OECD and EUROSTAT

GROSS PHOSPHORUS BALANCES

HANDBOOK

October 2007

For further information on Phosphorus 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.

Other sources of phosphorus input into the environment, besides agriculture, are households and industries e.g. in the form of detergents. However, in the context of this handbook, these sources will not be further dealt with.

Phosphorus can accelerate the process of eutrophication (i.e. algae growth and oxygen shortages in water) of surface water (rivers, lakes and coastal waters), which can damage the biodiversity of rivers and lakes and impair its use for drinking water, fishing and recreational purposes. Though eutrophication is also affected by nitrogen and carbon, phosphorus is especially important, since it often becomes the limiting element to control and reduce the accelerated eutrophication, while nitrogen and carbon are exchanged between the atmosphere and a water body.

While a surplus of phosphorus is potentially damaging to the environment, a deficiency of it can impair the resource sustainability of agriculture soil through soil degradation, or soil mining, resulting in declining fertility in areas under crop or forage production.

For this reason, the calculation of phosphorus (P) balances has been identified as a priority agri-environmental indicator by OECD Member countries. The information provided by P balances is 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]

This handbook sets out the main principles for a robust and feasible methodology to be used across OECD Member countries that is based on the draft OECD/Eurostat N-Handbook[2]. The aim is to be able to consistently produce an indicator based on a single methodology and harmonised definitions for all countries. Following this introduction, **Sections 2** and **3** provide an overview of the phosphorus cycle as well as the differences between different conceptual approaches (soil surface balances versus farm-gate balances). **Section 4** describes the methodology to be used to calculate inputs and outputs of phosphorus in agriculture.

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

[2]: For further information on the N-Handbook, see the OECD website at www.oecd.org/tad/env/indicators

2. The phosphorus cycle

Phosphorus (P) is essential to living organisms as a key element in many physiological and biochemical processes. It occurs in DNA and RNA structures in cells and is an essential component of the cells' energy transport system. Phosphorus does not exist naturally in the elementary state (i.e. as P_4), but is always combined with other elements to form phosphates. The only environmentally reactive form is orthophosphate (PO_4^{3-}).

The largest reserve of P is in rock, particularly the mineral apatite. P does not exist in nature as a gas, what little P exists in the atmosphere is associated with airborn dust particles. P also exists in organic forms within living and decaying plant and animal tissues. Inorganic P is derived primarily through the weathering of rock minerals to produce free or weakly bound phosphate ions within aqueous solutions.

