentage of annual time spent on fields
offfarm.p	Percentage of annual time spent off farm
havefeed	Logical (TRUE/FALSE) indicating if there are information on the ‘Feed’ table

Buffaloes (code 2) are classified as ‘Other adult cattle’. Most of the household have livestock (Figure 4, left), which are kept in a roofed building (Figure 4, right). In the dataset, 16% of livestock doesn’t have information on their location. In these cases, the average time spent per location per species are used (Figure 4, right).



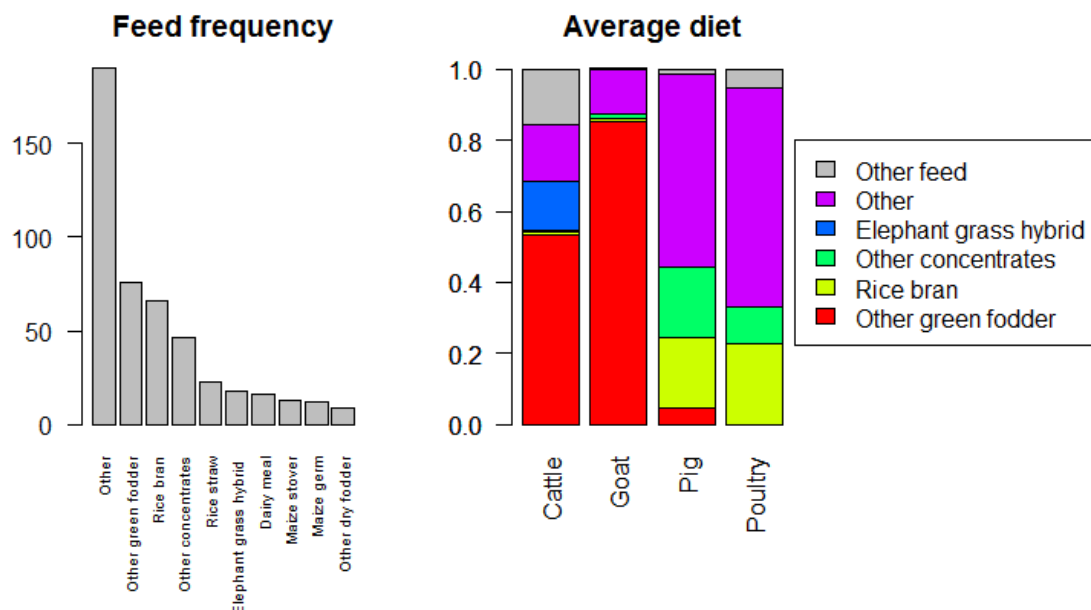
**Figure 4: Livestock characteristics for the 60 households in Vietnam. Left: popularity of the livestock species among households (in % of household having each species); right: average livestock location per species.**

## Feed

The feed basket is extracted from sheet '11\_Livestock feeding'. The feed basket is calculated per season, with the information available. The percentages are computed with the quantities given (it doesn't take into account the energy content nor the dry matter).

The script 'xlsx2db\_feed.R' extracts the information from livestock diet and organizes it in 6 variables, as explained below.

Name	Description
hhid	ID of household
lvst	Livestock code (correspond to the variable 'code' in livestock table)
season	Season (1 or 2)
feed	Feed code
quantity	Annual quantity given (in kg)
perc	Percentage of the feed in the annual feed basket



**Figure 5: Livestock diet characteristics for the 60 households in Vietnam. Left: feed frequency; right: average diet per species.**

There are 38% of the feed which are 'other feed' (Figure 5, left). Less than 10% of the livestock don't have information about their diets. In this case, we use the average diet of the region for the concerned species (Figure 5, right).

The average diet is computed per livestock type and saved in a table 'Diet\_average.csv'.

## Household

The general characteristics of the household (geography, name, gender) are extracted from sheet '00\_Cover'.

The percentage of dung used as fertilizer on the fields is extracted from sheet '12\_New\_Dung utilisation'. The average is calculated from the 4 locations and the two seasons. If no information is given in the table, the value is filled with 'NA'.

The N content of the fertilizers (defined in 'Inputs\_param.csv') applied to the field for the rice plots and the other crops (in kg/year) are extracted from sheet '06\_Crop activities'.

The cluster of the household (in term of forage experience and district) is extracted from the file 'HHinterview.csv'. This cluster is used to define the regional parameters.

The total land area cultivated (if grown two season, the land is counted twice), the percentage of land dedicated to rice and the number of crops grown are calculated from the crop table are calculated.

The number of cattle, number of poultry and the herd size in Tropical Livestock Unit (with coefficient 0.8 for improved dairy cow, 0.7 for local dairy cow and other adult cattle, 0.5 for

calves, 0.2 for pigs, 0.1 for goats and sheep, 0.005 for poultry) are calculated from the livestock table.

The script 'xlsx2db\_hh.R' extracts the information from households and organizes it in 23 variables, as explained below.

Name	Description	Source
Country	Country (here Vietnam)	00_Cover
County	County	00_Cover
District	District	00_Cover
Commune	Commune	00_Cover
Village	Village	00_Cover
Name of hh head	Name of the household head	00_Cover
Name of respondent	Name of the respondent	00_Cover
Gender of respondent	Gender of the respondent	00_Cover
hhid	Household id, unique ID used to connect the other tables	file name
hysize	size of the household	01_HHsize
headgender	gender of the household head	01_HHsize
fertN.rice	Quantity of fertilizer applied on rice field , (in kg N.year <sup>-1</sup> ).	06_Crop activities
fertN.other	Quantity of fertilizer applied on field (other than rice),(in kg N.year <sup>-1</sup> ).	06_Crop activities
manure.rice	Quantity of manure applied on rice field,(in kg N.year <sup>-1</sup> ).	06_Crop activities
manure.other	Quantity of manure applied on field other than rice (in kg N.year <sup>-1</sup> ).	06_Crop activities
manurefert.p	% of dung collected used as fertilizer.	12_New_Dung utilisation
offfarm.VND	Off farm income, in VND	18_Other Income
Totarea	Total area cropped annually (in ha). If the area is used for the two seasons, the area is counted twice.	Crop table
Maxarea	Largest area with crops in one season.	Crop table
rice.p	Percentage of land dedicated to rice	Crop table
ncrop	number of different crops grown annually	Crop table
poultry.n	number of poultry	Livestock table
cattle.n	number of cattle owned	Livestock table
tlu	herd size in Tropical Livestock Unit (TLU)	Livestock table
clust	Cluster	HHinterview
District.clean	Clean name of the district	HHinterview

## Region

Some of the needed information was not collected by the survey and were estimated per region/cluster, in a 'region' table. These parameters are assumed to be equal for all households within the same cluster.

Name	Description
Cluster	The number of the cluster (used to link with hh table)
Cluster Name	Name of the cluster
Climate	Climate (cool, temperate or warm). <i>Used for the Tier 2 calculation of CH<sub>4</sub> emission of manure, equation (5), in link with the file 'Manure_Ch4_T2_MCF.csv'.</i>
Landuse System	Land use system. <i>Used in the Erosion calculation, with the file 'Erosion_mngt.csv', equation (40).</i>
soil	Soil type. <i>Used in the Erosion calculation with 'Erosion_soil.csv', equation (40).</i>
MS	Manure management system. <i>Used for the Tier 2 calculation of CH<sub>4</sub> emission of manure (equation (5), direct and indirect N<sub>2</sub>O emission of manure- equation (12) and (15).</i>
soilClay	Clay content of the soil (in %). <i>Used for the calculation of N leaching and gaseous losses - equation (36) and (38).</i>
soilN	N content of the soil (in kg.ha <sup>-1</sup> ) <i>Used for the calculation of N content, equation (37).</i>
BD	Bulk density (in ppm). <i>Used for the calculation of N content, equation (37).</i>
DS	Soil depth in cm. <i>Used for the calculation of N leaching, equation (37).</i>
rainfall	Annual rainfall (in mm). <i>Used in the Erosion calculation for the calculation of R - equation (40) - and N balance - equations (29), (31), (36) and (37).</i>
slope	in % (of what ? on how long ?). <i>Used in the Erosion calculation with Erosion_slope.csv, equation (40).</i>
% manure collected from roofed	Percentage of manure from stable that is collected. <i>Used to compute the N<sub>2</sub>O emission from manure, equation (13).</i>
% manure collected from non roofed	Percentage of manure from non roofed environment that is collected. <i>Used to compute the N<sub>2</sub>O emission from manure, equation (13).</i>
% manure collected from fields	Percentage of manure from fields that is collected. <i>Used to compute the N<sub>2</sub>O emission from manure, equation (13).</i>
% manure collected from off farm	Percentage of manure from off farm that is collected. <i>Used to compute the N<sub>2</sub>O emission from manure, equation (13).</i>
Rice water regime	Water regime during the cultivation period, <i>used in the calculation of methane emission from rice (equation 23).</i>
Rice water regime prior to rice cultivation	Water regime during the cultivation period, <i>used in the calculation of methane emission from rice, equation (23).</i>
production days of rice	Length of the the production season of rice (in days). <i>Used in the calculation of methane emission by rice cultivation, equation (22).</i>

## Greenhouse gas emissions

The majority of equations are based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. We compute neither the Soil Organic Carbon (SOC) stock change nor the carbon stock change in woody biomass.

### ENTERIC FERMENTATION

The methane emissions from enteric fermentation of the entire herd are derived from the sum of the methane emissions from enteric fermentation of each animal species present on the farm (1).

$$CH4_{enteric} = \sum_g EF_g \times N_g \quad (1)$$

$CH4_{Enteric}$  is the methane emissions from Enteric Fermentation (kg CH<sub>4</sub>.yr<sup>-1</sup>)

$EF_g$  is the emission factor for the defined livestock species/category (kg CH<sub>4</sub> head<sup>-1</sup>. yr<sup>-1</sup>).

The value changes if we consider Tier 1 or Tier 2 calculation (Figure 6).

$N_g$  is the number of head of livestock species  $g$  on the farm. This information is available in the 'Livestock' table.

#### IPCC Tier 1

We consider 7 categories of livestock (in Lvst\_Param.csv, column 'EF\_entT1'):

Category	EFg (kg CH <sub>4</sub> .head <sup>-1</sup> .year <sup>-1</sup> )
Local dairy cows	46
Improved dairy cows	32
Other adult cattle	41
Calves	16
Sheep	5
Goats	5
Pigs	1
Poultry	0
Donkey/Horse	14

#### IPCC Tier 2

The Emission Factor Tier 2 is only computed for the cattle (dairy cows, calves or other cattle):

$$EF_g = \frac{GE_g \times 365 \times Ym_g}{55.65} \quad (2)$$

$EF_g$  is the emission factor of livestock species  $g$ , in kg CH<sub>4</sub>.head<sup>-1</sup>.yr<sup>-1</sup>.

