OECD and EUROSTAT

GROSS NITROGEN BALANCES

HANDBOOK

October 2007

For further information on Nitrogen Balances, see the OECD website at: www.oecd.org/tad/env/indicators

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1. Introduction

An adequate supply of nutrients in the soil is essential to crop growth. Some nutrients are required in large amounts, particularly nitrogen, phosphorus and potassium, while others, such as copper and iron, are needed in much smaller quantities but are equally essential to crop growth. Maintaining a healthy balance between nutrients added to the soil and nutrients removed, for example, in crops, is essential to ensure optimal use of resources, and to limit pollution problems, particularly those associated with nitrogen (and phosphate) surpluses.

These problems include pollution of:

- **Surface water** (rivers, lakes and coastal waters), accelerating the process of eutrophication (i.e. algae growth and oxygen shortages in water), which can damage the biodiversity of rivers and lakes and impair their use for drinking water, fishing and recreational purposes (this mainly concerns phosphates);
- **Groundwater** (drinking water), where high concentrations of nitrates can damage both livestock and human health, leading to the need for expensive water purification systems before the water is considered safe for drinking; moreover, groundwater pollution is potentially more problematic than surface water pollution, because once polluted it may take many years before pollutant levels decline even when the source of pollution has been reduced;
- **Air**, from nitrous oxide (N_2O, a greenhouse gas) which is directly emitted from excessive inorganic fertilisers applied to agricultural soil, and from ammonia (NH_3) which volatilises from livestock manure. Volatilised ammonia also contributes to acidification of soils and water.

On the other hand, if more nutrients are persistently removed from the soil than are added (nutrient deficit), the soil will begin to lose its fertility and crops will not thrive. It is important then to be able to calculate nutrient balances in order to identify areas where persistent surpluses or deficits may put natural resources at risk.

For this reason, the calculation of nitrogen (N) balances has been identified as a priority agri-environmental indicator by OECD Member countries. The information provided by N balances is also needed to analyse the interactions between agriculture and the environment, to monitor how environmental concerns are being integrated into agricultural policy, and to evaluate the impact of changes in agricultural policy on the environment. The reader is referred to the OECD (2008) publication: ***Environmental Performance of Agriculure in OECD Countries since 1990,*** which provides the overall framework in which this and other agri-environmental indicators are being developed.[1]

Several joint Eurostat/OECD meetings have been held over the past few years, to identify and agree on the most robust and feasible methodology for the calculation of a nitrogen balance. This handbook sets out the main principles of the agreed methodology across OECD Member countries, discusses the difficulties of their implementation and sets out the solutions agreed at the various meetings. The aim is to be able to consistently produce an indicator based on a single methodology and harmonised definitions for all countries (Eurostat/OECD are also developing a similar approach to phosphate balances).

1 For futher information on this report see the OECD website at www.oecd.org/tad/env/indicators

Sections 2 and **3** provide an overview of the nitrogen cycle and balances as well as the differences between different conceptual approaches (gross balances versus farm-gate balances). **Section 4** describes the methodology to be used to calculate inputs and outputs of nitrogen in agriculture. **Section 5** looks at the methods to calculate nitrogen balances at the regional (sub-national) level.

2. The nitrogen cycle

Nitrogen is used by living organisms to produce a number of complex organic molecules such as amino acids, proteins and nucleic acids. It is an essential element for plant growth. The largest store of nitrogen is found in the atmosphere where it exists as a gas (mainly N_2). This atmospheric store is about one million times larger than the total nitrogen contained in living organisms. Other major stores of nitrogen include organic matter in soil and the oceans. Within most ecosystems, nitrogen is primarily stored in living and dead organic matter.

Organic matter (humus, plant residues, livestock manure) contains large quantities of plant nutrients, including nitrogen. Conversion processes in the soil (mineralisation and nitrification) break down organic matter to supply the plants with nitrogen. This nitrogen may be dissolved in soil water or bound to soil colloids (colloidal clay and mull particles), and is directly available to the plants. Moreover, atmospheric nitrogen may be fixed naturally in the soil through the action of bacteria. A further source of nitrogen input to the soil is wet (in rainfall) and dry deposition of N compounds from the atmosphere. When plants die, nitrogen is returned to the soil and to a lesser degree to the atmosphere, and the cycle is completed.

