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LIST OF ABBREVIATIONS

AEI	Agri-Environmental Indicator(s)	
aGNS	atmospheric Gross Nitrogen Surplus	
BNF	Biological Nitrogen Fixation	
CAPRI	Common Agricultural Policy Regionalised Impact	http://www.capri-model.org/
CLTRAP	Convention on Long-range Transboundary Air Pollution	http://www.unece.org/env/lrtap/
CPSA	Standing Committee on Agricultural Statistics	
CRF	Common Reporting Format (of GHG emissions to UNFCCC)	http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php
d.m.	dry matter (dry biomass)	
EAA	Economic Accounts for Agriculture	http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Economic_accounts_for_agriculture_(EAA)
EEA	European Environment Agency	http://www.eea.europa.eu/
e.g.	exempli gratia (for example)	
EMEP	European Monitoring and Evaluation Programme	http://www.emep.int/
EPNB	Expert Panel on Nitrogen Budgets	http://www.clrtap-tfrn.org/epnb
EW-MFA	Economy-Wide Material Flow Accounts	http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/introduction
FAO	Food and Agriculture Organisation of the United Nations	http://www.fao.org
FSS	Farm Structure Surveys	http://epp.eurostat.ec.europa.eu/portal/page/portal/farm_structure_survey/introduction
GHG	Green House Gas	
GNB	Gross Nitrogen Budget	
GNS	Gross Nitrogen Surplus	
hGNS	hydrospheric Gross Nitrogen Surplus	
i.e.	id est (that is)	
IIR	Informative Inventory Report (on air pollutants to UNECE/CLTRAP)	http://www.ceip.at/status-of-reporting/
IPCC	Intergovernmental Panel on Climate	http://www.ipcc.ch/

	Change	
JRC	Joint Research Centre	http://ec.europa.eu/dgs/jrc/index.cfm
m.c.	moisture content	
N	Nitrogen	
NACE	Statistical classification of economic activities in the European Community	http://epp.eurostat.ec.europa.eu/portal/page/portal/product_details/publication?p_product_code=KS-RA-07-015
NFR	Nomenclature For Reporting (reports of air pollutants to UNECE/CLTRAP)	http://www.ceip.at/status-of-reporting/
NIR	National Inventory Report (of GHG emissions to UNFCCC)	http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php
NUTS	Nomenclature of Territorial Units for Statistics	http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction
OECD	Organisation for Economic Co-operation and Development	http://www.oecd.org/
P	Phosphorus	
PB	Phosphorus Budget	
PS	Phosphorus Surplus	
RDP	Rural Development Program	http://ec.europa.eu/agriculture/rurdev/index_en.htm
TFRN	Task Force on Reactive Nitrogen	http://www.clrtap-tfrn.org/
UNECE	United Nations Economic Commission for Europe	http://www.unece.org/
UNFCCC	United Nations Framework Convention on Climate Change	http://unfccc.int/2860.php
UAA	Utilized Agricultural Area	
WFD	Water Framework Directive	http://ec.europa.eu/environment/water/water-framework/index_en.html
WG	Working Group	

FOREWORD

This Handbook is an update and revision of the OECD/Eurostat Gross Nitrogen Balances Handbook 2007 and OECD/Eurostat Gross Phosphorus Balances Handbook 2007. It establishes the guidelines for the estimation of the following nutrient budgets in EU-27, Norway and Switzerland at national level: the **Gross Nitrogen Budget** (**GNB**) and the **Phosphorus budget** (**PB**). The Handbook is expected to be updated in the future as improvements on particular flows of the budgets are foreseen; the document is therefore foreseen with a version number. The Handbook is intended for national experts providing the budgets to Eurostat.

The Handbook does not include details for the transmission of the data; these are provided in a separate document to participants of the Working Group on Agri-Environmental Indicators (AEI) in advance of data collection.

Note that the name of the indicators have changed from Gross Nitrogen Balances to Gross Nitrogen Budgets and from Gross Phosphorus Balances to Phosphorus Budgets.

The term "**nitrogen budgets''** has been introduced by Leip, A. et al (2011)[1] and is used by the Expert Panel on Nitrogen Budgets (EPNB) of the Task Force on Reactive Nitrogen (TFRN) in the guidance document which is being prepared for the establishment of nitrogen budgets under the revision of the Gothenburg Protocol of the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Trans boundary Air Pollution (CLTRAP). In the guidance document the EPNB defines a nitrogen budget as follows: *"a nitrogen budget consists of the quantification of all major nitrogen flows across all sectors and media within given boundaries, and flows across these boundaries, in a given time frame (typically one year), as well as the changes of nitrogen stocks within the respective sectors and media. Nitrogen Budgets can be constructed for any geographic entity, for example at supra-national level (e.g., Europe), sub-national level (regions, districts), for watersheds or even individual households or for economic entities (such as farms)"*. A "**balance''** is defined as: *"Ideally, the balance of a pool, a sub-pool, or a full Nitrogen Budget is closed, i.e. all nitrogen flows can be explained as input, output or stock changes. The balance equation is then* $N_{output} + N_{stock\_change} - N_{input} = 0$*. Such a closed N-balance is theoretically possible for each pool defined and for a full Nitrogen Budget. In practice however a closed balance is not a requirement of a Nitrogen Budget"*. The same terminology can be applied to phosphorus budgets. In this Handbook the word "**surplus**" is used to refer to the result of the particular balance calculation for the total nutrient budget: total inputs minus total outputs. The calculated surplus represents the nutrients which are potentially emitted to the air, leached or run-off to waters or add to nutrient accumulation or depletion in the soil. The surplus can be positive representing a nutrient surplus or negative, representing a nutrient deficit. The surplus is often expressed per ha.