$GE_g$  is the daily gross energy intake of livestock species  $g$ , in MJ head<sup>-1</sup>.day<sup>-1</sup>. It is calculated from (3).

$Ym_g$  is the methane conversion factor of livestock species  $g$ , i.e. the percentage of gross energy in feed converted to methane. It is given in the column 'Ym' of the 'Lvst\_param.csv' file.

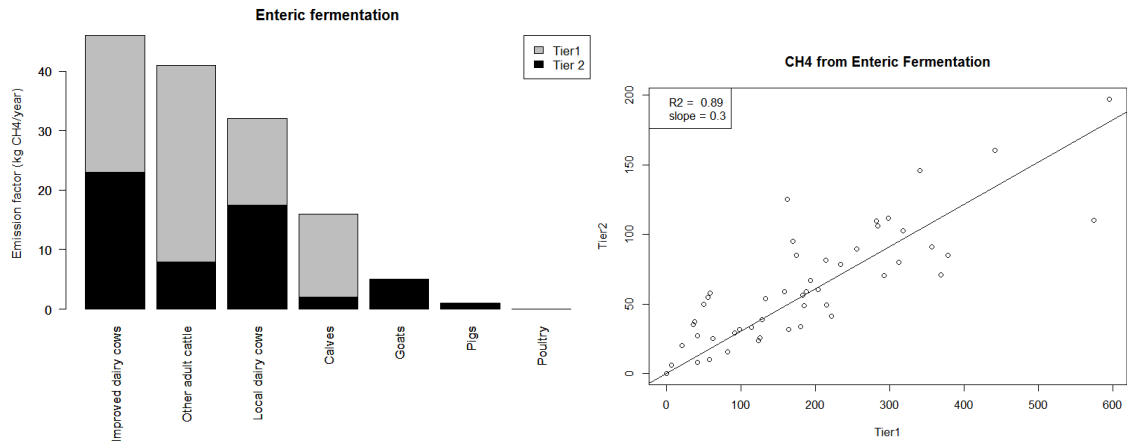
The factor 55.65 is the energy content of methane in MJ.kg CH<sub>4</sub><sup>-1</sup>. It is saved in the parameter list under the name 'energy\_CH4'.

$$GE_g = (BW_g \times 0.1) + \frac{5.5 \times Milk_g}{365} \quad (3)$$

$BW_g$  is the body weight of livestock species  $g$ , in kg. It is given in the column 'Body weight' of the 'Lvst\_param.csv' file.

$Milk_g$  is the average milk production of livestock species  $g$ , in l. head<sup>-1</sup>.yr<sup>-1</sup>. It is given in the column 'Milk Production' of the 'Lvst\_param.csv' file.

## Visual comparison Tier 1 vs Tier 2



**Figure 6: Comparison of the Tier 1 and Tier 2 emission factor of enteric fermentation. On overall, the methane emission from Tier 2 is a third of the Tier 1 emission.**

## METHANE EMISSIONS FROM MANURE

The methane emissions from manure of the entire herd are derived from the sum of the methane emissions from manure from each animal species present on the farm (4).

$$CH4_{manure} = \sum_g EF_g \times N_g \quad (4)$$

$CH4_{manure}$  is the methane emissions from manure management, in kg CH<sub>4</sub>. yr<sup>-1</sup>

$EF_g$  is the emission factor for the defined livestock species  $g$ , in kg CH<sub>4</sub>. head<sup>-1</sup>. yr<sup>-1</sup>. The value changes if we consider Tier 1 or Tier 2 calculation

$N_g$  is the number of head of livestock from species  $g$ . This information is available in the 'Livestock' table.

### IPCC Tier 1

Default values are in the file 'Lvst\_Param.csv', column 'EF\_manT1':

Category	EFg (kg CH <sub>4</sub> .head <sup>-1</sup> .year <sup>-1</sup> )
Local dairy cows	1
Improved dairy cows	1
Other adult cattle	1
Calves	1
Sheep	0.15
Goats	0.17
Pigs	1
Poultry	0.02
Donkey/Horse	1.64

### IPCC Tier 2

$$EF_g = (VS_g \times 365) \times (Bo_g \times 0.67) \times MCF_{SC} \quad (5)$$

$EF_g$  is the annual methane emission factor for livestock species  $g$ , in kg CH<sub>4</sub>.head<sup>-1</sup>.yr<sup>-1</sup>.

$VS_g$  is the daily volatile solid excreted for livestock species  $g$ , in kg DM.head<sup>-1</sup>.day<sup>-1</sup>. It is calculated in (6).

$Bo_g$  is the maximum methane producing capacity for manure produced by livestock species  $g$  (m<sup>3</sup> CH<sub>4</sub>. kg<sup>-1</sup> of VS excreted). Default values are in Lvst\_Param.csv, column 'Bo'.

$MCF_{SC}$  is the methane conversion factors for the manure management system  $S$  and climate  $C$ . Default values are in 'Manure\_Ch4\_T2\_MCF.csv'. The manure management system and the climate are given in the table 'Region\_param.csv'.

$$VS_g = [GE_g \times (1 - DE_g) + (UE \times GE_g)] \times \frac{1 - ASH}{18.45} \quad (6)$$

$GE_g$  is the daily gross energy intake of species  $g$ , in MJ head<sup>-1</sup>.day<sup>-1</sup>. It is calculated from (3).

$DE_g$  is the digestibility of the feed in % for the specie  $g$ . It is computed from equation (7).

$UE$  is the urinary energy expressed as a fraction of GE. It is saved in the parameter list under the name 'UE'. Typically 0.04 x GE can be considered urinary energy excretion by most ruminants.

$ASH$  is the ash content of the manure calculated as a fraction of the dry matter feed intake. It is saved in the parameter list under the name 'ASH' (e.g. 0.08 for cattle).

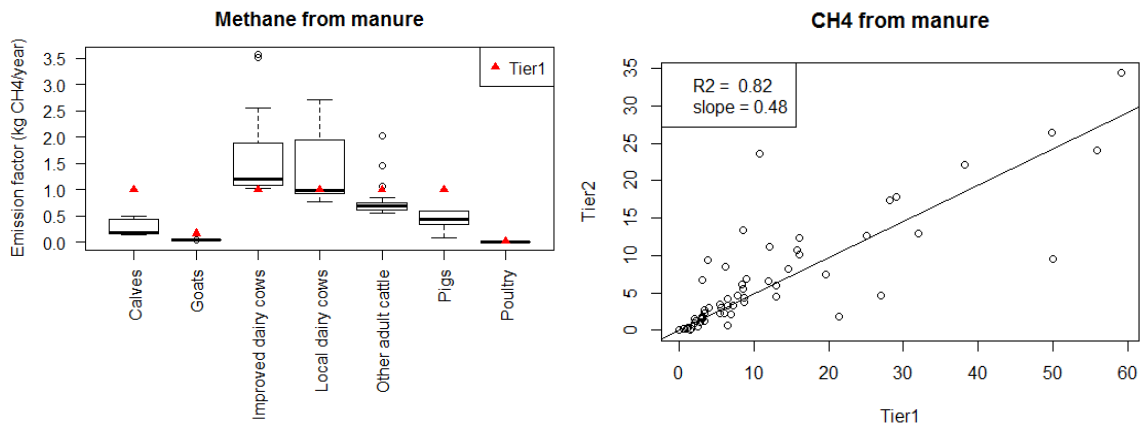
18.45 is the conversion factor for dietary GE per kg of DM (MJ. day<sup>-1</sup>). It is saved in the parameter list under the name 'dietGE'. This value is relatively constant across a wide range of forage and grain-based feed commonly consumed by livestock.

$$DE_g = \sum_f DE_f \times p_{f,g} \quad (7)$$

$DE_f$  is the digestibility of feed  $f$ , given in the table 'Feed\_param.csv'.

$p_{f,g}$  is the percentage of feed  $f$  in the diet of livestock species  $g$ . This information is available in the table 'Feed' or in the file 'Diet\_average.csv'.

### Visual comparison Tier 1 vs Tier 2



**Figure 7: Comparison of the Tier 1 and Tier 2 emission factor of methane manure emission. Emission factor Tier 2 depends on the digestibility of the feed. It is represented as a boxplot. Tier 1 emission factor is a red triangle.**

## NITROGEN EXCRETION FROM MANURE

### IPCC Tier 1

$$Nex_g = N_{rate\ g} \times \frac{BW_g}{1000} \times 365 \quad (8)$$

$Nex_g$  is the annual N excretion for livestock species  $g$  (kg N. head<sup>-1</sup>.yr<sup>-1</sup>)

$N_{rate\ g}$  is the default N excretion rate for livestock species  $g$ , in kg N. t animal<sup>-1</sup>. day<sup>-1</sup>. The values are in the file 'Lvst\_Param.csv', column 'Nrate'.

$BW_g$  is the body weight for livestock species  $g$ , in kg. It is given in the column 'Body weight' of the 'Lvst\_param.csv' file.

### IPCC Tier 2

$$Nex_g = N_{intake\ g} \times (1 - N_{retention\ g}) \quad (9)$$

$Nex_g$  is the annual N excretion for livestock species  $g$  (kg N. head<sup>-1</sup>.yr<sup>-1</sup>).

$N_{intake\ g}$  is the annual N intake per head of animal of species  $g$  (kg N. head<sup>-1</sup>.yr<sup>-1</sup>). It is calculated following equation (10).

$N_{retention\ g}$  is the fraction of annual N intake that is retained by the livestock species  $g$ . The values are in the file 'Lvst\_Param.csv', column 'N retention'.

$$N_{intake\ g} = \frac{GE_g}{18.45} \times \frac{CP_g}{6.25} \times 365 \quad (10)$$

$GE_g$  is the daily gross energy intake of species  $g$ , in MJ head<sup>-1</sup>.day<sup>-1</sup>. It is calculated from (3).

$CP_g$  is the percent crude protein in diet for the specie  $g$ . It is computed from equation (11).

18.45 is the conversion factor for dietary GE per kg of dry matter (MJ. kg<sup>-1</sup>). It is saved in the parameter list under the name 'dietGE'.

6.25 is the conversion factor from kg of dietary protein to kg of dietary N. ). It is saved in the parameter list under the name 'proteinN'.

$$CP_g = \sum_f CP_f \times p_{f,g} \quad (11)$$

$CP_f$  is the percent of crude protein of feed  $f$ , given in the table 'Feed\_param.csv'.

$p_{f,g}$  is the percentage of feed  $f$  in the diet of livestock species  $g$ . This information is available in the table 'Feed' or in the file 'Diet\_average.csv'.