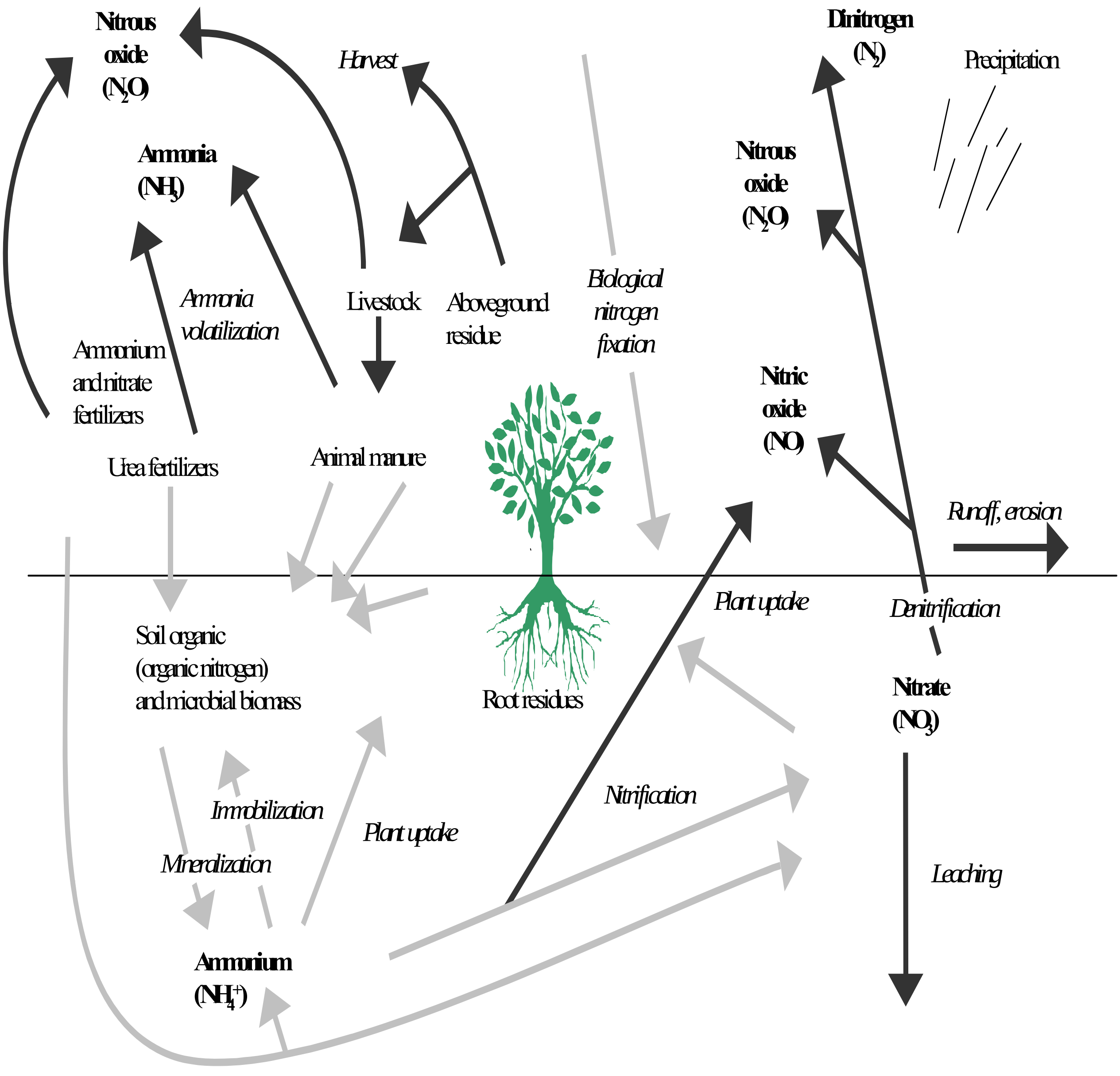
In agriculture this natural nitrogen cycle is interrupted when organic matter is removed in harvested crops and through grazing. Also, certain agricultural practices, such as flooding of paddy fields, lead to loss of soil nitrogen through denitrification (Annex 1). In denitrification, bacteria in anaerobic soils convert nitrate into gaseous nitrogen or nitrous oxide.

Leaching of nitrates from vulnerable soils is also responsible for important losses of soil nitrogen, especially when soils are left bare after harvest, rainfall is heavy and temperatures are low (which reduces the conversion activity of the soil bacteria).

Thus despite its abundance in the atmosphere, nitrogen is often the most limiting nutrient for plant growth. A supplementary input of nitrogen is needed to compensate for these removals and losses and to maintain the balance of nitrogen in the soil.

A supplementary input of nitrogen can be achieved by encouraging natural fixation of nitrogen through the deliberate planting of leguminous plants (the bean family), often in a crop rotation system. But the most common method of supplying supplementary nitrogen is through the spreading of inorganic fertilisers and livestock manure. Not all of this supplementary nitrogen is available to the plants. Some will volatilise from manure, in the form of ammonia (NH_3), during and shortly after spreading, and rainfall will cause run off and leaching of highly soluble nitrate before the plants can absorb it (Annex 1). The volatilisation process can be offset by an increase in the amount of ammonia deposited from the atmosphere. The complex interrelations are illustrated in Figure 1, below.

Figure 1: The nitrogen cycle



Source: OECD (2001), *Environmental Indicators for Agriculture — Volume 3: Methods and Results*, Publications Service, Paris, France

3. Nitrogen balances of agricultural systems

A nitrogen balance calculates the balance between nitrogen added to an agricultural system and nitrogen removed from the system per hectare of agricultural land. Ideally the balance result should be related to the area of agricultural land which is potentially fertilised, to avoid a bias in the result for countries with large extensive and not utilised areas. A deficit over a number of years indicates that the farming system, in particular the soil, is losing its fertility, while a large surplus of N suggests a risk of pollution of soil, water and air, though this may depend also on other factors, such as agricultural practices, weather conditions and soil type.

In many countries, nitrogen surpluses per hectare of agricultural land can be highly variable, with some sub-national regions severely affected by the problem of “excessive” nitrogen and others not. National balances are, in this sense, much less powerful indicators than regional level balances (see Section 5).