This Handbook has been drafted to improve the coherence and transparency of GNB and PB estimations across EU-27, Norway and Switzerland. It is based on discussions with relevant stakeholders and delegates of the Eurostat Working Group on Agri-Environmental Indicators[2] and the Standing Committee on Agricultural Statistics (CPSA)[3]. 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 nitrogen and phosphorus budgets following the land budget approach, see

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[1] Leip, A., et al., Farm, land, and soil budgets for agriculture in Europe calculated with CAPRI, Environmental Pollution (2011)

[2] All documents discussed in the Working group on AEI are available on Circabc. For some documents access is limited to members of the discussion group. Access to the site can be requested under the section "subscription and contact information" on the site.

[3] All documents discussed in the CPSA are available on Circabc. For some documents access is limited to members of the discussion group. Access to the site can be requested under the section "subscription and contact information" on the site.

subchapter 2.2. This handbook sets out the main principles of the agreed methodology across EU Member States, Switzerland and Norway, and discusses the difficulties of their implementation and sets out the solutions agreed at the various meetings.

The Handbook draws on the results of the research project DireDate[4]. DireDate investigated the data requirements for agri-environmental indicators and related policies such as the Rural Development Program (RDP), Water Framework Directive (WFD), and Nitrates Directive (ND). Nutrient budgets are for instance required for the monitoring of the RDP[5] and are often used for identifying vulnerable areas to nutrient leaching (WFD and ND). A particular task (task 3) of DireDate was to analyse methodologies for calculating greenhouse and ammonia emissions and nutrient balances. Many activity data needed for the GNB and PB are also needed to fulfil other AEI and policy data requirements. DireDate identified clear prospects for a common and harmonized data collection – processing – reporting chain which could lead to improvements in efficiency of data collection and reporting. DireDate also identified key areas for which data availability and quality should be improved, of which many relating to GNB and PB.

The revision of the Handbook has been coordinated with work on national nitrogen budgets in the UNECE CLTRAP Expert Panel on Nitrogen Budgets[6] to (i) increase the coherence between the GNB estimations and the national nitrogen budgets and (ii) to improve the efficient use and coherence of activity data of GNB and GHG and NH3 emissions inventories. Specific thanks go to Adrian Leip from the Joint Research Centre (JRC) for his inputs in drafting this Handbook.

Chapter 1 provides an overview of the nitrogen and phosphorus cycles. In Chapter 2 the GNB and PB are introduced. Subchapter 2.2 discusses the differences between different conceptual approaches (soil, farm and land budgets). Subchapter 2.3 discusses the estimation of the total nitrogen surplus and the partitioning into a part at risk to the air and a part at risk for leaching and run-off.

In Chapter 3 the guidelines for the estimation of nutrient budgets are described. An ideal budget approach is described as well as a practical implementation (a compromise between the ideal world budget and what can be achieved in the real world taking into account financial restrictions and the need to prioritise data requirements). Though in principle the aim is to include all nutrient flows, problems in data availability and quality, has led to exclude certain flows (which ideally should be included in the nutrient budgets) in the described practical implementation of the nutrient budgets, atmospheric deposition of P, crop residue inputs and BNF by free living organisms. A further distinction has been made in the practical implementation between flows for which data reporting are obligatory and flows for which data reporting is optional. For obligatory flows of the practical implementation default estimations procedures are established. Some flows are currently optional in the practical implementation because data are not available for all countries and default estimations are difficult to establish, e.g. use of other organic fertilizers and manure treatment. For obligatory flows a minimum data reporting requirement is established in the practical implementation to ensure a minimum level of comparability and transparency of GNB and PB estimations across countries. Countries are however encouraged to go beyond this minimum data requirement to provide as much as possible complete information on the flow.

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[4] All DireDate reports are accessible to the general public at Circabc and at the publication section of the dedicated section on Agri-environmental indicators in the Eurostat website: http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/publications.

[5] The Common Monitoring and Evaluation Framework (CMEF) provides a single framework for monitoring and evaluation of all rural development interventions for the programming period 2007-2013. The GNB and PB are baseline indicators under this framework: http://ec.europa.eu/agriculture/rurdev/eval/index_en.htm

[6] Information on the Expert Panel on Nitrogen Budgets can be found at: http://www.clrtap-tfrn.org/node/110.