## Visual comparison Tier 1 vs Tier 2

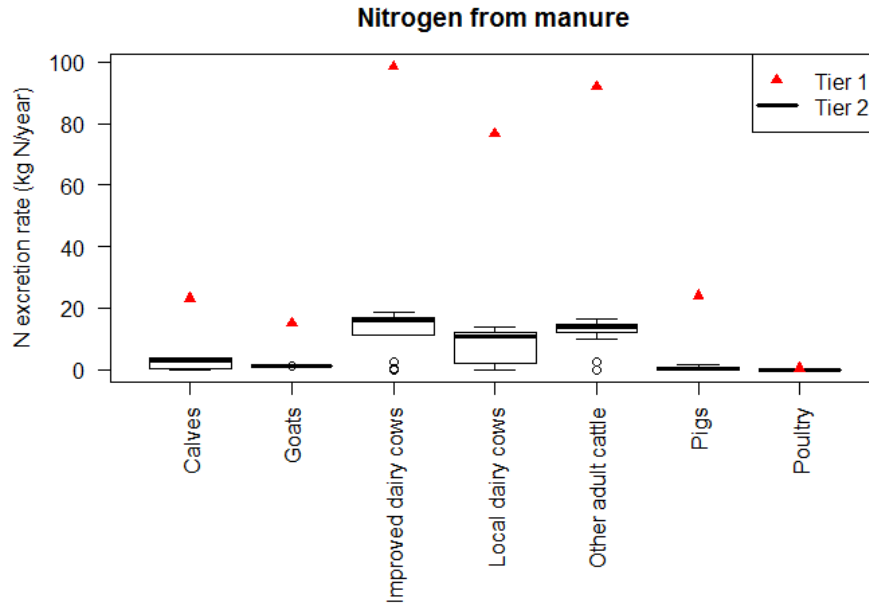


Figure 8: Comparison of the Tier 1 and Tier 2 nitrogen excretion rate from manure.

## DIRECT N<sub>2</sub>O EMISSIONS FROM MANURE

$$N2O_{dir} = \sum_g (N_g \times Nex_g \times MS_g) \times EF3_s \times \frac{44}{28} \quad (12)$$

$N2O_{dir}$  is direct N<sub>2</sub>O emissions from Manure Management (kg N<sub>2</sub>O. yr<sup>-1</sup>)

$N_g$  is the number of head of livestock from species  $g$ . This information is available in the 'Livestock' table.

$Nex_g$  is the annual average N excretion rate per head of livestock species  $g$  at the farm (in kg N . head<sup>-1</sup> .yr<sup>-1</sup>). It is calculated following equation (8)– Tier 1 and equation (9)- Tier 2).

$MS_g$  is the percentage of the total manure excreted collected by the household. It is calculating following (13).

$EF3_s$  is the emission factor for direct N<sub>2</sub>O emissions from manure management system  $S$  (kg N<sub>2</sub>O-N .kg N<sup>-1</sup> in manure management system  $S$ ). The manure management system is given in the table 'Region\_param.csv'. Default values of EF2 are in the table 'Manure\_N<sub>2</sub>O\_direct.csv'.

44/28 is the conversion of (N<sub>2</sub>O-N) emissions to N<sub>2</sub>O emissions. It is saved in the parameter list under the name 'N<sub>2</sub>O.N'.

$$MS_g = \sum_l time_{g,l} \times collected_l \quad (13)$$

$time_{g,l}$  is the proportion of time spent by species  $g$  in the location  $l$  (available in table livestock).

$collected_l$  is the percentage of manure collected in the location  $l$ . The values are available in the table 'region\_param.csv'.

## INDIRECT N<sub>2</sub>O EMISSIONS FROM MANURE

$$N_2O_{MM} = N_{volatilization-MMS} \times EF_4 \times \frac{44}{28} \quad (14)$$

$N_2O_{MM}$  is the indirect N<sub>2</sub>O emissions due to volatilization of N from Manure Management on the farm (kg N<sub>2</sub>O.yr<sup>-1</sup>)

$N_{volatilization-MMS}$  is the amount of manure nitrogen that is lost due to volatilisation of NH<sub>3</sub> and NO<sub>x</sub> (in kg N.yr<sup>-1</sup>). It is calculated from (15).

$EF_4$  is the emission factor for N<sub>2</sub>O emissions from atmospheric deposition of nitrogen on soils and water surfaces, in kg N<sub>2</sub>O-N (kg NH<sub>3</sub>-N + NO<sub>x</sub>-N volatilized)<sup>-1</sup>. It is saved in the parameter list under the name 'EF4.man'.

44/28 is the conversion of (N<sub>2</sub>O-N) emissions to N<sub>2</sub>O emissions. It is saved in the parameter list under the name 'N2O.N'.

$$N_{volatilization-MMS} = \sum_g \left[ (N_g \times Nex_g \times MS_g) \times \left( \frac{Fracgas_s}{100} \right)_g \right] \quad (15)$$

$N_g$  is the number of head of livestock from species  $g$ . This information is available in the 'Livestock' table.

$Nex_g$  is the annual average N excretion rate per head of livestock species  $g$  at the farm (in kg N . head<sup>-1</sup> . yr<sup>-1</sup>). It is calculated following equation (8)– Tier 1 and equation (9)- Tier 2).

$MS_g$  is the percentage of the total manure excreted collected by the household. It is calculating following (13).

$Fracgas_s$  is the percent of managed manure nitrogen for livestock category  $g$  that volatilizes as NH<sub>3</sub> and NO<sub>x</sub> in the manure management system  $s$ . The manure management system is given in the table 'Region\_param.csv'. Default values of EF2 are in the table 'Manure\_N2O\_in direct.csv'.

## Visual comparison Tier 1 vs Tier 2, and direct vs Indirect

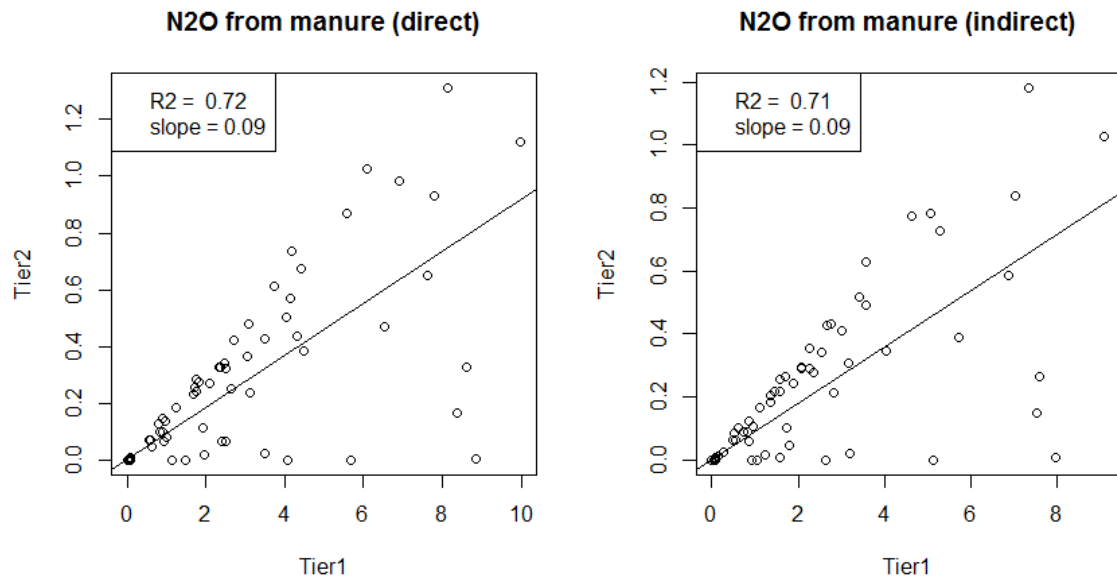


Figure 9: Comparison of the N<sub>2</sub>O emission from manure (in kg N<sub>2</sub>O-N.yr<sup>-1</sup>) considering Tier1 (x-axis) and Tier 2 (y-axis) methods, from direct emissions (left side) and indirect emission (right side).

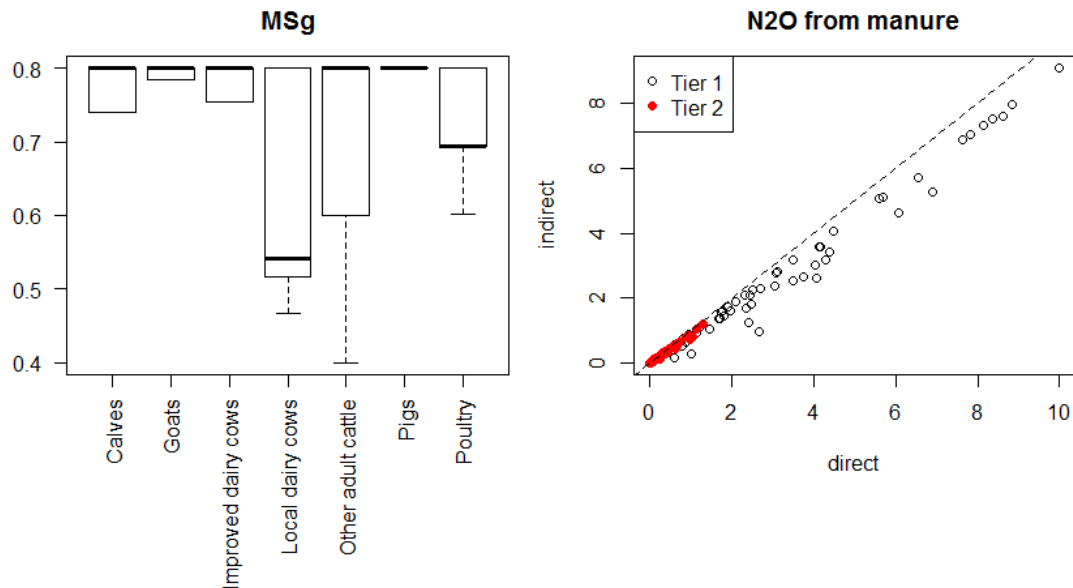


Figure 10: Distribution of the percentage of the total manure excreted collected by the household per livestock species (MSg, left side). Comparison of direct and indirect emissions from soil in kg N<sub>2</sub>O-N.yr<sup>-1</sup>, right side.

## DIRECT N<sub>2</sub>O-N EMISSIONS FROM MANAGED SOILS

$$N_2O_{direct} - N = N_2O - N_{N\ inputs} + N_2O - N_{grazed} \quad (16)$$

$N_2O_{direct} - N$  is the annual direct N<sub>2</sub>O–N emissions produced from managed soils, in kg N<sub>2</sub>O–N.yr<sup>-1</sup>.

$N_2O - N_{N\ inputs}$  is the annual direct N<sub>2</sub>O–N emissions from N inputs to managed soils, in kg N<sub>2</sub>O–N.yr<sup>-1</sup>. It is calculated following equation (17)

$N_2O - N_{grazed}$  is the annual direct N<sub>2</sub>O–N emissions from urine and dung inputs to grazed soils, in kg N<sub>2</sub>O–N.yr<sup>-1</sup>. It is calculated following equation (18).

$$N_2O - N_{N\ inputs} = \sum_c (F_{SN} + F_{ON} + F_{CR}) \times EF1_c \quad (17)$$

$F_{SN}$  is the annual amount of synthetic fertilizer N applied to soils, in kg N.yr<sup>-1</sup>. The information is available in the table ‘hhinfo.csv’.