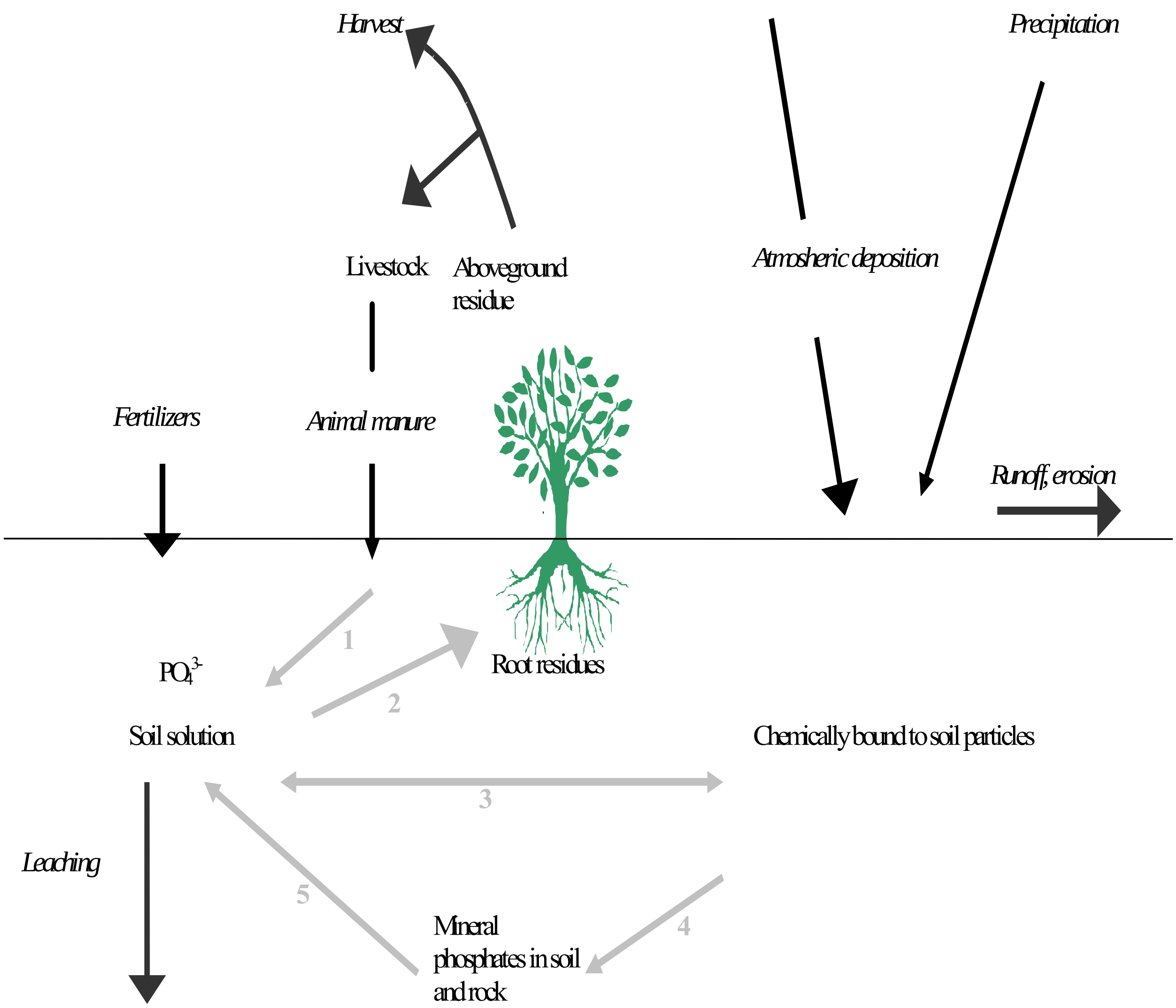
Organic P in soil can be associated with both highly-decomposed organic matter such as humus or with recently added poorly-decomposed materials such as crop residues. In this molecular form, the organic P cannot be taken up by plant roots and is referred to as being "unavailable" to plants. Soil microbes must break these molecules down in order to produce and release (known as mineralization) inorganic phosphate ions into the soil solution, to generate the form of phosphorus considered to be "available" to plants. Solubilized phosphate ions are quickly chemically bound by soil particles to prevent their further movement through the soil by water, yet remain slowly available to plant roots when bound in this way.

During heavy rainfalls, the inorganic phosphates in the soil solution can migrate into the groundwater system. However, due to the soils affinity for phosphate to act as a storage media, leaching is generally limited. Surface runoff accompanied with soil erosion is the main source for phosphorus pollution of (surface) water.

In agriculture, the natural phosphorus cycle is interrupted when organic matter is removed in harvested crops and through grazing (Figure 1). Furthermore, phosphorus is lost due to surface runoff or chemical binding to soil particles. A supplementary input of phosphorus is thus needed to compensate for the removals and losses, and maintain the balance of phosphorus in the soil.

The most common method of supplying supplementary phosphorus is through the spreading of inorganic fertilisers and livestock manure, but as discussed above, not all of this supplementary phosphorus will be available to the plants. Pesticides (e.g. organophosphates) are another source of phosphorus input. However, organophosphates do not seem to be broken down to inorganic phosphate ions (and thus available for plant uptake) and are not considered here.

Figure 1: The phosphorus cycle



Explanation of soil processes:

1. Breakdown of soil organic matter, organic debris (plant and animal remains) and manure by soil microbes, releasing inorganic phosphate ions. (Mineralisation)
2. Plant uptake of inorganic phosphate ions.
3. Chemical bondage of phosphate ions to soil particles; a reversible process with various stages.
4. Geologic processes of sedimantation and alteration.
5. Chemical weathering to produce phosphate ions in solution.

Source: OECD Secretariat

3. Phosphorus balances of agricultural systems

A phosphorus balance calculates the balance between phosphorus added to an agricultural system and phosphorus removed from the system expressed on a per hectare of agricultural land basis. Ideally the balance result should be related to the area of agricultural land that is potentially fertilised, to avoid a bias in the result for countries with extensive unfertilised agricultural land. 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 P suggests a risk of water pollution, though this may depend also on other factors, such as agricultural practices, weather conditions and soil type.