In subchapters 3.2 to 3.4 the statistical limits (sector coverage, area and reference period) of the nutrient budgets which are the topic of this Handbook are defined. The different nutrient flows taken into account in the nutrient budgets are described in the subchapters 3.2 to 3.16. These subchapters follow a common structure, see also subchapter 3.1.

CONTENTS

1. NITROGEN AND PHOSPHORUS CYCLES

1.1. The Nitrogen Cycle

1.1.1. Introduction

Nitrogen (N) is important to all life. It is required for all organisms to live and grow because it is the essential component of DNA, RNA, and protein. N in the atmosphere or in the soil can go through many complex chemical and biological changes, be combined into living and non-living material, and return back to the soil or air in a continuing cycle. With respect to agricultural nitrogen budgets, the nitrogen cycle can be described by 5 main processes: biological fixation, uptake, mineralization, nitrification, and denitrification. Most of these processes are driven by micro-organisms.

1.1.2. Nitrogen fixation

The largest store of N can be found in the atmosphere, where it exists as a gas (mainly N_2). N_2 is an inert compound and biologically unavailable to most organisms. In order to be utilized in most biological processes, N_2 must be converted to reactive N (Nr), which includes inorganic reduced forms (NH_3 and NH_4^+), inorganic oxidized forms (NO, NO_2, HNO_3, N_2O, and NO_3^-), and organic compounds (urea, amines, and proteins).

Almost the entire N found in any terrestrial ecosystem originally came from the atmosphere. Some amounts enter the soil through the effects of lightning, with rainfall or through dry deposition. The energy from lightning causes nitrogen (N_2) and water (H_2O) to combine to form ammonia (NH_3) and nitrates (NO_3). Rainfall carries the ammonia and nitrates to the ground.

Under pre-industrial conditions, however, the majority is biochemically fixed within the soil by specialized micro-organisms. These micro-organisms convert N_2 into ammonia (NH_3) by the process called nitrogen fixation; the micro-organisms are either free-living or form symbiotic associations with leguminous and other plants or other organisms (e.g. termites, protozoa). In exchange for some of the N these micro-organisms fix, the micro-organisms receive from the plants carbohydrates and special structures (nodules) in roots where they can exist in a moist environment. Although the first stable product nitrogen fixation is ammonia, this is quickly incorporated into protein and other organic nitrogen compounds either by a host plant, the bacteria itself, or another soil organism.

1.1.3. Nitrogen mineralization and ammonification

Other stores of N include organic matter in soil and the oceans. When organisms die, decomposers (such as bacteria and fungi) consume the organic matter and lead to the process of decomposition. Decomposers also decompose the droppings and waste of organisms (excretion). During this process, a significant amount of the N in organic form contained in the dead organism or waste is converted into inorganic forms, this process is called nitrogen mineralization. This process is also often referred to as ammonification as it leads to the release of ammonia (NH_3). In most soils, the ammonia dissolves in water to form ammonium (NH_4). Once in the form of ammonium, N is available for use by plants or for further transformation into nitrate (NO_3^-) through the process called nitrification.

1.1.4. Nitrification

Certain micro-organisms in the soil convert ammonium (NH_4) into nitrite (NO_2). Other micro-organisms finish the conversion of nitrite (NO_2) into nitrate (NO_3). Most plants obtain the N they need as nitrate. Nitrification requires the presence of oxygen, so nitrification can happen only in oxygen-rich environments like circulating or flowing waters and the very surface layers of soils and sediments. The process of nitrification has some important consequences. Ammonium ions are positively charged and therefore stick (are sorbed) to negatively charged clay particles and soil organic matter. The positive charge prevents ammonium N from being washed out of the soil (or leached) by rainfall. In contrast, the negatively charged nitrate ion is not held by soil particles and is very soluble; it is easily lost from the soil system by leaching.

1.1.5. *Uptake of nitrogen*

Most plants can only take up N in two solid forms: ammonium ion (NH_4^+) and nitrate ion (NO_3^-). Most plants obtain the N they need as inorganic nitrate from the soil solution. Animals (and humans) receive the required N by the consumption of plants and/or animals.

1.1.6. *Denitrification*

Through denitrification, oxidized forms of N such as nitrate (NO_3^-) and nitrite (NO_2^-) are converted to dinitrogen (N_2) and, to a lesser extent, nitrous oxide gas (N_2O). Denitrification is an anaerobic process that is carried out by denitrifying bacteria, which convert nitrate to nitrite to nitrogenous gases nitric oxide (NO), nitrous oxide (N_2O) and N_2. Nitric oxide and nitrous oxide are both environmentally important gases. Nitric oxide (NO) contributes to smog, and nitrous oxide (N_2O) is an important greenhouse gas, thereby contributing to global climate change. Nitrous oxide is also relevant for stratospheric chemistry (ozone layer). Once converted to dinitrogen (N_2), N is unlikely to be reconverted to a biologically available form because it is a gas and is rapidly lost to the atmosphere. Denitrification is the only N transformation that removes N from ecosystems (essentially irreversibly), and it roughly balances the amount of N fixed by the nitrogen fixation described above.