$F_{ON}$  is the annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, in kg N.yr<sup>-1</sup>. It is calculated from equation (19).

$F_{CR}$  is the annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, in kg N.yr<sup>-1</sup>. It is calculated from equation (20).

$EF1_c$  is the emission factor for N<sub>2</sub>O emissions from N inputs, in kg N<sub>2</sub>O–N.(kg N.input)<sup>-1</sup>. The value is different if the crop is rice or not. It is saved in the parameter list under the name ‘EF1.soil.other’ and ‘EF1.soil.rice’.

$$N_2O - N_{grazed} = \sum_g Nex_g \times N_g \times time_{field,g} \times (1 - collected_{field}) \times EF3_g \quad (18)$$

$Nex_g$  is the annual average N excretion rate per head of livestock species  $g$  at the farm (in kg N . head<sup>-1</sup> .yr<sup>-1</sup> ). It is calculated following equation (8)– Tier 1 and equation (9)- Tier 2)..

$N_g$  is the number of head of livestock species  $g$ . This information is available in the ‘Livestock’ table.

$time_{field,g}$  is percentage of time spent by species  $g$  on the field (available in table livestock).

$collected_{field}$  is the percentage of manure collected from the field. The values are available in the table ‘region\_param.csv’.

$EF3_g$  is the emission factor for N<sub>2</sub>O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, in kg N<sub>2</sub>O–N.(kg N.input)<sup>-1</sup>. The values are

defined in the parameters and are different for Cattle, Poultry and Pigs (EF3.soil.CPP), and Sheep and Other animals (EF3.soil.SO).

$$F_{ON} = \sum_g (Nex_g \times N_g \times MS_g) \times \%fert + manure \quad (19)$$

$\%fert$  is the percentage of manure collected used on the field. The information is available from the household table 'hhinfo.csv'.

$manure$  is the percentage of manure bought, in kg N.yr<sup>-1</sup>. The information is available from the household table 'hhinfo.csv'.

$$F_{CR} = \sum_c A_c \times Yl_c \times (1 - HI_c) \times DMcr_c \times Ncr_c \times mulch_c \quad (20)$$

$A_c$  is the area of cultivation (in ha) under crop  $c$  (available in table crop.csv)

$Yl_c$  is the yield of the crop  $c$  (in kg.ha<sup>-1</sup>). The information is available in table 'crop\_param.csv' (but in t.ha<sup>-1</sup>).

$HI_c$  is the harvest index of the crop  $c$  (in percentage). The information is available in table 'crop\_param.csv'.

$DMcr_c$  is the Dry matter content of residues (in %). The information is available in table 'crop\_param.csv'.

$Ncr_c$  is the N content of the crop residue ( kg N . kg CR). The information is available in table 'crop\_param.csv'.

$mulch_c$  is the fraction of crop residues that is kept as mulch (from crop.csv table)

Assumptions:

$N_2O - N_{os}$  , the annual direct N<sub>2</sub>O–N emissions from managed organic soils is ignored and assumed to be null.  $F_{SOM}$  , the annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management (kg N.yr<sup>-1</sup>) is ignored and assumed to be null.

At the moment only above ground residues are considered in the calculations

## INDIRECT N<sub>2</sub>O-N EMISSIONS FROM MANAGED SOILS

$$N_2O_{(ATD)} - N = [(F_{SN} \times Frac_{GAS\ F}) + ((F_{ON} + F_{PRP}) \times Frac_{GAS\ M})] \times EF_4 \quad (21)$$

$N_2O_{(ATD)} - N$  is the annual amount of N<sub>2</sub>O–N produced from atmospheric deposition of N volatilized from managed soils (in kg N<sub>2</sub>O–N.yr<sup>-1</sup>)

$F_{SN}$  is the annual amount of synthetic fertilizer N applied to soils, in kg N.yr<sup>-1</sup>. The information is available in the table ‘hhinfo.csv’.

$Frac_{GAS\ F}$  is the fraction of synthetic fertilizer N that volatilizes as NH<sub>3</sub> and NO<sub>x</sub>, expressed in kg N volatilized. (kg of N applied)<sup>-1</sup>. The value is saved in the parameter list under the name ‘FracGasF’.

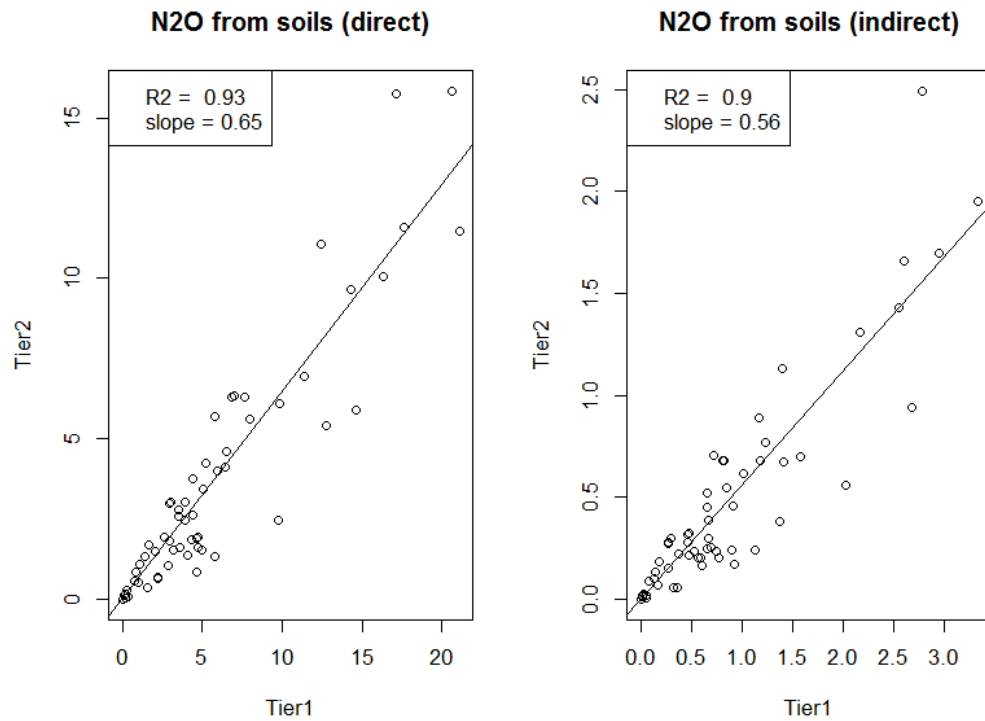
$F_{ON}$  is the annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, in kg N.yr<sup>-1</sup>. It is calculated from equation (19).

$F_{PRP}$  is the annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (in kg N.yr<sup>-1</sup>). It is similar to  $N_2O - N_{grazed}$  calculated from equation (18) but without multiplying by EF3.

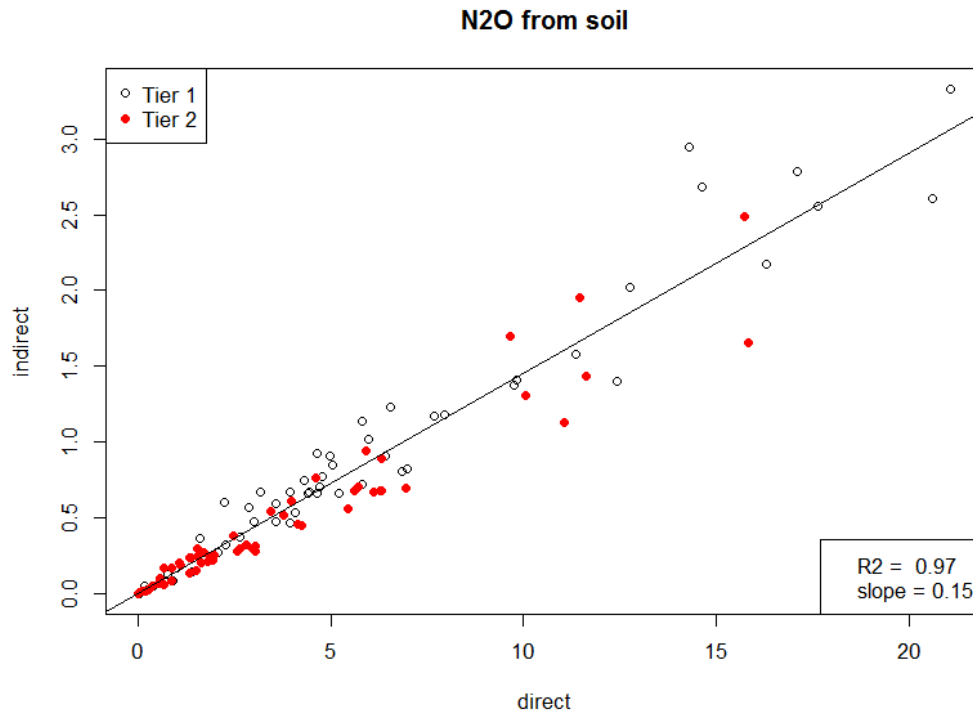
$Frac_{GAS\ M}$  is the fraction of applied organic N fertilizer materials and of urine and dung N deposited by grazing animals that volatilizes as NH<sub>3</sub> and NO<sub>x</sub>, expressed in kg N volatilized.(kg of N applied or deposited)<sup>-1</sup>. The value is saved in the parameter list under the name ‘FracGasM’.

$EF_4$  is the emission factor for N<sub>2</sub>O emissions from atmospheric deposition of N on soils and water surfaces, expressed in kg N–N<sub>2</sub>O (kg NH<sub>3</sub>–N + NO<sub>x</sub>–N volatilised)<sup>-1</sup>. The value is saved in the parameter list under the name ‘EF4.soil’.

**Visual comparison Tier 1 vs Tier 2, and direct vs Indirect**



**Figure 11:** Comparison of the N<sub>2</sub>O emission from soil (in kg N<sub>2</sub>O-N.yr<sup>-1</sup>) considering Tier1 (x-axis) and Tier 2 (y-axis) methods, from direct emissions (left side) and indirect emission (right side).



**Figure 12:** Comparison of direct and indirect emission from soil (in kg N<sub>2</sub>O-N.yr<sup>-1</sup>).

## RICE - Methane emissions from rice production

$$CH_4_{Rice} = \sum_i EF_i \times t_i \times A_i \quad (22)$$

$CH_4_{Rice}$  is the annual methane emissions from rice cultivation in kg CH<sub>4</sub>.yr<sup>-1</sup>.