Among the methods to calculate the nitrogen balance, two types are in general use:

- The **Farm-gate balance** *(Farm balance or sector balance)* treats the farm (or national agricultural industry) as an entity. Nitrogen recycled within the entity is ignored. This type of balance takes into account the amount of nitrogen imported into the farm or national agricultural industry (i.e. in fertilisers, feedstuffs, etc.) and exported from the farm or the national agricultural industry, i.e. in animal products (e.g. milk, eggs, meat) and crops, excluding fodder crops and grass which are consumed on the farm. The difference between imports and exports is the nitrogen surplus or deficit. This type of balance is very suitable for use at individual farm level and at national level[2].
- The **Gross balance** also treats the farm as the unit to be observed, but attempts to calculate all inputs and outputs from this unit, i.e. the amount of nitrogen used by the farm (e.g. fertilisers, animal manure), through atmospheric deposition, fixed in the soil through biological process, and removed from the soil (in crops and through grazing). In practice the soil includes un-harvested plant material, but not the livestock moving over the land. Thus grass harvested or grazed which is recycled internally within a farm-gate balance, must be explicitly accounted for as nitrogen removed by cutting or grazing and re-deposited as manure.

Although the farm-gate balance and the gross balance use different basic data for the calculation, at national level both methods could be used. However, it is generally more difficult to calculate the farm-gate balance at regional level, as the regional data required on imports and exports are rarely available. ***At present the gross balance methodology is considered by OECD Member countries as the appropriate indicator for calculating comparable nitrogen balances, but does not prevent that some countries use other indicators to track nitrogen balances.***

[2] The principles of the farm-gate balance can also be applied to livestock, to calculate a ‘livestock balance'. A livestock balance assumes that what goes into an animal or herd (feed), must come out again, either as animal product (milk, meat, eggs) or as urine/manure. This livestock balance is an important element in the calculation of manure input or manure coefficients, see Annex 3.

Gross versus net balances

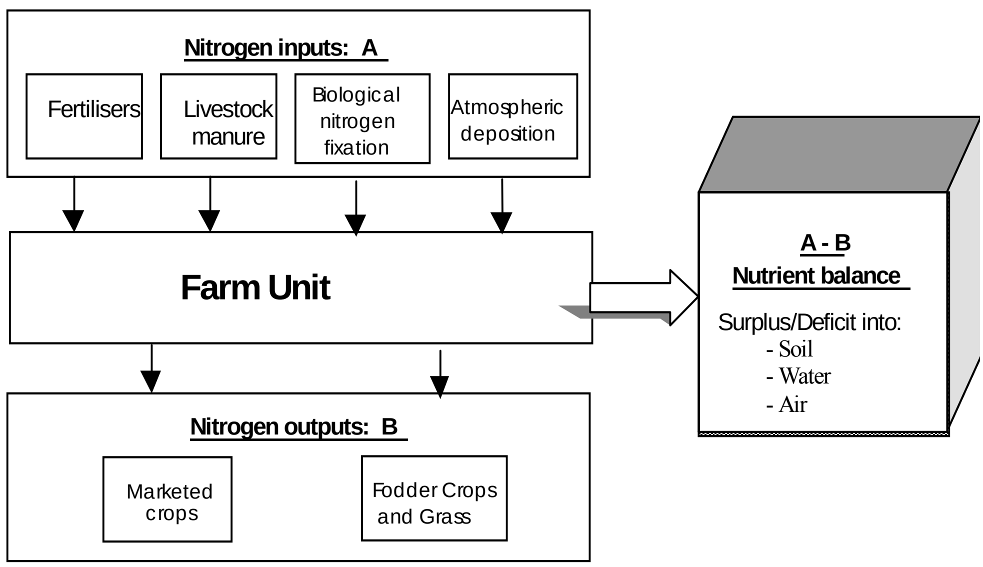
Nitrogen balances can be gross or net. The **gross** nitrogen balance includes all residual emissions of environmentally harmful nitrogen compounds from agriculture into the soil, water and the air. The **net** nitrogen balance includes only emissions into the soil and water, while emissions into the air are excluded; in particular, the net balance deducts the volatilisation of ammonia from agriculture.

The methodology described below refers to the **gross** nitrogen balance, i.e. includes ammonia (NH_3) volatilisation during the process of manure accumulation and manure storage and nitrogen losses from the soil (leaching, denitrification (N_2O), and ammonia volatilisation). These nitrogen losses have the potential to contribute to environmental pollution from excess nitrogen (see also Annex 1). In this way, the gross nitrogen balance could form the basis for other indicators and models describing the potential pollution risk, such as ammonia emissions from agriculture, leaching of nitrates to groundwater, etc. Such indicators/models are beyond the scope of this methodological handbook.

4. The gross nitrogen balance

The following diagram shows the components of the gross nitrogen balance. It shows nitrogen inputs to and outputs from agricultural land by category and the calculation of the surplus or deficit.