1.1.7. *Human interventions in the Nitrogen cycle*

The activities of humans have severely altered the nitrogen cycle.

Agricultural production for the market

Agricultural production for the market means that crops and/or animal products are removed from the ecosystem and used elsewhere. The N contained in these products therefore often does not return to the ecosystem. Without adding fertilizers to complement this loss in N the soil fertility degrades. Prior to the mid-19th century, different practices were used by farmers to replenish the soil with N, which include crop rotations with leguminous crops, fertilisation by manure etc. However the global amount of reactive N limited the possibilities for agricultural expansion.

Introduction of Mineral N-fertilizers

With the introduction of the Haber–Bosch process in the early 1900s the amount of global reactive N increased significantly. The Haber–Bosch process combines under high temperatures and very high pressures, hydrogen from natural gas and N from the air (atmosphere) to produce ammonia, a key ingredient in the production of mineral nitrogenous fertilizers. The increase in reactive N made it possible to increase agricultural production and supported the increase in human population. More than 100 years after its invention, the Haber-Bosch process remains the most economical anthropogenic means of fixing N and is responsible for sustaining nearly 40 per cent of the current world population due to its ability to increase agricultural yields. The annual rate of production of reactive N with the Haber-Bosch process now exceeds that from natural sources.

Specialisation and Intensification

In West Europe there has been a strong trend towards intensification and specialisation after WWII. In Eastern Europe both intensification and specialisation could be noted (especially in large state or collective farms) as extensive mixed farming (especially in small, subsistence farms). Intensification and specialisation can lead to nutrient imbalances. Regions specialised in livestock raising import feed from other regions, combined with high livestock densities this often lead to high N surpluses, while regions specialised in crop production are depending on the import of fertilizers to avoid N deficits. High N surpluses are also often found in intensive crop-specialist regions due to excessive use of fertilizers. In general N inputs and outputs are more balanced in mixed extensive farming systems however these are often found in marginal areas and risks of further extensification or land abandonment can exist. Intensive livestock rearing also adds to environmental pollution through emissions of methane and reactive N during animal housing and manure storage.

Environmental pollution

In Europe the excess availability of reactive N has resulted in diverse environmental problems. Excessive use of manure and fertilizers can increase the amount of nitrates in the soil and therefore increase the risk of N leaching and N_2O and NO volatilisation. Depending on the amount of nitrate in the soil, the type of soil and the amount of rainfall and use of water and nitrate by plants, nitrate can leach into surface and groundwater, contributing to pollution of drinking water and eutrophication of surface waters. Denitrification depends on the amount of organic matter, soil water content, soil oxygen supply, soil temperature, soil nitrate levels and soil pH. N_2O is a potent greenhouse gas and contributes to climate change. Nitric oxide (NO) contributes to smog. A part of N in fertilizers and manure applied to the soil, and in a lesser degree in decaying plants, is transformed into ammonia (NH_3) and emitted into the air. This process also occurs in manure and fertilizers during storage and in animal housings. Ammonia emissions contribute to acidification, eutrophication and atmospheric particulate pollution. This process also occurs in manure and fertilizers during storage and in animal housings. Farmer practices such as direct incorporation of fertilizers and manure into the soil, or coverage of manure storage facilities can decrease the risk of ammonia volatilisation, however increase the N input into the soil and therefore the risk of N leaching and run-off and N_2O and NO volatilisation. Ammonia emissions contribute to acidification, eutrophication and atmospheric particulate pollution. A part of N in manure volatilises as NO and N_2O during storage, and N_2O in animal housing, contributing to climate change, smog and acid rain.

There are interactions between emissions to the atmosphere and leaching of N. For example, reducing the possibility of N to volatilise during animal housing, storage and application of manure to the land, means that a higher amount of N is available in the manure applied to the soil, increasing the availability of N for plant uptake, but on the other hand also increasing the potential risk of N leaching and run-off. Thus the reduction of N volatilisation and risks to climate change, acidification etc., might come at the cost of increasing the risk of water pollution, eutrophication etc.

Other human interventions

Not only agriculture has influenced the nitrogen cycle, for instance the introduction of sewage systems and industrialisation has also altered the cycle. Human excretion is nowadays collected in sewage and is released with or without treatment into waterways. Industrial combustion processes, e.g. in car engines, lead to emissions of NO, NO_2.

1.2. The Phosphorus cycle

1.2.1. Introduction

Phosphorus (P) is important to all life. It is required for all organisms to live and grow because it is an essential and non-substitutable component of DNA and RNA and is important for the transfer of energy in organisms. P is often the limiting element for plant growth, as the plant-available P in soils is often very low. P in contrast with N is not part of a global ecological cycle; large amounts of P (in the same magnitude of crop uptake) are lost by erosion and end up in ocean sediments. Recycling from ocean sediments takes place during a period of millions of years. P can therefore be considered as a finite resource.