$EF_i$  is a daily emission factor for  $i$  condition, in kg CH<sub>4</sub>.ha<sup>-1</sup>.day<sup>-1</sup>. It is calculated from (23).

$t_i$  is the cultivation period of rice for  $i$  condition in days. The values are given in the table 'Region\_param.csv'.

$A_i$  is the annual harvested area of rice for  $i$  condition, in ha. The area is given in the crop table.

$$EF_i = EFC \times SF_w \times SF_p \times SF_o \quad (23)$$

$EFC$  is the baseline emission factor for continuously flooded fields without organic amendments. The value is saved in the parameter list under the name 'EFC'.

$SF_w$  is the scaling factor to account for the differences in water regime during the cultivation period. The water regime during the cultivation period is given in the table 'Region\_param.csv'. Default values of  $SF_w$  are in the table 'Rice\_WS.csv'.

$SF_p$  is the scaling factor to account for the differences in water regime in the pre-season before the cultivation period. The water regime in the pre-season is given in the table 'Region\_param.csv'. Default values of  $SF_p$  are in the table 'Rice\_PreWS.csv'.

$SF_o$  is the scaling factor vary for both type and amount of organic amendment applied. It is calculated following equation (24).

$$SF_o = 1 + F_{CR} \times CFOA_{cr} + F_{ON} \times CFOA_{man} \quad (24)$$

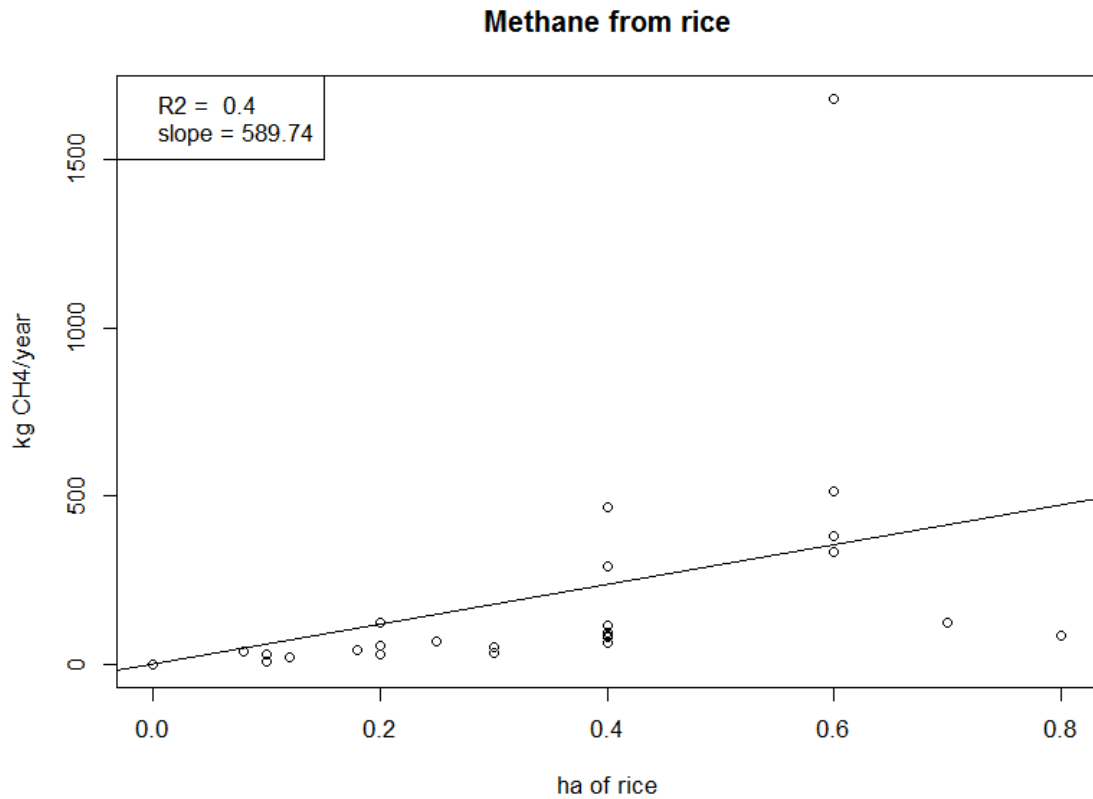
$F_{CR}$  is the annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, in kg N.yr<sup>-1</sup>. It is calculated from equation (20), only what is applied to rice is taken into account here.

$CFOA_{cr}$  is .... The value is saved in the parameter list under the name 'CFOA.cr'.

$F_{ON}$  is the annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, in kg N.yr<sup>-1</sup>. It is calculated from equation (19), only what is applied to rice is taken into account here.

$CFOA_{man}$  is .... The value is saved in the parameter list under the name 'CFOA.man'.

### Visual comparison of emission and area



**Figure 13: Emission of methane vs the area of rice cultivation. In average in the region, 1 ha of rice emits 600 kg of CH<sub>4</sub> per year.**

The emission factor of rice is in the range given per:

Zhang, Y., Wang, Y. Y., Su, S. L., & Li, C. S. (2011). Quantifying methane emissions from rice paddies in Northeast China by integrating remote sensing mapping with a biogeochemical model. *Biogeosciences*, 8(5), 1225-1235.

## BURNING

$$L_{fire} = M_B \times C_f \times G_{ef} \quad (25)$$

$L_{fire}$  is the amount of greenhouse gas emissions from fire (in kg CH<sub>4</sub>.yr<sup>-1</sup>, kg N<sub>2</sub>O.yr<sup>-1</sup> and kg CO<sub>2</sub>.yr<sup>-1</sup>)

$M_B$  is the mass of fuel available for combustion, in tons. It is calculated from (26).

$C_f$  is the combustion factor, dimensionless. The value is saved in the parameter list under the name 'CF'.

$G_{ef}$  is the emission factor, in g. kg dry matter burnt<sup>-1</sup>) The values depend on the gas, they are saved in the parameter list under the name 'Gef.CO2', 'Gef.CH4' and 'Gef.N2O'.

$$M_B = \sum_c A_c \times Yl_c \times (1 - HI_c) \times DMcr_c \times burnt_c \quad (26)$$

$A_c$  is the area of cultivation (in ha) under crop  $c$  (available in table crop.csv)

$Yl_c$  is the yield of the crop  $c$  (in t.ha<sup>-1</sup>). The information is available in table 'crop\_param.csv'.

$HI_c$  is the harvest index of the crop  $c$  (in percentage). The information is available in table 'crop\_param.csv'.

$DMcr_c$  is the Dry matter content of residues (in %). The information is available in table 'crop\_param.csv'.

$burnt_c$  is the fraction of crop residues that is burnt (from crop.csv table or average per crop if not available)

On overall, burning of crop residue is not an important source of GHG emissions (less than 0.1%)

## GHG emissions

All the previous emissions are converted to CO<sub>2</sub> equivalent (either 23 kg CO<sub>2</sub>.kg CH<sub>3</sub><sup>-1</sup> or 310 kg CO<sub>2</sub>.kg N<sub>2</sub>O<sup>-1</sup>). The parameters to convert gas to CO<sub>2</sub> equivalent are in the parameter list under the name 'CH<sub>4</sub>toCO<sub>2</sub>' and 'N<sub>2</sub>OtoCO<sub>2</sub>'. The sum of all the emissions are saved in the variable 'GHGEmissions.T1' and 'GHGEmissions.T2', and expressed in kg CO<sub>2</sub>.yr<sup>-1</sup>.

### Visualization of the distribution of GHG emission and its sources

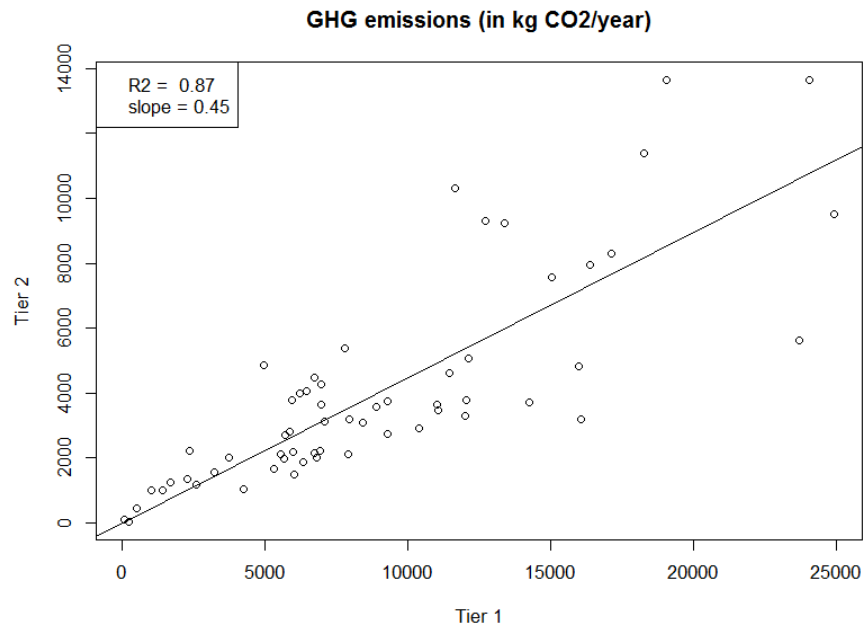


Figure 14: Comparison of the total GHG emission from Tier 1 and Tier 2 calculation.

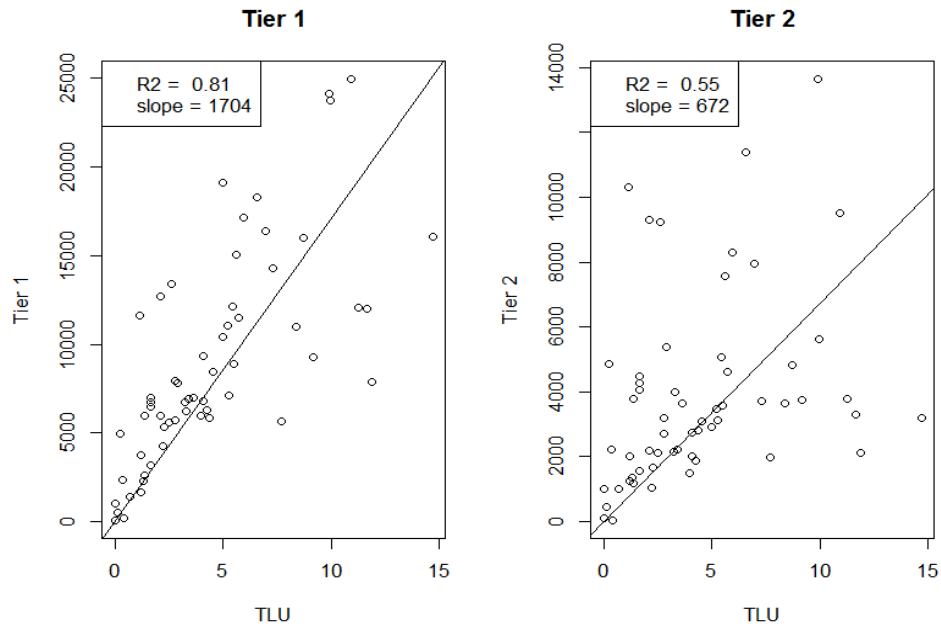


Figure 15: Comparison of the herd size (in TLU) with the total GHG emission from Tier 1 and Tier 2 calculation.