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

In line with the draft OECD/Eurostat Nitrogen (N) N-handbook, two calculation methods could be applied to calculate the phosphorus balance:

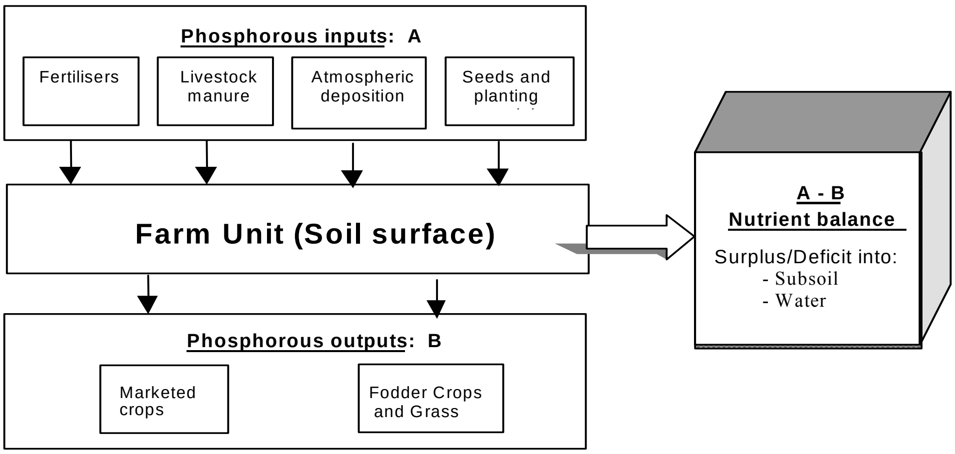
- The **Farm-gate balance** *(Farm balance or sector balance)* treats the farm (or national agricultural industry) as an entity. Phosphorus recycled within the entity is ignored. This type of balance takes into account the amount of phosphorus imported into the farm or national agricultural industry (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 phosphorus surplus or deficit. This type of balance is very suitable for use at individual farm level and at national level.
- The **Soil surface 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 phosphorus used by the farm (e.g. fertilisers, animal manure), deposited from the atmosphere, 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 phosphorus removed by cutting or grazing and re-deposited as manure.

Although the farm-gate balance and the soil surface 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. ***The OECD/Eurostat Secretariats propose, in line with the calculation of the N-balances, to apply the soil surface balance methodology as the appropriate indicator for calculating comparable phosphorus balances. This however does not prevent that some countries use other methods to track phosphorus balances.***

4. The soil surface phosphorus balance

The *phosphorus balance* calculates the difference between the total quantity of phosphorus entering the soil and the quantity of phosphorus leaving the soil annually, based on the cycle. The excess phosphorus, or surplus, may remain in the soil, leach into groundwater or run-off into surface water. The inputs and outputs of phosphorus included in the calculation are indicated in Figure 2 and described below.

Figure 2: The main elements in the soil surface phosphorus calculation



The soil surface **balance** is calculated as total phosphorus inputs minus total phosphorus outputs and includes the following:

Total inputs to farm unit

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

b. Livestock manure

c. Atmospheric deposition of phosphorus compounds

d. Other inputs (e.g. 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)

3 "Fertilisers" and "Livestock manure" are the main sources of inputs in the soil surface phosphorus balance. The term "Fertilisers" in this context covers inorganic phosphorus 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 phosphorus 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 Inputs

4.1.a Fertilisers

Inorganic fertilisers are chemical mixtures, applied to agricultural land:

- Simple mineral fertilisers, e.g. superphosphate
- Complex mineral fertilisers, e.g. NP and NPK mixtures
- Mineral-organic fertilisers

Data on sales or consumption of inorganic fertilisers in terms of P content are generally readily available within countries. Fertilises inputs are expressed in kg

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.

4.1.b Livestock manure

The quantities of P 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 phosphorus in livestock manure are estimated by multiplying the number of animals by a manure coefficient, for each category of livestock:

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

Ideally the calculation of phosphorus 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 (kg P) = Livestock manure production (kg P) – 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.

The above-mentioned calculation method of P 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 P in livestock manure [kg P] = Number of animals [heads] **X** Manure coefficient [kg P/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 P/head/year or kg P/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.

The manure coefficient in the first equation may also be used in the unit "kg P_2O_5/head/year" instead of in the unit "kg P/head/year". The estimated quantity will then be expressed in "kg P_2O_5/year". This figure will have to be multiplied with a factor 0.44, in order to have the quantity in P.

Countries are requested to provide all their coefficients for the phosphorus balances in P. Whenever this is not possible, coefficients may also be provided in P_2O_5. This should be clearly indicated in the country's table of P coefficients.