The global phosphorus cycle has four major components: (i) tectonic uplift and exposure of P-bearing rocks to the forces of weathering; (ii) physical erosion and chemical weathering of rocks producing soils and providing dissolved and particulate P to rivers; (iii) riverine transport of P to lakes and the ocean; and (iv) sedimentation of P associated with organic and mineral matter and burial in sediments. The cycle begins anew with uplift of sediments into the weathering regime.

For agriculture the phosphorus cycle in soils is of importance. This chapter therefore focus on the phosphorus cycle in soils.

1.2.2. *Forms of Phosphorus in soils*

In soils P may exist in many different forms. In practical terms, however, P in soils can be thought of existing in 3 "pools":

Solution P pool

This pool is very small. The P dissolved in the soil solution will usually be in the orthophosphate form, but small amounts of organic P may exist as well. Plants will only take up P in the orthophosphate form. The solution P pool is important because it is the pool from which plants take up P and is the only pool that has any measurable mobility. Most of the P taken up by a crop during a growing season will probably have moved only an inch or less through the soil to the roots. A growing crop would quickly deplete the P in the soluble P pool if the pool was not being continuously replenished.

Active P pool

This pool is the main source of available P for crops. It contains P in solid form which is relatively easily released to the soil solution, the water surrounding soil particles. As plants take up phosphate from the solution P pool, the concentration of phosphate in solution is decreased and some phosphate from the active P pool is released. The ability of the active P pool to replenish the soil solution P pool in a soil is what makes a soil fertile with respect to phosphate. The active P pool will contain inorganic phosphate that is attached (or adsorbed) to small particles in the soil, phosphate that reacted with elements such as calcium or aluminum to form somewhat soluble solids, and organic P that is easily mineralized. Adsorbed phosphate ions are held on active sites on the surfaces of soil particles. The amount of phosphate adsorbed by soil increases when the amount of phosphate in solution increases and vice versa. Soil particles can act either as a source or a sink of phosphate to the surrounding water depending on conditions.

Fixed P pool

This pool contains inorganic phosphate compounds that are very insoluble and organic compounds that are resistant to mineralization by microorganisms in the soil. Phosphate in this pool may remain in soils for years without being made available to plants and may have very little impact on the fertility of a soil. Some slow conversion between the fixed P pool and the active P pool does occur in soils.

1.2.3. *P transformation processes in soils*

Weathering

Soils naturally contain P-rich minerals, which are weathered over long periods of time and slowly made available to plants. This reaction increases the availability of P to plants.

Precipitation

Phosphate precipitation is a very slow process in which P reacts with another substance to form a solid mineral. As phosphate is removed from the soil solution this reaction decreases the availability of P to plants.

Mineralization

The release of inorganic P from organic P is called mineralization and is caused by microorganisms breaking down organic compounds. The activity of microorganisms is highly influenced by soil temperature and soil moisture. The process is most rapid when soils are warm and moist but well drained. This reaction increases the availability of P to plants.

Immobilization

The reverse process of mineralization, immobilization, refers to the tie-up of plant-available P by soil minerals and microbes that use phosphorus for their own nutritional needs. This reaction reduces the availability of P to plants.

The availability of P is primarily dependent upon the pH of the soil. Soil pH levels indicate how certain minerals – iron, aluminum, and calcium – interact with P in the soil, and it is this interaction that affects P availability. When the soil pH is less than 5, iron and aluminum concentrations are very high and react very quickly with P, creating iron or aluminum phosphate minerals. When the soil pH is more than 7, calcium concentrations are very high and P fixation with calcium occurs. P fixation occurs to some degree for all soils - even for pH levels from 6 to 7. This pH range is where P availability is at its highest and fixation due to iron, aluminum, and calcium is at its lowest.

Microbes may compete with plants for P, if the decomposing organic materials are high in carbon and low in N and P (e.g. wheat straw). Mineralization and immobilization occur simultaneously in soil. If the P content of the organic material is high enough to fulfil the requirements of the microbial population, then mineralization will be the dominant process.

Adsorption

Adsorption is the chemical binding of plant available P to soil particles, which makes it unavailable to plants. This is a rather quick process, whereas the opposite process, desorption, is usually a slow process. Adsorption differs from precipitation: adsorption is reversible chemical binding of P to soil particles while precipitation involves a more permanent change in the chemical properties of the P as it is removed from the soil solution.

Since phosphate is an anion, particles that generate an anion exchange capacity (e.g. aluminum and iron oxides) will form strong bonds with phosphate. Additionally, in calcareous soils adsorption may occur as phosphates sorb to impurities such as aluminum and iron hydroxides or displace carbonates in calcium carbonate minerals. The soil mineral types therefore affect the P adsorption, volcanic soils and highly weathered soils have high P adsorption capacities. As the amount of clay increases in the soil, the P-sorption capacity increases as well. This is because clay particles have a tremendous amount of surface area for which phosphate sorption can take place. At low pH, soils have greater amounts of aluminum in the soil solution, which forms very strong bonds with phosphate. Generally, P-sorption increases as temperature increases. Organic matter can reduce the adsorption capacity and therefore increase the P availability for plants; e.g. organic anions can displace sorbed phosphate, it coats aluminum and iron oxides, which reduces P sorption. Flooding the soil reduces P-sorption by increasing the solubility of phosphates that are bound to aluminum and iron oxides and amorphous minerals.