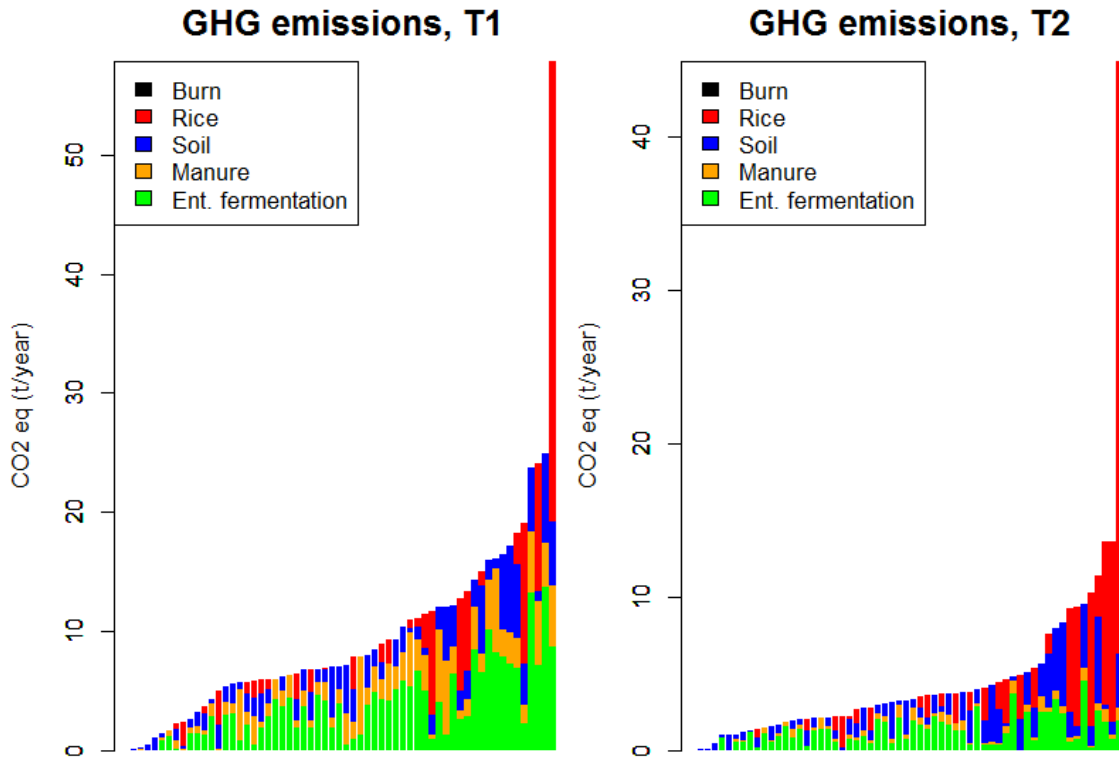


Figure 16: Distribution of the GHG emission among the 60 households, ordered per level of emissions.

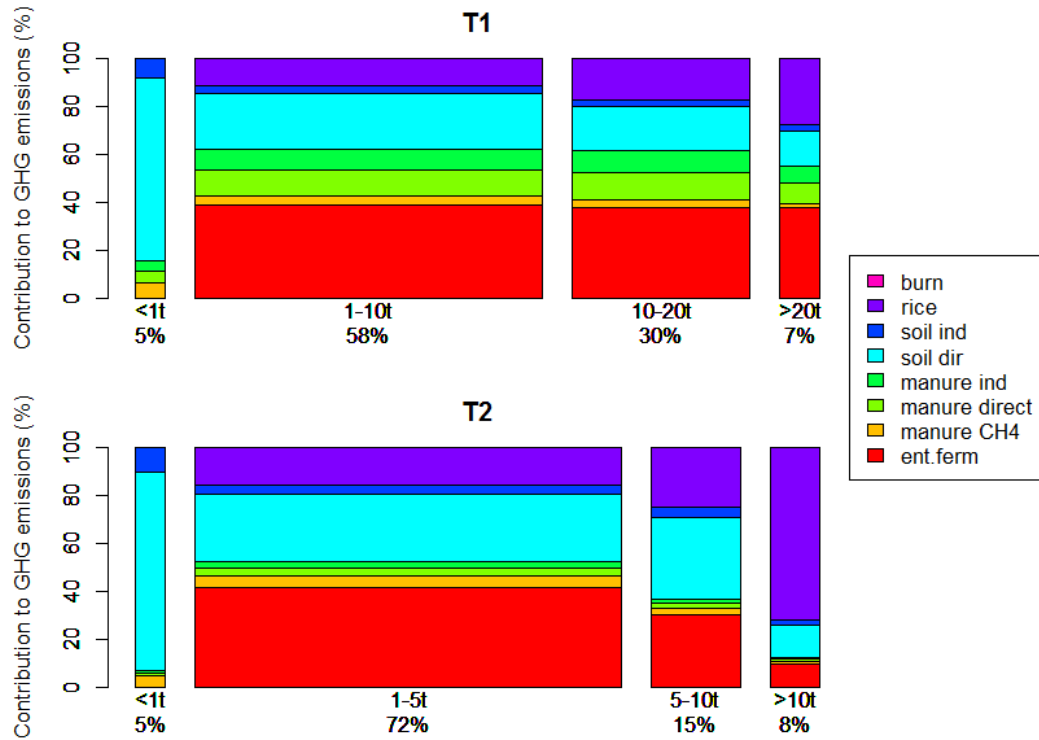


Figure 17: Contribution (in %) of the different sources of GHG emissions, households have been clustered according to their level of GHG emissions.

## N Balance Calculations

### IN1: Mineral fertilizer

$$IN1 = F_{SN} \quad (27)$$

$IN1$  is the N content of the mineral fertilizer applied to fields per hectare (in N kg. yr<sup>-1</sup>)

$F_{SN}$  is the annual amount of synthetic fertiliser N applied to soil (kg N.yr<sup>-1</sup>). It is available in the 'HHinfo' table.

### IN2: Manure

$$IN2 = F_{ON} \quad (28)$$

$IN2$  is the N content of the manure applied to the field (in N kg. yr<sup>-1</sup>)

$F_{ON}$  is the annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (kg N.yr<sup>-1</sup>). It is calculated from (19), following Tier 1 calculation.

### IN3: Atmospheric deposition

$$IN3 = 0.14 \times \sqrt{rainfall} \times A \quad (29)$$

$IN3$  is the N content of the atmospheric deposition (in N kg. yr<sup>-1</sup>)

0.14 is a coefficient of atmospheric deposition of N per hectare and per amount of rainfall in kg.ha<sup>-1</sup>.mm<sup>-1/2</sup>. The value is saved in the parameter list under the name 'depo'.

$rainfall$  is the annual rainfall in the region (available in the region\_param.csv file).

$A$  is the area cultivated in ha (in HHinfo table).

### IN4: Biological N-fixation

$$IN4 = N_{nosymbiotic} + N_{symbiotic} \quad (30)$$

$IN4$  is the N fixation (in N kg. yr<sup>-1</sup>)

$N_{nosymbiotic}$  is the Non symbiotic N fixation by crops. It is calculated from (31).

$N_{symbiotic}$  is the Symbiotic N fixation by crops (N fixing crops only). It is calculated from (32).

$$N_{nosymbiotic} = (2 + (rainfall - 1350) \times 0.005) \times A \quad (31)$$

$A$  is the area cultivated in ha (in HHinfo table).

$rainfall$  is the annual rainfall in the region (available in the region\_param.csv file).

$$N_{symbiotic} = 0.5 \times \sum_c A_c \times Yl_c \times N_c \quad (32)$$

$A_c$  is the area of cultivation (in ha) under crop  $c$  (available in table crop.csv)

$Yl_c$  is the yield of the crop  $c$  (in kg.ha<sup>-1</sup>). The information is available in table 'crop\_param.csv' (but in t.ha<sup>-1</sup>).

$N_c$  is the N content of the crop  $c$  (in percentage of N in the total crop and crop residue produced). It is calculated from (33).

0.5 is a constant

$$N_c = (1 - HI_c) \times DMcr_c \times Nres_c + (HI_c \times DM_c \times Ncrop_c) \quad (33)$$

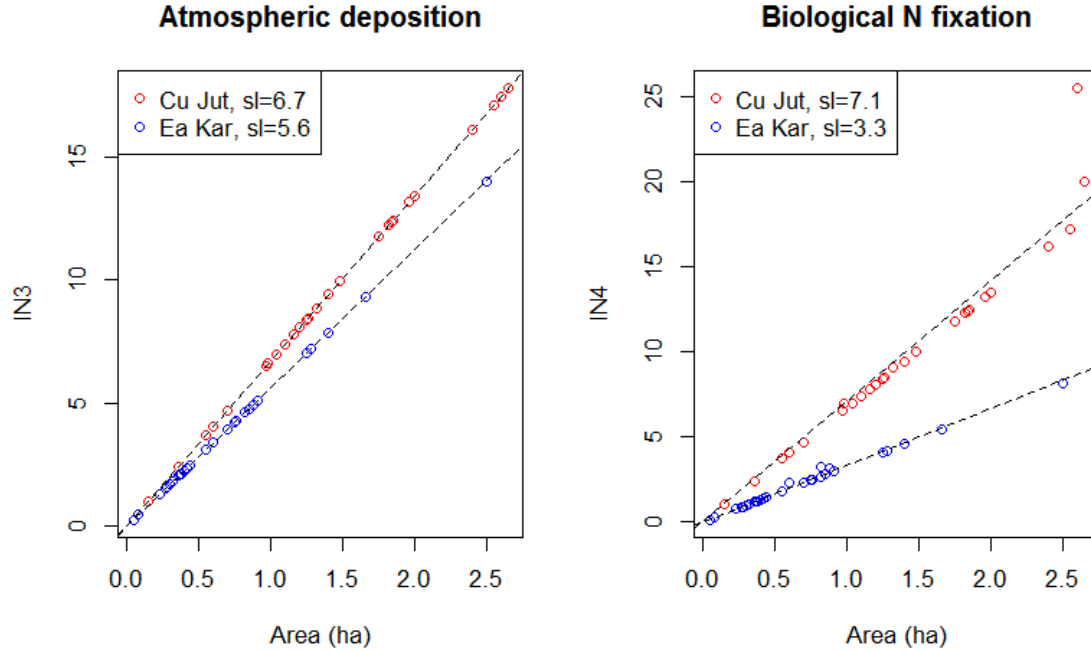
$HI_c$  is the harvest index of the crop  $c$  (in %). The information is available in table 'crop\_param.csv'.