Figure 2: The main elements in the gross nitrogen balance calculation



Source: OECD (2001), *Environmental Indicators for Agriculture — Volume 3*: *Methods and Results*, Publications Service, Paris, France

The gross **balance** is calculated as total nitrogen inputs minus total nitrogen outputs and includes the following (see also the "Basic data structure" in Annex 2):

Total inputs to farm unit

a. Fertilisers[3]
   a.1 Inorganic fertilisers
   a.2 Organic fertilisers (excluding livestock manure)

b. Livestock manure

c. Biological nitrogen fixation (nitrogen fixed in the soil)

d. Atmospheric deposition of nitrogen compounds

e. Other inputs (seeds and planting material, …)

Total outputs from farm unit

a. Marketed crops, including marketed fodder crops

b. Non-marketed fodder crops and grass (harvested and grazed)

4.1 Inputs

4.1.a Fertilisers

Inorganic fertilisers are chemical mixtures, applied to agricultural land:

- Simple mineral fertilisers, e.g. urea, ammonium nitrate and sulphate, etc.
- Complex mineral fertilisers, e.g. NP, NK and NPK mixtures
- Mineral-organic fertilisers, e.g. calcium cyanamid

Data on sales or consumption of inorganic fertilisers in terms of N content are generally readily available within countries.

Organic fertilisers (excluding livestock manure) include urban compost and sewage sludge disposed of by spreading on agricultural land. Generally urban compost data are not available for this component of the balance, although data on the industrial production (not actual use) of these organic fertilisers are available from the manufacturers in some countries. However, if its contribution to the balance is considered to be small, it can be left out of the calculations, which will have little effect on the final balance.

[3] "Fertilisers" and "Livestock manure" are the main sources of inputs in the gross nitrogen balance. The term "Fertilisers" in this context covers inorganic nitrogen fertilisers and organic fertilisers (excluding livestock manure) applied to agricultural land in order to enrich the soil. The term "Livestock manure" covers the volume of manure generated by livestock. For the calculation of the nitrogen balances, the term "organic fertilisers" covers only organic inputs from non-agricultural sectors, such as sewage sludge and urban compost. As such "Fertilisers" and "Livestock manure" are clearly distinguished in the calculation (see also Figures 1 and 2).

4.1.b Livestock manure

The quantities of N excreted by livestock and subsequently spread on agricultural land as manure are directly related to the number and category of livestock present. The quantities of nitrogen in livestock manure[4] are estimated by multiplying the number of animals by a manure coefficient, for each category of livestock.

<u>For each livestock category:</u>
Estimated quantity of N in livestock manure [kg N/year]
=
Number of animals [heads]
X
Manure coefficient [kg N/head/year]

Ideally the calculation of nitrogen in livestock manure input should take into account:

a) livestock manure not used on agricultural land (including national exports, if any)

b) change in livestock manure stocks intended for use on agricultural land

c) national livestock manure imports for use on agricultural land.

The input of livestock manure to agricultural land over a given period is then as follows:

Total input of livestock manure to agricultural land
=
Livestock manure production – total manure withdrawals (including national manure exports) + change in manure stocks (beginning stocks – end stocks) + national manure imports

However, in most cases, "national exports", "change in stocks" and "national imports" are negligible.

Care must be taken when determining the "Number of animals", especially with those animals like fattening pigs and poultry which have several production cycles a year. These production cycles should be directly reflected in the "Manure coefficients". In this case, the total number of animals should be the recorded number on a given census day during the year.

4 For the gross N balance, the N in manure is equal to the N in excretion, because no deduction is made for volatilisation of NH_3 during the process of manure accumulation and storage, which occurs between the time of excretion and the time of spreading of the manure.

The above-mentioned calculation method of N in livestock manure is preferred. But where countries are unable to provide the manure coefficients in terms of "kg/head/year", the unit "kg/head" can be applied. This leads to the following alternative calculation method:

For each livestock category:
Estimated quantity of N in livestock manure [kg N]
=
Number of animals [heads]
X
Manure coefficient [kg N/head]

The production cycles are then directly reflected in the "Number of animals" (and not in the "Manure coefficients"). In this case, the total number of animals should not just be the recorded number on a given census day during the year, but number should be multiplied by the average number of production cycles per year. For example, when there are three production cycles for fattening pigs during a year, and 30 fattening pigs are kept at the census day, the number of animals used in the calculation should be 90. However, where data are lacking on the number of production cycles, the total number of these animals could be estimated from the number of slaughtered animals during the year.

There are two approaches to the calculation of coefficients of livestock manure. The first and preferred approach is to derive coefficients (i.e. kg N/head/year or kg N/head) directly from livestock manure itself. The second approach is to apply the concept of the 'livestock balance' (see Annex 3). The latter approach additionally requires data sets on total feed consumed and total livestock products (e.g. milk, meat, eggs and non-commercial parts of animals such as head, skin, bones and intestines) and their respective conversion rate to nitrogen content.

4.1.c Biological nitrogen fixation (nitrogen fixed in the soil)

Nitrogen is fixed in the soil:

1. Through the action of bacteria which live symbiotically in root nodules of leguminous crops (field beans, soybeans, clover, alfalfa, …).

2. By free living soil organisms.

<u>Leguminous crops</u>

The amount of N fixed in the soil by symbiotic bacteria is directly related to the area under crop and is calculated as:

Quantity of N fixed in the soil [kg N]
=
Cultivated area of leguminous crop [hectare]
X
N fixation coefficient for the given crop [kg N/hectare]

Normally, farm surveys provide data at national and regional level on the areas under cultivation. However, leguminous crops, especially those planted specifically for N fixation, are often grown as secondary crops during the period when the field might otherwise be bare. Statistics on crop areas may thus not be available, as these generally refer only to main crops.