Desorption

Desorption is the release of adsorbed P from its bound state into the soil solution. Other anions, such as silicates, carbonates, sulphates, arsenate, and molybdate, compete with phosphate for a position on the anion exchange site. As a result, these anions can cause the displacement, or desorption, of phosphate from the soil exchange site. Desorption causes phosphate availability in the soil solution to increase.

1.2.4. Agriculture and soil P cycle

In natural systems P is taken up by plants from the soil, utilized by animals that consume plants, and returned to soils with animal excretion and decay of plants and animals. Much of the P used by living organisms becomes incorporated into organic compounds. Organic P is held very tightly by the soil and is generally not available for plant uptake until the organic materials are decomposed and the P released via the mineralization process. The P which becomes available for plant uptake can however also potentially be lost through soil erosion and to a lesser extent to water running over or through the soil.

The natural level of phosphate in the soil is very low and is limiting to plant growth. Many natural ecosystems and low-input farming systems have adapted to low P supply by recycling from litter and soil organic materials. In modern agriculture most of the nutrients removed from the soil with the harvest of crops and the consumption of animal products do not return to the agricultural soil, a substantial part ends up for instance in human excreta and ends up through the sewage system in rivers and the sea. To sustain soil fertility with high levels of productivity external nutrient inputs are required. A breakthrough by means of the external application of phosphate occurred in the 19th century with the mining of phosphate deposits. This was one of the preconditions for the increase in agricultural production and for the increase in the world population from approximately 1 billion people in 1850 to the current population of 6.8 billion. Nowadays agriculture in Europe has become largely dependent on imports of phosphate for fertilizers; very little is mined in the EU. External P-inputs have however also decoupled patterns of supply, consumption and waste products from natural nutrient cycles. The paragraph on specialisation and intensification in Europe in section 1.1.7 also applies to Phosphorus.

It should be noted that not all of P in fertilizers and manure applied to soils are directly available to the plant; a part is converted from the active P pool to the fixed P pool (see subchapter 1.2.2). Opposite to N, soils can store excessive P inputs depending on the soil P capacity. However, an important aspect of the ability of a soil to hold phosphate is that a soil cannot hold increasing amounts of phosphate in the solid phase without also increasing soil solution phosphate. Increased amounts of phosphate in solution will potentially cause more phosphate to be lost to water running over the soil surface or leaching through the soil. Loading soils with very high levels of phosphate will generally not hurt crops but may result in increased phosphate movement to nearby bodies of water. Morgan, 1997 estimated that 25% or less of P applied annually is actually taken up by the growing crop; the remaining 75% becomes bond in the soil profile or is lost to the water. The crop uptake of P is in sharp contrast to the crop use of N and K fertilizers, where the recovery in the season of application can be as high as 80% according to Bomans et al, 2005. Yield and therefore the uptake of P by crops is not only determined by inputs but also by uncontrollable factors like climate. Due to their role in the eutrophication of surface waters, diffuse P losses from agricultural land to water have become a major environmental concern in many European countries. In many catchments agriculture is the major contributor of P to surface waters today. While a surplus of P 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.

2. NUTRIENT BUDGETS

2.1. Introduction

A nutrient budget estimates the nutrient surplus as the difference between nutrient inputs and nutrient outputs for a certain boundary. Nutrient budgets for agriculture can be distinguished by the definition of the boundary (farm, soil or land) they refer to. The nutrient budgets, which are the subject of this Handbook, can be categorised as following the land budget approach (the different types of budgets are discussed in the next paragraph). Different terms are in use to describe nutrient budgets estimated following a land, a soil or a farm budget approach. The term "Gross Nitrogen Balances" was introduced by the OECD to distinguish this type of budget (which is estimated based on the land budget approach) from the other types of budgets for Nitrogen. The term "gross" refers to the fact that the main result of the budget, the Gross Nitrogen Surplus, includes all N emissions to the air. Other approaches to estimate nitrogen budgets, e.g. soil (surface) budgets, result in N surpluses excluding (i.e. 'net' of) N emissions occurring before the application of manure and fertilizers to the soil.

Nutrient budgets provide insight into links between agricultural nutrient use, losses of nutrients to the environment, and sustainable use of soil nutrient resources. Sustainability could in this context be defined as preserving and/or improving the level of production without degrading natural resources.

Nutrient budgets estimate nutrient surplus from nutrient inputs to the soil and nutrient outputs from the soil. Nutrient stock changes in the soil are a specific case as they are difficult to quantify. Therefore, in the current version of the handbook, they are accounted in the surplus.