$DMcr_c$  is the Dry matter content of residues (in %). The information is available in table 'crop\_param.csv'.

$DM_c$  is the Dry matter content of the crop (in %). The information is available in table 'crop\_param.csv'.

$Nres_c$  is the N content of the crop residue ( kg N . kg CR<sup>-1</sup>). The information is available in table 'crop\_param.csv'.

$Ncrop_c$  is the N content of the crop ( kg N . kg crop<sup>-1</sup>). The information is available in table 'crop\_param.csv'.



**Figure 18:** Relation between the area (in ha) and the atmospheric deposition and the biological N fixation. The symbiotic component of the N fixation is small and concerns only few households.

Figure 18 shows that 1ha of land receive between 5.6 and 6.7 kg N.yr<sup>-1</sup> from atmospheric deposition, and between 3.3 and 7.1 kg N.yr<sup>-1</sup> from non-symbiotic N fixation. These numbers (and equations) are estimations from empiric studies and have not been “verified” for Vietnam. They will be removed from the global N balance because of their unreliability.

### OUT1: Crop yield

$$OUT1 = \sum_c A_c \times Yl_c \times HI_c \times DM_c \times Ncrop_c \quad (34)$$

*OUT1* is the N content of crop harvested (in kg N .yr-1)

*A<sub>c</sub>* is the area of cultivation (in ha) under crop *c* (available in table crop.csv)

*Yl<sub>c</sub>* is the yield of the crop *c* (in t.ha<sup>-1</sup>).

*HI<sub>c</sub>* is the harvest index of the crop *c* (in %)

*DM<sub>c</sub>* is the Dry matter content of crop (in %)

*Ncrop<sub>c</sub>* is the N content of the crop ( kg N . kg crop)

## OUT2: Crop residue

$$OUT2 = \sum_c A_c \times Yl_c \times (1 - HI_c) \times DMcr_c \times Ncr_c \times (1 - mulch_c) \quad (35)$$

*OUT2* is the N content of crop residue removed (in kg N .yr-1)

*A<sub>c</sub>* is the area of cultivation (in ha) under crop *c* (available in table crop.csv)

*Yl<sub>c</sub>* is the yield of the crop *c* (in t.ha<sup>-1</sup>).

*HI<sub>c</sub>* is the harvest index of the crop *c* (in %)

*DMcr<sub>c</sub>* is the Dry matter content of residues (in %)

*Ncr<sub>c</sub>* is the N content of the crop residue ( kg N . kg CR)

*mulch<sub>c</sub>* is the fraction of crop residues that is kept as mulch (from crop.csv table)

## OUT3: Leaching

From Smaling 1993:

$$OUT3 = (Ncontent \times A + IN1 + IN2) \times (\alpha_s \times rainfall + \beta_s) \quad (36)$$

*OUT3* is the N content leaching (in N kg. yr<sup>-1</sup>)

*Ncontent* is the N content of soil (in kg N. ha<sup>-1</sup>). The information is computed from (37).

*A* is the total area cultivated in ha (in hhinfo.csv)

*IN1* and *IN2* are defined previously and are respectively the N content from fertilizer - equation (27), and manure - equation (28).

*rainfall* is the annual rainfall in the region (available in the region\_param.csv file).

$\alpha_s$  and  $\beta_s$  are parameters varying depending on the clay content of the soil (in the parameters list, under the name 'alpha' and 'beta'). The clay content is available in the region\_param.csv file.

$$Ncontent = 0.1 \times soilN \times BD \times SD \quad (37)$$

*soilN* is the weight of N per unit of weight of soil in ppm (or mg N.kg<sup>-1</sup>)

*BD* is the bulk density (in g.cm<sup>-3</sup>). The information is available in the region\_param.csv file.

*SD* is the soil depth (in cm). The information is available in the region\_param.csv file.

## Out 4: Gaseous losses

$$OUT4 = (Ncontent \times A + IN1 + IN2) \times [(0.13 \times soilClay - 9.4) + (0.01 \times rainfall)] \quad (38)$$

$OUT4$  is the N content from gaseous losses (in N kg. yr<sup>-1</sup>)

$Ncontent$  is the N content of soil (in kg N. ha<sup>-1</sup>). The information is computed from (37).

$A$  is the total area cultivated in ha (in hhinfo.csv)

$IN1$  and  $IN2$  are defined previously and are respectively the N content from fertilizer - equation (27), and manure - equation (28).

$rainfall$  is the annual rainfall in the region (available in the region\_param.csv file).

$soilClay$  is the clay content of the soil (in %). It is available in the region\_param.csv file.

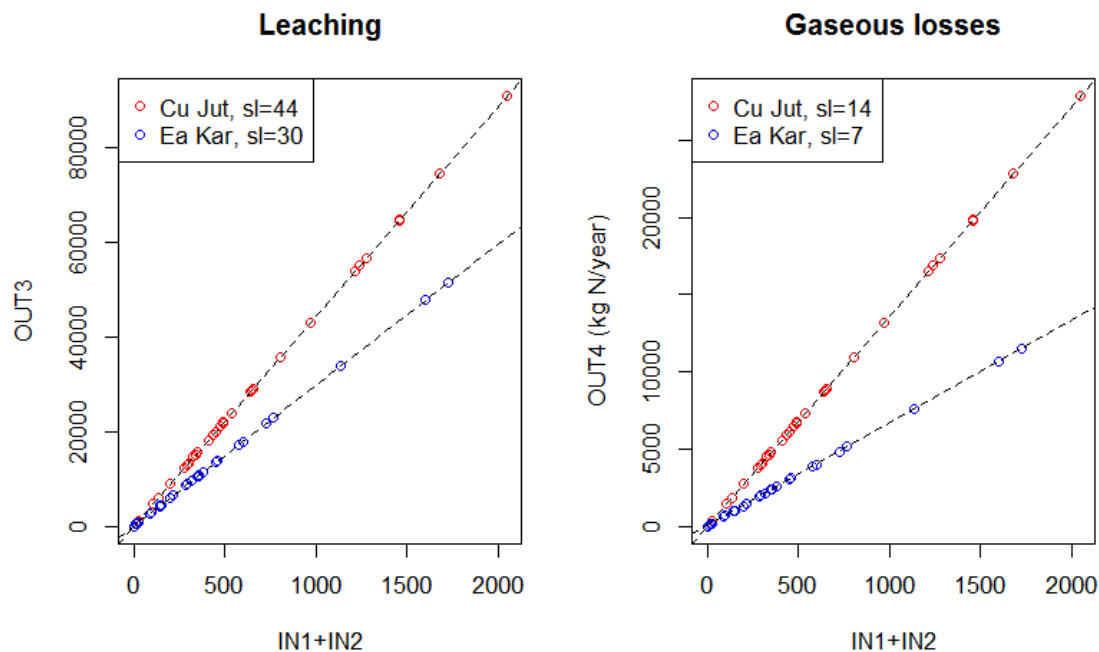


Figure 19: Relation between N input of fertilizer and manure and the leaching.

Figure 19 shows that 1kg N.yr<sup>-1</sup> applied on the field is responsible for between 30 and 44 kg N.yr<sup>-1</sup> leaching, and 7 to 14 kg N.yr<sup>-1</sup> lost as gases! More N go out of the system than N applied on the field ! These numbers (and equations) are estimations from empiric studies and have not been “verified” for Vietnam (in that case, they are obviously wrong!). They will be removed from the global N balance because of their unreliability.

## OUT5: Erosion

$$OUT5 = erosion \times Ncontent \times 1.5 \times A \quad (39)$$

*OUT4* is the N content from gaseous losses (in N kg. yr<sup>-1</sup>)

*erosion* is the soil loss in kg.ha<sup>-1</sup>. It is calculated from (40)

*A* is the total area cultivated in ha (in hhinfo.csv)

*Ncontent* is the N content of soil (in kg N. ha<sup>-1</sup>). The information is computed from (37).

1.5 is a constant

$$Erosion = R \times K \times LS \times C \times P \quad (40)$$

*R* is the erosivity of rainfall. This is calculated as a function of rainfall (mm) which is in the 'region' table.  $R = 0.55 \times rainfall - 4.7$

*K* is the erodibility of soil. *K* values are dependent on the 'soil' in the 'region' table. The *K*-factors default values are loaded in the 'Parameters' from the file 'Erosion\_soil.csv'.

*LS* is the length and steepness of slope. The *LS* values are dependent on the 'slope' in the 'region' table. The *LS* factors default values are loaded in the 'Parameters' from the file 'Erosion\_slope.csv'.

*C* is the crop cover factor. The *C* values are dependent on the 'Land cover' in the 'crop' table. The *C*-factors default values are loaded in the 'Parameters' from the file 'Crop\_Param.csv'

*P* is the management factor. The *P* values are dependent on the 'Landuse' system in the 'region' table. The *P* factors default values are loaded in the 'Parameters' from the file 'Erosion\_mngt.csv'.

The soil erosion calculation is done in the function 'erosion', taking as parameters the crop table, the region table and the parameters. All crops (in a given region) are grown on similar soil, slope, management and rainfall environment. The erosion is clearly proportional to the land area, with a *C* factor having low variation of values.