Where no data on coefficients are available, agricultural advisory services or other research sources may be able to provide an indicative figure for N fixation per hectare for the country or region. This can then be applied to the total area (hectares) under leguminous crops in the country or region to give an estimate of the total N fixed by these crops, and also provide a rough estimate for leguminous plants in grassland.

Free living soil organisms

The amount of N fixed by free living soil organisms is directly related to the land area data, i.e. arable, permanent crop and permanent pasture land, and is calculated as;

Quantity of N fixed by free living soil organisms [kg N]
=
area of each type of land [ha]
X
N fixation coefficient for the given type of land [kg N/ha]

4.1.d Atmospheric deposition of nitrogen compounds

Nitrogen (N_2), the dominant component of the atmosphere, is comparatively unreactive. However, nitrogen is also present in the atmosphere in other chemical forms[5], some of which are relatively reactive. Rainfall often contains dissolved nitrogen compounds which are then deposited on the land. Dry deposition also occurs.

Countries which are signatories to the international conventions to reduce emissions of acidifying and global warming substances will generally have data on the deposition of these substances (e.g. the data from the monitoring programme of the Convention on Long-Range Transboundary Air Pollution in Europe).

Atmospheric deposition [kg N]
=
Utilised agricultural area (UAA[1]) [ha]
X
N deposition rate [kg N/ha]
([1]) UAA = land used for arable crops + permanent crops + permanent grass and meadows

[5] Nitrogen compounds in the atmosphere may be formed naturally, e.g. through the action of lightning, or may be the result of human activities, especially agriculture. The most significant emissions from agricultural sources are ammonia (NH_3), nitrous oxide (N_2O) and nitrogen oxides (NO_x), primarily from livestock manure and inorganic fertilisers.

In the **gross** nitrogen balance, no deduction is made for the volatilisation of NH_3. Therefore, some double-counting (bold terms in the following two equations) can happen in the calculation of the atmospheric deposition.

1) N content of ammonia emitted from agriculture (fertilisers + livestock manure)
   = deposited domestically (on **agricultural land** + non-agricultural land)
   + exported to other countries + remaining in the air

2) Total atmospheric N deposition to agricultural land
   = N-deposits from non-agricultural sector
   + N-deposits from agriculture (**produced domestically** + imported)

To avoid this error, the above bold term (N contents of ammonia from agriculture which is deposited to domestic agricultural land) should be estimated and deducted from the total atmospheric deposition of nitrogen compounds. However, this is difficult to estimate in many cases, but it could be possible if countries have regional data on ammonia volatilisation based on the air monitoring programmes (see section 5.1.d).

4.1.e Other inputs (seeds and planting material,…)

Other inputs cover, for example, the nitrogen contained in seeds and other planting materials (e.g. cereals, potato tubers). Little data are generally available for this component of the balance. Its contribution is considered to be small and can be ignored if no data are available.

4.2 Outputs

When crops are harvested or grass is grazed, some of the N contained in the plant is removed with the harvested crop. Therefore it is necessary to have coefficients for the amount of N removed per tonne of crop, for each of the major crop types. These coefficients are generally available from specialist institutes.

In calculating the nitrogen removed with harvested crops there are two cases to be considered:

a) *Marketed crops, including marketed fodder crops* sold off-farm, for which production and yield data are usually available;

b) *Non-marketed fodder crops and grass (harvested and grazed)* that are consumed on the farm, for which production and yield data are not usually available.

4.2.a Marketed crops, including marketed fodder crops

For marketed crops, data on production, areas cultivated and yields are generally available. If necessary, production can be estimated as:

Production [tonnes]
=
cultivated area [ha]
X
yield [tonnes/ha]

The N removed in these crops can be calculated by applying coefficients for the amount of N removed per tonne of crop, for each of the major crop categories.

Amount of N removed in harvested crop of category*(i)* [kg N]
=
crop production of category*(i)* [tonnes of fresh-matter]
X
N coefficient for category*(i)* [kg N/tonne of fresh-matter]

There are several points to take into consideration here:

1. As in the case of crops associated with biological fixation, care is needed to ensure that the data available on crop production and the N coefficients refer to the same unit, i.e. tonnes of fresh or dry matter. If data on harvested crops are given in dry matter, coefficients for the N content of dry matter have to be used in the calculation. Data on fodder are often given in dry matter.

2. Further research is needed on crop residues (e.g. straw and leaves) in the gross nitrogen balance. In particular, examination is required with respect to the nitrogen conversion coefficients. Therefore, the quantity of the output is not taken into account in this handbook, whether it may or may not be removed from the field[6].

4.2.b Non-marketed fodder crops and grass (harvested and grazed)

If data on the quantities produced or yields of this category are available, the calculation can just follow the method described in *section 4.2.a* above.

However, they are often not recorded as these products are not marketed, which poses particular estimation problems. This makes it difficult to use a simple coefficient multiplied by production figures to estimate the N removed in these crops. If this is the case, the following estimation method can be used to resolve the problems.