Nutrient budgets provide valuable information about the link between agricultural activities and environmental impacts of nutrient use and management in agriculture. Nutrient budgets can be used to determine areas at risk of nutrient pollution (when estimated at low regional levels), to identify driving factors behind nutrient pollution resulting from agriculture and to follow trends over time.

2.2. Types of nutrient budgets

There are basically three approaches[7] to estimate nutrient budgets:

(1) Farm budget

(2) Soil budget

(3) Land budget

The differences between the three approaches are explained by the boundaries by which the budget is defined. The **farm budget** is constructed in the boundaries of the farm and records the nutrients in all kinds of products that enter and leave the farm-gate. It should be noted that this does not mean that this type of budget can only be estimated for individual farms. The budget can also be calculated at a country level with the farm budget approach, in that case the whole farming sector in a country is considered as a single farm.

The land and soil approaches have many similarities. The **soil budget** takes the soil as the boundary. Only nutrient inputs to the soil and nutrient outputs from the soil are taken into account. The soil budget therefore requires data on manure and fertilizer applications to the soil. The **land budget** approach aims to estimate the total nutrient at risk of pollution (air, soil and water). The land budget therefore requires data on excretion.

For the Phosphorus Budget the land and soil budget are comparable.

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[7] A discussion of these three approaches can be found in the final report of DireDate on Task 3 and the article "Farm, land, and soil nitrogen balances for agriculture in Europe calculated with CAPRI", by Leip, A. et al.

For the Gross Nitrogen Budget the soil and land budgets are slightly different: N which volatilizes before the application of manure and fertilizers (e.g. in animal housing, manure storage etc.) is not included in the budget calculations using a soil budget approach. The soil nitrogen budget estimates the N surplus excluding N emissions before application, which provides a more accurate estimation of the N at risk of leaching and run-off. The nitrogen budget following the land budget approach requires data on excretion (N losses through volatilisation are included in excretion as excretion coefficients to translate animal numbers into nutrients excreted represent the nutrient content at the time of excretion). The N surplus estimated with the land budget therefore includes N emissions to the air during animal housing and manure management.

Table 1. N inputs, outputs and surpluses in farm, land and soil budgets (Leip et al, 2011)

	Input			Output			Surplus		
	Farm	Land	Soil	Farm	Land	Soil	Farm	Land	Soil
Animal products (meat, milk, etc.)				x					
Sold crop products				x	x	x			
Fodder[a]					x	x			
Mineral fertilizer	x	x	x						
Feed (concentrates)	x								
External organic nitrogen sources[b]	x	x	x						
Net manure import/export, and withdrawals[c]	x	x							
Manure excretion		x							
Manure application[d]			x						
Crop residues					x	x			
Crop residues returned to/left on the soil		x	x						
Biological N fixation	x	x	x						
Atmospheric deposition	x	x	x						
Soil N-stock changes[e]						x	x	x	
N-gas emissions before manure application[f]							x	x	
Leaching and run-off before manure appl.							x	x	
N-gas emissions from soil[f]							x	x	x
Leaching and run-off from soils							x	x	x

[a] Fodder crops, cereals and other crops grown for feeding, grazed and cut grass.
[b] Sewage sludge, compost, etc.
[c] In the soil budget manure import/export and withdrawals must be implicitly considered in the application rate. Note that for the farm and land N-budget manure export and withdrawals are considered as negative N input with manure.
[d] Net of losses from housing and manure management systems.
[e] Soil N-stock changes are accounted as positive contribution of NS for farm and land budgets if the soil is depleting in nitrogen. It is accounted as positive contribution to the output of the soil N-budget if nitrogen is accumulating in the soil.
[f] NH_3, NO_x, N_2O, N_2.

Table 1 shows a summary of these three types of approaches to estimate nitrogen budgets. It shows clear differences in:

a) Data requirements to estimate the budgets

It must however be noted that though there are theoretical differences in the data required by these approaches, in practice data for all these three approaches are more or less required regardless of which approach is taken to estimate nitrogen budgets and to estimate Greenhouse Gas (GHG) and ammonia (NH_3) emissions:

- DireDate recommends estimating the budgets with the farm and the land/soil approach to be able to cross-check and improve the results.
- Data on animal feed including grassland products are required to estimate and improve excretion coefficients and to capture farmer mitigation actions by changing animal diets.
- Excretion coefficients are needed to fulfil the requirements for GHG and NH_3 emissions inventories.

b) Nitrogen surplus estimated

In principle the N surplus estimated with the farm or land budget as described in Table 1 includes N gas emissions, whereas the N surplus estimated with the soil budget approach excludes N gas emissions occurring before application of manure to the soil. In some variances of the soil budget, direct emissions from the application of manure and fertilizers are also excluded. An N surplus excluding N gas emissions can also be derived from the land and farm approaches by deducting them from the estimated total N surplus. Vice versa, a total N surplus can be estimated from the soil budget approach by adding the excluded N gas emissions to the estimated surplus.

c) Stock changes of nitrogen in the soil

Soil resources of N can be depleting (e.g. under cultivation of drained peat lands) or accumulating when building up new organic matter in the soil (e.g. under appropriate crop residue and manure management, or in no-tillage systems). From Table 1 it can be seen that in principle stock changes in the soil should be considered in the soil budget at the output side of the budget.