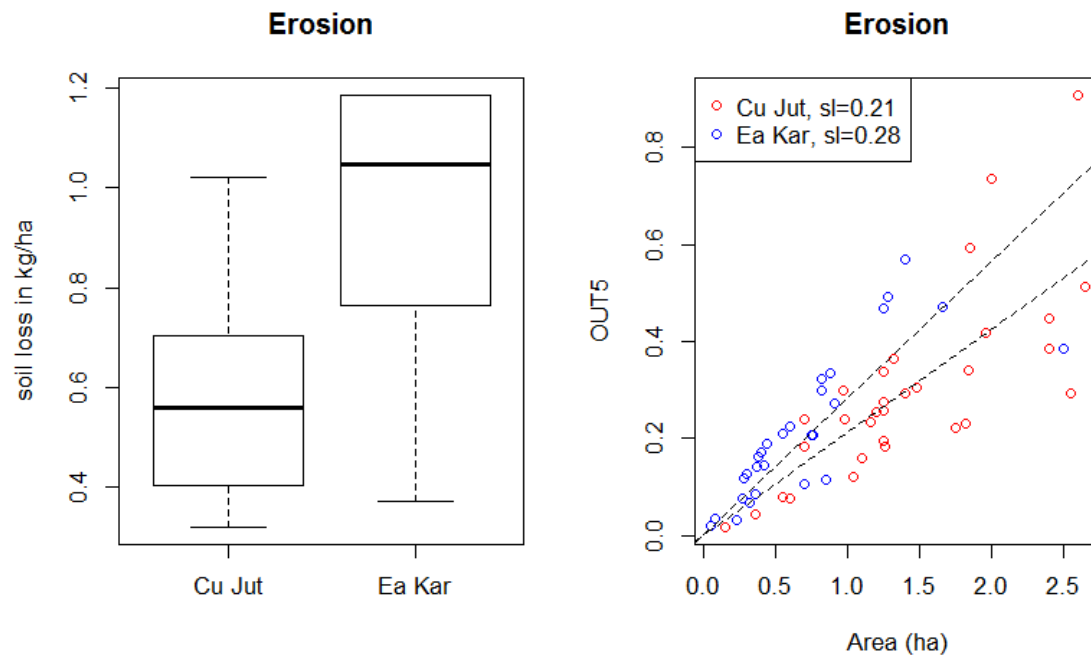
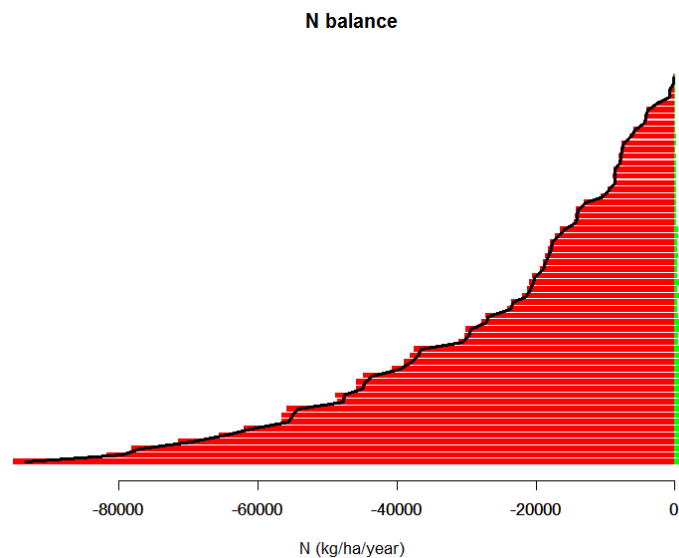
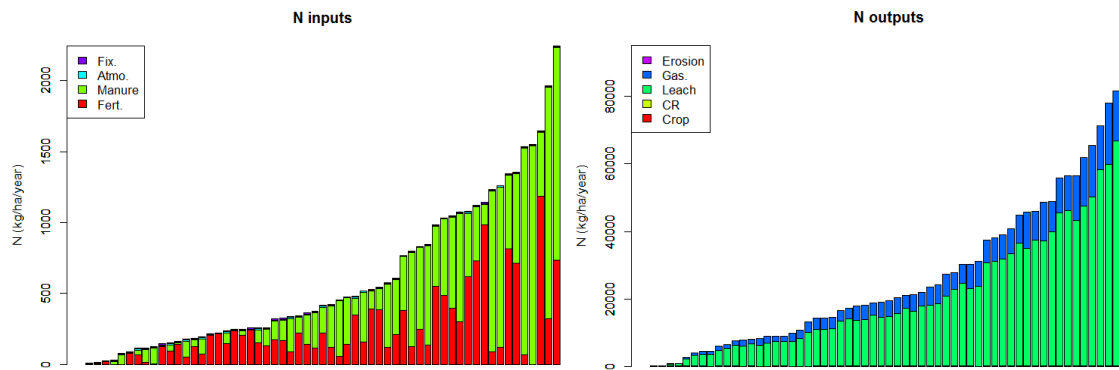


Figure 20: Erosion (= soil loss ) per hectare, and N loss due to erosion vs the land area.

#### Visualization of the distribution of GHG emission and its sources

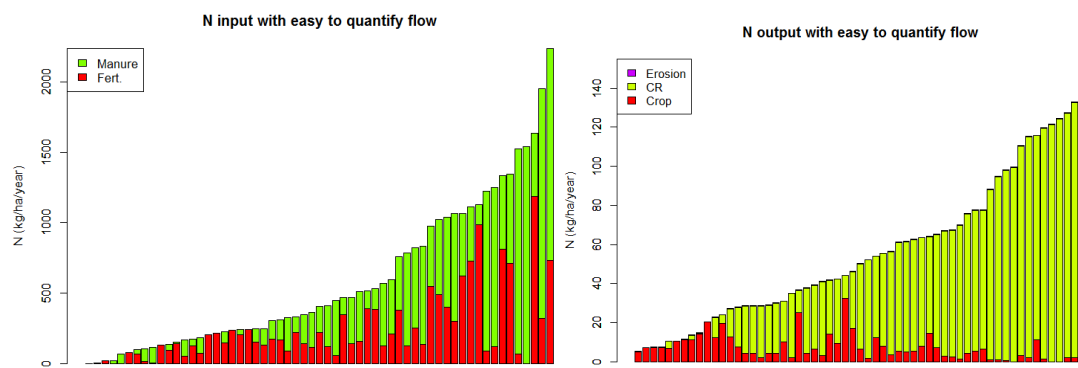
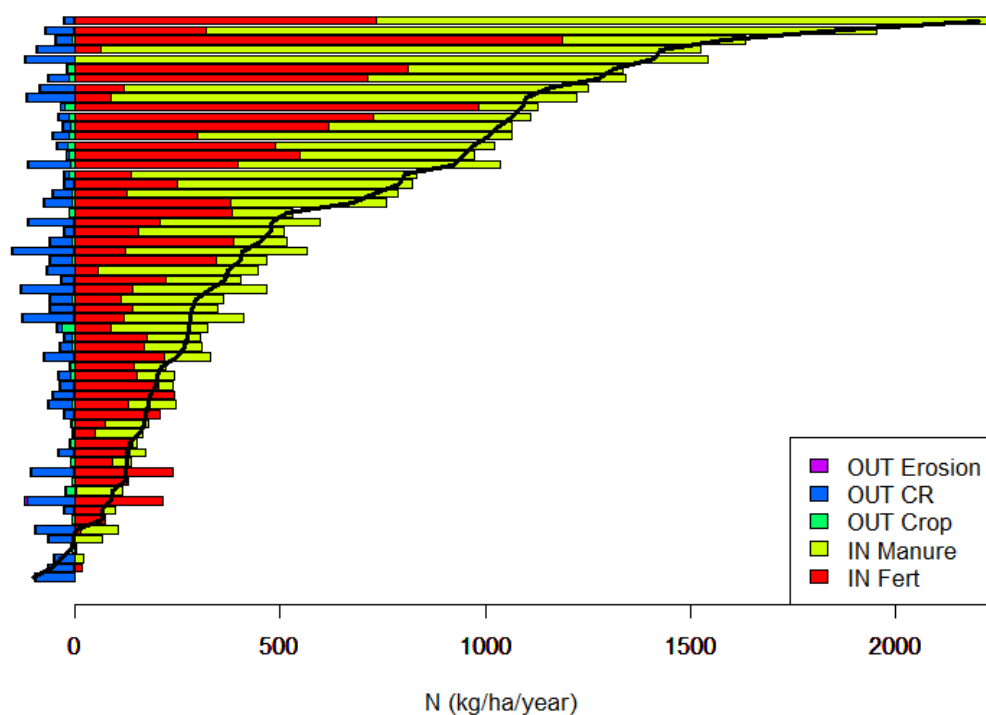
If we keep the difficult-to-quantify nutrient flows (IN3, IN4, OUT3, OUT4), the OUT3 is the dominant factor and bring all N balances negative.





If we remove the difficult to estimate flows, then we get :

### N output with easy to quantify flow



## Remarks:

### About GHG emissions:

- Calculation seems quite robust but the emission factors between Tier 1 and Tier 2 are quite different.
- If Tier 2 calculation is “right”, then Tier 1 calculation make on average an over estimation of 100% (Figure 14)! That’s quite an error! This is clearly visible from Enteric Fermentation (Figure 6) and for the nitrogen excreted from manure (Figure 8). In these two cases, the differences are too high to be true! In other words, we may speak of other quantities or other realities; or some of the parameters are not correct for the region/site.  
For example, one calf has an enteric fermentation of 16kg CH<sub>4</sub>/year (Tier 1) or 2kg CH<sub>4</sub>/year (Tier 2). The same calf excretes 22 kg N/year (Tier 1) or 3 kg N/year (Tier 2). There are clearly 2 different realities here!
- The low emitting farmers do not have livestock, and the only resource emitting GHG is the soil and the little fertilizer they use. For the other households, enteric fermentation is responsible for around 40% of the GHG emissions. Livestock is the main emitting factor, but rice can overpass the emissions of livestock for the large rice grower (Figure 17).

### About N balance :

- N balance is very region specific, the flows are estimated on empirical evidence and the equations are quite “weird”. At this stage neither of the two solutions shown above are satisfactory:  
removing difficult to estimate flows is quite incorrect since “major nutrient flows are lacking”, i.e. leaching and gaseous losses  
keeping difficult to estimate flows is wrong since we create N from nothing !

## Way further:

- Checking the calculation with data having a known range of GHG emission and N balance.
- Make an automatic link with FA calculation and computing the GHG emission per capita and GHG per unit output (kcal/person/day).
- Process other dataset, with more precise data on the feed basket and on manure management to implement proper Tier 2 calculation.
- Find a solution for the N balance that could be applied worldwide, without changing the equation per region. Or estimate the leaching and gaseous losses of N from GHG emission.

[To be continued]

## References

### **GHG emission:**

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). Published: IGES, Japan.

Kuyah, S., Dietz, J., Muthuri, C., Jamnadass, R., Mwangi, P., Coe, R., & Neufeldt, H. (2012). Allometric equations for estimating biomass in agricultural landscapes: I. Aboveground biomass. *Agriculture, Ecosystems and Environment*, 158, 216–224. doi:10.1016/j.agee.2012.05.011

Vlaming, J. Monitoring nutrient flows and economic performance in tropical farming systems ( NUTMON) Annex p.3 ,4 and 5

Bosch, H et. al. (1998) Monitoring nutrient Flows and economic performance in African farming systems ( NUTMON ) II Tool development p.55

Gachimbi, L.N et al. (2005). Nutrient balances and their monitoring (word doc; dropbox)

Stoorvogel, J J et. Al (1993) Calculating soil nutrient balances in Africa at different scales - I. Supra-national scale p. 230

### **N balance:**

Amdihun, A., Gebremariam, E., Rebelo, L. and Zeleke, G. (2014). Modelling soil erosion dynamics in the Blue Nile Abbay Basin: A landscape approach. *Research Journal of Environmental Sciences*. ISSN 1819-3412/DOI 10.3923/rjes.2014 (pp. 4-6)

L. T. Phong • J. J. Stoorvogel, M. E. F. van Mensvoort • H. M. J. Udo (2011). “Modeling the soil nutrient balance of integrated agriculture-aquaculture systems in the Mekong Delta, Vietnam”, *Nutr Cycl Agroecosyst* (2011) 90:33–49