In most countries recommended animal feed requirements for different types of livestock exist. This estimation method is based on the assumption that the vast majority of farmers will apply the recommendations in order to obtain the maximum yield, whether of milk, meat, eggs, etc. The agricultural advisory services can provide recommended animal feed requirements usually *in terms of dry matter* for different livestock types.

[6] Similarly, the quantity of crop residues which are returned to the soil as compost should not be counted as input.

(1)	**<u>For each livestock category:</u>** Recommended animal feed requirements = fodder crops + grass (harvested and grazed) + bought feedstuffs

Which can be rewritten as:

(2)	Fodder crops + grass (harvested and grazed) = Recommended animal feed requirements – bought feedstuffs

Therefore the intake in the form of fodder crops and grass (harvested and grazed) is assumed to be equal to the recommended feed intake for livestock minus the estimated commercial (bought) feed consumption.

Data on bought feedstuffs (sales of commercial feedstuffs), by type of livestock, can normally be obtained from producers and/or importers. There are several complications in this calculation:

1. Animal feed requirements are usually available only in terms of dry matter, whereas commercial feedstuffs data are usually available in tonnes of fresh matter. This problem can be overcome by assuming that commercial feedstuffs have a dry matter content of 85%, since feeds have usually a moisture content of around 15%. This makes the calculation of fodder and grass (harvested and grazed) in dry matter feasible.

2. An estimate is required for fodder and grass (harvested and grazed) in terms of N content. The possible solutions to this include the following:

- For lack of better data, a coefficient of N in fodder crops and grass (harvested and grazed) should be estimated. This will vary from one country to another and one region to another depending on the mix of fodder crops and grass. If no information on this is available, it is proposed to use:

0.032 [nitrogen/unit of fodder crops and grass (kg N/kg)] which comes from: 0.2 [raw protein/unit of fodder crop or grass, in dry matter (kg/kg)] **X** 0.16 [nitrogen/unit of raw protein (kg N/kg)]

- Care also must be taken with the difference of N-content between fodder crops and grass. This might be estimated by taking into account the percentage share of grass and fodder crops according to national or regional statistics.

The above calculations are based on dry matter requirements. They could also be calculated using energy requirements, in which case different coefficients would be needed, but the basic calculation would be the same.

It is clear that this is a very rough method of estimating output, and will strongly bias the calculations in extensive farming areas, where farmers produce most of the feed needed for their livestock. ***For this reason, if the above estimation method is applied, it is advisable to use the calculation method for manure coefficients based on livestock balances, and therein the calculation of N removed by fodder crops and grass (harvested and grazed) should be consistent with the calculation of manure coefficients (see section 4.1.b and Annex 3)***

5. Calculation of the gross nitrogen balance at the regional (sub-national) level

The method outlined in section 4 sets out the main principles for the calculation of N balances. As explained in section 3, in order to have meaningful balances, they should be calculated at the regional (sub-national) level. However, in most countries detailed regional data are not available, and further refinement is needed in order to calculate regional N balances. A method to calculate the different components of the N balance at regional level is given below.

5.1 Inputs

5.1.a Inorganic fertilisers

Regional balances require data on use of fertilisers at regional level. Regular surveys to farmers on their use of fertilisers is the preferred source for such information, but it is recognised that this will not be possible for all countries and for all years. At present only a few countries carry out such surveys. Therefore it will be necessary to estimate regional use of fertilisers. One such estimation method is outlined below.

This method depends on the co-operation of the national fertiliser manufacturing industry, or for example in Europe, the European Fertiliser Manufacturers Association - EFMA.

In general, data on total fertiliser use or sales, by type (N, P, K), are available within countries or from FAO.

Information on application rates of inorganic fertilisers [kg N/ha] for different crops are supplied by national fertiliser manufacturers (e.g. EFMA for Europe) and are used to redistribute the total fertiliser use for the country to the regions.

It is expected that countries will have regional data on cultivated area for different crops.

By combining application rates [kg N/ha] with the crop area for each crop and each region, a first estimate of regional fertiliser use is made.

First estimate of inorganic fertiliser use for the region [kg N] = Σ (crop(i) area in the region [ha] **X** Application rate of inorganic fertiliser for crop(i) [kg N/ha])

If necessary, these figures should be adjusted so that the total of all the regions within a country corresponds to national total inorganic fertiliser use.

Adjustment factor = National inorganic fertiliser use / Σ (inorganic fertiliser use per region)

It should be noted that additional work may be needed to convert the information on application rates to the crop categories for which area data are available, or vice versa.

5.1.b Livestock manure

Data on the regional distribution of livestock are generally available from standard agricultural statistics. These data are usually classified by category of livestock (see Annex 2).

Within each region – for each livestock category: Estimated quantity of N in livestock manure for category*(i)* [kg N/year] = Number of animals of category*(i)* for the region [heads] **X** manure coefficient of category*(i)* [kg N/head/year]

For each region: Estimated quantity of N in livestock manure [kg N/year] = Σ (estimated quantity of N in livestock manure per livestock category) [kg N/year]

To facilitate the calculation, it is assumed that for a given livestock category the manure coefficients are the same for all regions. However if a country has calculated different manure coefficients for its regions, these should be used in the calculations.

