# Atmospheric deposition

Atmospheric deposition was only calculated for nitrogen, while phosphorus dust deposition was assumed negligible. Data for wet and dry deposition was collated from EMEP for the period 2000-2017. For the remaining years (i;1987-1999), atmospheric N deposition was scaled according to total annual ammonia emissions and using the year 2000 as baseline.

Atmospheric N deposition was calculated separately for the the different fertiliser allocation mechanisms implemented (i.e., with or without manure surplus and the two different approaches employed; **currently only method 1 is implemented**), as these heavily influence total ammonia emissions.

# Fodder production

### Getting other animal population for sheep and goat

The remaining sub-modules calculate sheep and goat nutrient flows based on the total population as the N excretion already includes for younglings and the N excretion rate is the same for these categories. In order to properly calculate the energy requirement for growth and lactation, these populations were disaggregated according to Statistics Portugal data. Data was collected at the agrarian region level. Fractions of these subclasses’ populations were calculated at this spatial resolution and “downscaled” to the municipality scale, followed by its computation based on downscaled-and-interpolated total animal populations at the municipality scale.

Similarly, sheep and goat milk production were collated from Statistics Portugal. The same procedure was used as in dairy cows’.

Because goat population data does not account for milking goats, it was assumed that 10% of the goats (var\_id = ‘11’) are lactating. When interpolating milk produced per head, a minimum of 500 milk head-1 was assumed. Furthermore, for wool production, it was assumed that 5% of each Sheep subclass are younglings and do not produce wool.

### Nitrogen feed intake

Nitrogen feed intake here is estimated as the sum of the N retention and N excretion. Total N excreted per the different animals was calculated in the manure module; the N retained in the body was estimated according to the GLEAMS model for the three different main classes: ruminants (large and small; dairy and non-dairy), pigs and poultry.

For large ruminants, GLEAMS distinguishes three different cohorts: adult females (dairy cows), adult males (>2 years and Non\_dairy) and the remaining. For dairy animals, N retention (kg N head-1 yr-1) was calculated as follows:

where:

Milk – Daily milk production (kg milk head-1 day-1)

Milkprot – the protein content of the milk ( protein/100)

Ckg – younglings’ weight (calves, goat and lamb kids) (kg head-1 day-1)

NEgro – the net energy for growth of replacement animals (i.e., calves , goat and lamb kids) (Mj head-1 day-1)

DWGrf – daily weight gain (kg head-1 day-1)

For dairy cows, the protein content was collated from Statistics Portugal for the period 2003-2017 and linearly interpolated to the remaining years; for sheep and goat it was set to 5.4 and 3.1%, respectively. The same procedure was applied to annual milk production for sheep and goats, though a minimum threshold of 50 and 500 kg head-1 year-1 was applied. The remaining parameters were collated from the national inventory reports and GLEAMS. Furthermore, NEgro was computed also according to GLEAMS for large and small ruminants.

For large ruminants:

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where

LW – live weight of growing animals (kg head-1)

Cgro – GLEAMS parameter (Table 3.27 in GLEAMS documentation)

AFkg – live weight of an adult animal (>2 years) (kg head-1)

For small ruminants:

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where

a, b and c - GLEAMS parameters (Tablel 3.28 in GLEAMS documentation

Ckg – weight of lambs/kids at birth (kg head-1)

# Gaseous emissions

### Ammonia (NH3)

Ammonia emissions were calculated for manure management systems (housing including yards, storage), the field application of organic and inorganic fertilisers (biosolids, manure, synthetic fertilisers and grazing) and crop residues burnt *in situ*. Emissions from manure spreading were calculated for slurry and solid manure. The methodology used follows **EMEP (2016)**.

### Nitrous oxide (N2O)

### Nitrogen oxides (NOx)

Nitrogen oxides emission were calculated

# Runoff module

Runoff losses are calculated for the **recent application of nutrients to the soil from grazing and the field application of fertilisers** (sludge, manure and synthetic fertilisers) and for the “**memory effect**” over time (Beusen et al., 2015). The former applies the MITERRA-EUROPE approach to first estimate the runoff fraction (frunoff; %N-input) based on environmental parameters (Velthof et al., 2009). Runoff parameters receive as input static data (slope, soil texture and depth to rock) and dynamic data calculated on a yearly basis (land use, precipitation surplus). Land use classes were derived from the land use module.

Two different methodologies were applied to calculate frunoff: one based on **the potential land use allocation to different crops and management practices**, the other calculated by accounting **for spatial explicit crop areas** (*to be implemented*). The first approach was implemented by firstly separating management practices (fertilisers and grazing) and by defining allowed land use classes to allocate different crop nutrient flows. Land use classes were crop nutrient flows are not allowed were masked out and set to NA, while the authorized land uses were set to 1 and multiplied by the annual runoff fraction. The following crop classes were aggregated and further allocated: AnnualCrops (cereals, vegetables, potatoes, pulses), FruitTrees (citrus, fresh fruits, dried nuts), IntensivePasture, OliveGrove, Vineyards and Rice. For grazing, it was assumed that this practice only occurs in certain LU classes.

The second approach was calculated by masking spatially explicit crop areas from the runoff fraction mask.

Table 2. Allowed land use (allocation) classes for AnnualCrops (Activity\_data/General\_params/LULCC/Runoff/LU\_allocation)

|  |  |  |  |
| --- | --- | --- | --- |
| clc\_id | label | LULCC\_label | allow\_runoff |
| 1 | urban | urban | 0 |
| 2 | forest | forest | 0 |
| 3 | wetlands | wetlands | 0 |
| 211 | Non-irrigated arable land | Non\_irrigated | 1 |
| 212 | Permanently irrigated land | Permanently\_irrigated | 1 |
| 213 | Rice fields | Rice | 0 |
| 221 | Vineyards | Vineyards | 0 |
| 222 | Fruit trees and berry plantations | Fruit\_trees | 0 |
| 223 | Olive groves | Olive\_groves | 0 |
| 231 | Pastures | Pastures | 0 |
| 241 | Annual crops associated with permanent crops | Annuals\_permanents | 1 |
| 242 | Complex cultivation patterns | Complex\_patterns | 1 |
| 243 | Land principally occupied by agriculture with significant areas of natural vegetation | Agriculture\_naturalVeg | 0 |
| 244 | Agro-forestry areas | AgroForestry | 0 |
| 321 | Natural grasslands | Natural\_grasslands | 0 |
| 512 | Water bodies | Water\_bodies | 0 |

Nutrient runoff losses from recent application (NutRes, rf) were calculated as the product of runoff fractions and the net nutrient returned to the soil (NutRes, net). For nitrogen, ammonia (NH3) emissions were subtracted from the field application of fertilisers and grazing.It is implied that that the total Nutres, rf is the sum of the runoff losses from all crop classes **and** for grazing and field application.

For instance, for the nitrogen losses of Irrigated\_maize (an annual crop) from manure application, frunoff was calculated by allocating the net nutrient losses to the allowed land use classes (i.e., gross manure spreading minus the NH3 emissions following application (Table 1).

## Summary of operations

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| --- | --- |
| **Implemented** | * NITROGEN: Runoff losses from recent application of fertilisers (biosolids, manure, synthetic fertilisers) for all crops and for grazing * frunoff calculated using the first approach (land use allocation approach) |
| **Not implemented yet** | * NITROGEN, PHOSPHORUS: “Memory effect” of runoff losses * NITROGEN, PHOSPHORUS: frunoff using spatially explicit crop areas * PHOSPHORUS: runoff losses |