4.1.c Atmospheric deposition of phosphorus compounds

Rainfall can contain phosphorus compounds, which are deposited on the land. Dry (dust) deposition also occurs. However, the contribution of atmospheric deposition to phosphorous input is considered to be small. If data are available, the input of atmospheric deposition over a given period is as follows:

Atmospheric deposition [kg P]

=

Utilised agricultural area (UAA[1]) [ha]

X

P deposition rate [kg P/ha]

([1]) UAA = land used for arable crops + permanent crops + permanent grass and meadows

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

Other inputs cover, for example, the phosphorus 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 P contained in the plant is removed with the harvested crop. Therefore it is necessary to have coefficients for the amount of P removed per tonne of crop, for each of the major crop types. These coefficients are generally available from specialist institutes.

In calculating the phosphorus 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 P removed in these crops can be calculated by applying coefficients for the amount of P removed per tonne of crop, for each of the major crop categories.

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

There are several points to take into consideration here:

1. Care is needed to ensure that the data available on crop production and the P 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 P content of dry matter have to be used in the calculation. Data on fodder are often given in dry matter.

2. The P within non-harvested plant materials (e.g. straw, leaves, stacks, roots) is not included in the soil surface P balance calculation. It is important that the coefficient used must relate to harvested P concentrations not whole plant concentrations. The P in non-harvested materials is neither considered an output nor an input regardless of whether it is removed or not from the field.

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

If data on the quantities produced or yields of this category as well as the corresponding P coefficients 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 P 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.

(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.

In this calculation, care is needed as 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.

If the coefficients for the amount of P removed per tonne of fodder crops and per tonne of grass are available, the calculation method described in section 4.2.a *above can be applied, taking into account the percentage share of fodder crops and grass according to national or regional statistics:*

Amount of P removed in non-marketed crop or grass of category*(i)* [kg P]

=

Total amount of fodder crops and grass [tonnes of fresh-matter]

X

Share of crop or grass of category*(i)* in total amount

X

P coefficient for category*(i)* [kg P/tonne of fresh-matter]

The total amount of P removed in non-marketed crops (harversted and grazed) and grass will be gained by taking the sum of the various categories of crops (and grass).

It is questionable whether countries will have P coefficients for the various categories of crops (and grass). In this case, an estimated P-coefficient may be taken for the non-marketed crops and grass together.

5. Proposed methods for calculation of the soil surface phosphorus balance at regional level

The method outlined in section 4 sets out the main principles for the calculation of P 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 P balances. A proposal for the calculation of the different components of the P 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 P/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 P/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 P]
=
Σ (crop(i) area in the region [ha]
X
Application rate of inorganic fertiliser for crop(i) [kg P/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 P in livestock manure for category*(i)* [kg P/year]

=

Number of animals of category*(i)* for the region [heads]

X

manure coefficient of category*(i)* [kg P/head/year]

For each region:

Estimated quantity of P in livestock manure [kg P/year]

=

Σ (estimated quantity of P in livestock manure per livestock category) [kg P/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 Atmospheric deposition of phosphorus compound

As it is questionable whether national figures on deposition of P compounds are available, regional figures may also not be available. If data are available at the national but not at the regional level, it is assumed that the figures calculated in 4.1.c 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.

For each region – for each crop:

Amount of P removed in marketed crop*(i)* [kg P]

=

crop*(i)* area [ha]

X

yield of crop*(i)* [tonnes of fresh-matter / ha]

X

P coefficient in marketed crop*(i)* [kg P/tonne of fresh-matter]

For each region:

Amount of P removed in marketed crops [kg P]

=

Σ (amount of P removed for each marketed crop) [kg P]

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.

For each region:

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.

Annex 1

Basic data structure

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

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

F1: Total Fertilisers

F11: Total Inorganic Fertilisers
F111: **Phosphorus fertilisers**, covering consumption of phosphorus fertilisers, expressed in phosphorus (P) content.

F12: Total Organic Fertilisers (excluding livestock manure)
F121: Sewage Sludge, covering use of treated public sewage sludge
F122: **Urban compost**, covering use of urban compost from public garbage collection
F123: **Industrial waste products**, covering use of industrial waste, such as products from the food processing industry
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

C218: Ornamental crops

C219: Total Other Harvested Crops

C22: Total Forage

C221: Total Harvested Fodder Crops

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

Other Inputs

C1: Total Seeds and Planting Materials

L111: Atmospheric Deposition