5.1.c Biological nitrogen fixation (nitrogen fixed in the soil)

The basic calculation method given in 4.1.c can be applied to each region.

5.1.d Atmospheric deposition of nitrogen compounds

Regional figures are available from the air monitoring programmes, especially for those countries which are signatories to the international conventions (see section 4.1.d). If no data for regional deposition are available, it is assumed that the figures calculated in 4.1.d are deposited evenly across the country.

5.2. Outputs

5.2.a Marketed crops, including marketed fodder crops

The method outlined in 4.2.a can be applied to each region. If regional production figures are not available, they can be estimated from data on yields (quantities produced per hectare), which are more generally available, and from data on areas in each region under the given crops.

<u>For each region – for each crop:</u>
Amount of N removed in marketed crop*(i)* [kg N]
=
crop*(i)* area [ha]
X
yield of crop*(i)* [tonnes of fresh-matter / ha]
X
N coefficient in marketed crop*(i)* [kg N/tonne of fresh-matter]

<u>For each region:</u>
Amount of N removed in marketed crops [kg N]
=
Σ (amount of N removed for each marketed crop) [kg N]

5.2.b Non-marketed fodder crops and grass (harvested and grazed)

The estimation method presented in section 4.2.b can be applied at regional level.

<u>For each region:</u>
Total quantity of fodder crops + grass (harvested and grazed)
=
Σ (Recommended animal feed requirements – bought feedstuffs) for all livestock categories

If regional data on bought feedstuffs are not available, it must be assumed that they are consumed uniformly around the country, i.e. that a dairy cow in one region of the country consumes the same amount of feed as a dairy cow in another region.

Therefore the country total for feed sold is allocated to the regions based on the livestock numbers in those regions, to give a regional estimate of feed consumption in that region.

As in the case of national balances, it is important to ensure consistency between this method and the method and assumptions used in the calculation of the coefficients of N in manure.

Annex 1

Major losses of N to the atmosphere

Not all the nitrogen available on a farm unit is taken up by plants, some remains in the soil. In addition, some may be washed away or leached during heavy rainfall, and some will end up in the atmosphere as a result of volatilisation or denitrification.

- **Volatilisation**

Nitrogen volatilisation is the result of the conversion of nitrogenous matter to NO, N_2O and more particularly to ammonia (NH_3), by high-temperature reaction. It occurs especially in stables, just after excretion, during storage of livestock manure and again during the spreading of the manure on the soil.

Ammonia emissions from animal manure depend on:

- the amount of nitrogen in the animal wastes;
- the properties of animal wastes including dry matter, viscosity and pH;
- soil properties such as pH, Cation Exchange Capacity, calcium content, water content, buffer capacity and porosity;
- meteorological conditions including precipitation, temperature, humidity and wind speed;
- the method and rate of application of animal wastes, including the time between application and ploughing;
- the height of the crop (or grass) at the time of spreading
- storage conditions of livestock manure

These emissions, mainly of NH_3, are part of the pollution problem associated with excessive N surpluses and, for the purpose of the gross N balance calculation, are included in the calculation. In fact, some countries require manure to be injected into the soil to reduce volatilisation and the related NH_3 emissions, as part of their policy to reduce acidifying emissions.

- **Denitrification**

Denitrification is the final stage in the process of reduction of nitrate to gaseous nitrogen (N_2), the major component of the atmosphere.

Denitrification is common in anaerobic soils and is carried out by heterotrophic bacteria. The process of denitrification can reduce nitrate to gaseous nitrogen (N_2) or nitrous oxide (N_2O). Both gases diffuse into the atmosphere, but from the perspective of environmental pollution N_2 is neutral. This process is important for soil bacteria because it supplies them with oxygen. Denitrification is encouraged by high soil temperatures and occurs during and after flood irrigation and/or heavy rainfall, sufficient to waterlog the soil profile.

The conversion of excess nitrate to N_2 is a process that reduces the N surplus in the soil. However, the denitrification process can also result in N_2O emissions. N_2O is a greenhouse gas which should be included in the nitrogen balance calculation. At present there is no satisfactory method of separating neutral N_2 emissions from polluting N_2O emissions that arise from the denitrification process. Therefore, denitrification resulting in N_2 emissions is excluded from the N balance, only where information on this is available.

Annex 2

Basic data structure

The basic data structure (e.g. crops and livestock data) to provide a standardised cross-country set of nitrogen balances is outlined below. This structure provides a simplified version of that of OECD national nitrogen balance calculations, available on the OECD agri-environmental indicator website database at: www.oecd.org/tad/env/indicators

[Codes are those used in the OECD national nitrogen balances]

F1: Total Fertilisers

F11: Total Inorganic Fertilisers
- **F111: Nitrogenous Fertilisers**, covering consumption of nitrogenous fertilisers, expressed in nitrogen (N) content

F12: Total Organic Fertilisers (excluding livestock manure)
- **F121: Sewage Sludge**, covering use of treated public sewage sludge
- **F129: Other Products**, covering other organic products used as fertilisers

A1: Livestock Manure Production

A11: Total Cattle
- A111: Bovines < 1 year
- A112: Bovines 1-2 years
- A113: Bovines > 2 years
  - A1131: Dairy Cows
  - A1132: Other Cows

A12: Total Pigs (Live Weight)
- A121: Piglets (Pigs < 50 kg)
- A122: Fattening Pigs > 50 kg
- A123: Breeding Pigs > 50 kg
- A129: Other Pigs

A13: Total Sheep and Goats
- A131: Sheep and Lambs
  - A1311: Sheep
  - A1312: Lambs
- A132: Goats

A14: Total Poultry
- A141: Chickens
  - A1411: Broilers
  - A1412: Layers
  - A1419: Other Chickens
  - A149: Other Poultry

A19: Total Other Livestock
- A191: Horses
- A199: Other Livestock

M21: Total Manure Withdrawals, representing the amount of manure withdrawn from agriculture and not applied to agricultural land (in a given country).

M212: Non-agricultural use, such as for private gardens.
M213: Processed as industrial waste, covering manure processed as industrial waste in a processing plant and not used on agricultural land.
M214: Exported Organic Fertilisers, covering manure and other organic fertilisers exported from a country.
M219: Other Withdrawals, covering other manure withdrawals.

M22: Change in Manure Stocks, covering the increase or decrease of livestock manure stocks intended for use on agricultural land. It is obtained by deducting the beginning stocks (M221) from the ending stocks (M222).
M221: Beginning Stocks
M222: Ending Stocks

M23: Imported Organic Fertilisers, covering manure and other organic fertilisers imported.

C2: Total Harvested Crops and Forage

C21: Total Harvested Crops, regardless of their final destination, including for human consumption, livestock feed, industrial use and seeds, covering crop categories C211 to C219.

C211: Total Cereals
C2111: Wheat
C2112: Rice
C2113: Coarse Grains
C21131: Barley
C21132: Maize
C21139: Other Coarse Grains
C2119: Other Cereals

C212: Total Oil Crops
C2121: Soybeans
C2122: Sunflower seed
C2123: Rapeseed
C2129: Other Oil Crops

C213: Total Dried Pulses and Beans

C214: Total Root Crops

C215: Total Fruit

C216: Total Vegetables

C217: Total Industrial Crops

C219: Total Other Harvested Crops

C22: Total Forage

C221: Total Harvested Fodder Crops

C222: Total Pasture
C2221: Temporary Pasture
C2222: Permanent Pasture

B1: Biological Nitrogen Fixation

B11: Leguminous Crops

B12: Free Living Organisms

Other Inputs

C1: Total Seeds and Planting Materials

L111: Atmospheric Deposition

D2: Denitrification

D21: Wet Paddy
D211: Rice planted area
D212: Other Types

D29: Others
D291: Dry Field
D292: Permanent Crops
D293: Permanent Pasture

Annex 3

The coefficients of livestock manure

Many of the coefficients used for the nitrogen content in manure are technical coefficients based on analysis of samples of manure, which can vary widely. A step forward would be to validate these coefficients on the basis of the following assumption based on a single animal:

What livestock consumes must result, either in urine/manure or in product (milk, meat, etc).

Thus for the total national animal stock: (*all in terms of N content*)

Total feed consumed = Total livestock manure + Total livestock product

or:

Total livestock manure = Total feed consumed – Total livestock product

The figure for total livestock manure should be divided by the total number of animals in the livestock category to give a manure coefficient for that category:

For each livestock category:
Manure coefficient [kg N/head/year]
=
(Total feed consumed [kg N] – Total livestock product [kg N]) / Total livestock (heads) / year

Standard agricultural statistics can provide data on animal products, i.e. meat, milk, eggs, etc. Total livestock product also includes non-commercial parts of animals such as head, skin, bones and intestines, which should be estimated in calculation (see section *4.1.b*). These data have to be converted to N equivalents in order to be able to calculate the N content of 'Total livestock product'.

For 'Total feed consumed', the same recommended animal feed requirements that were used in the calculation of N output in fodder crops and grass (harvested and grazed), in section 4.2.b, should be used. In this case it will be necessary to have these requirements in terms of Nitrogen content. If the Nitrogen content in recommended animal feed requirements does not exist, the equation (1) in section *4.2.b* is available to calculate the N content. Regarding the N content of the **bought feedstuffs**, it should be possible for the animal feed manufacturers to provide these data, as they know the composition of their product. This principle can also be applied at regional level, if regional data for the different components exist.

The main advantage of calculating manure coefficients in this manner, rather than using measurements of N in samples, is that this calculation is based on the same fundamental data as used in the estimation of the output of **fodder crops and grass**.

The gross balance is calculated as:

Fertilisers **+ livestock manure** + other nitrogen inputs – marketed crops
– fodder crops and grass
=
surplus/deficit

but can be specified as:

Fertilisers **+** (**feed consumed – livestock product**) + other nitrogen inputs – marketed crops
– fodder crops and grass
=
surplus/deficit

or:

Fertilisers + **(fodder crops and grass + bought feedstuffs – livestock product**)
+ other nitrogen inputs – marketed crops – **fodder crops and grass**
=
surplus/deficit

or:

Fertilisers + **(bought feedstuffs – livestock product**) + other nitrogen inputs – marketed crops
=
surplus/deficit

Any major errors in the estimation of the nitrogen in the output of **fodder crops and grass** will cancel out in the final equation.