The reasons for including the changes in the N stock of the soil are:

- Changes in soil organic matter content happen within the system boundaries, while emissions of gaseous N or losses of N to the hydrosphere is a flux of N across system boundaries (be it farm, land or soil).
- Changes in soil N-stocks are reversible, while the fate of reactive N released to the environment is not any more under control of farmers. A farmer has however the possibility to switch from an N-depleting to an N-accumulating management and the accumulated N can be regarded as a 'useful product' of his activities. Accordingly, useful crop and animal products generated at the cost of the soil's quality are adjusted by the amount of N-depletion. Neglecting soil stock changes would lead e.g. to very high NUEs in situations where crop production predominantly draws on available soil nitrogen often in a non-sustainable manner, as can be observed in the results obtained in a study using the IMAGE model for many African and Latin American countries (Bouwman et al, 2009).

In the farm and land N-budgets, the N which adds to soil N accumulation or depletion is included in the N surplus. It could be argued however to adapt the land budget to include changes in the N stock of the soil in the output side as well. Soil fertility is an important service of agriculture. Inclusion of soil N-stock changes in the **output**, would mean that all production that is at the cost of soil depletion would not be considered as output (output – negative stock changes) and low productivity will be rewarded if the management leads at the same time to increases in soil organic matter and nitrogen (output + positive stock changes). The resulting surplus would not include the N which is added or extracted from the stock of N in the soil.

However, currently the data on stock changes in the soil is insufficient available or of insufficient quality. Therefore, in the current land budget approaches for Gross Nitrogen budgets and Phosphorus Budgets changes of nutrient stocks are not requested to be quantified and thus – in practice – soil nutrient stock changes in the soil remain in the surplus. It must be noted, however, that this practice is limited to situations where on average no soil nutrient stock changes occur or where changes are positive (i.e. accumulation of nutrients in the soil). As calculation for different regions in Turkey have shown (Ozbek et al., in preparation), neglecting soil stock changes in the output terms leads to problematic results as soon as the data are used to derive efficiency indicators or when comparing regions/countries.

In the Task Force meeting on Gross Nutrient Balances in 2011 participants mentioned the following arguments in favour and against different types of budgets:

Farm budget

Advantages

- Most integrative, most meaningful indicator overall N pressure agricultural activities (see e.g. Bach, 2005. Nevens et al, 2006. Oenema et al, 2003. Schröder et al, 2004).
- Most accurate estimation according to DireDate and other scientists: throughputs such as excretion and home produced fodder do not need to be specified.
- That's why some countries use this approach for national use.
- Easiest for the farmer to understand: inputs to and outputs from the farm.
- Inputs bought and outputs sold should be available from farmers bookkeeping.
- Data at national scale available from sales, trade and production statistics.

Disadvantages

- Some data needed, e.g. animal feed, not everywhere available and difficult to survey.
- Not always easy to assign nutrient contents to individual feeding stuff such as to vegetable cakes and meals which can vary by some degree.
- Data are not available at regional level.

Soil budget

Advantages:

- More meaningful indicator for identifying aquatic risk.
- More appropriate approach to disaggregate to regional level (data availability).

Disadvantages:

- Data on manure applied required, which are often not available and difficult to collect. Therefore often estimated based on excretion corrected for volatilisation of N before application.

Land budget

Advantages:

- Long experience: the Eurostat/OECD GNB corresponds to the land N budget.
- Coherence with GHG and NH_3 estimations.
- More appropriate approach to disaggregate to regional level (data availability).

Disadvantages:

- Data on manure and fodder production are required. Measured data generally not available and are therefore generally estimated with model calculations.

The land budget approach has been agreed by members of the Eurostat Working Group on AEI and other relevant stakeholders to be most appropriate to estimate the Gross Nitrogen Budget and the Phosphorus Budget required by Eurostat/OECD and other Commission institutes.

2.3. The Gross Nitrogen Budget

The Gross Nitrogen Budget (GNB) estimates the Gross Nitrogen Surplus (GNS). The **GNS** represents an indication of the total potential risk of N agriculture poses to the environment (N emissions to the air, leaching and run-off to waters) and depletion/accumulation of N in the soil. A persistent N surplus indicates potential risks of N leaching and run-off to water, emissions to the air. This could lead to environmental problems such as nitrate pollution of ground- and surface water, emissions of N_2O a potent greenhouse gas, NH_3 contributing to acidification etc. A persistent nitrogen deficit indicates a potential risk of decline in soil fertility which can also lead to other soil related problems such as erosion. In practice, depletion of soils with nutrients does not avoid that emissions of nutrients to the environment occur.

It is important to note that the GNB can only indicate a potential risk to the environment. The actual risk of N leaching, run-off and volatilisation or changes in soil stocks of N depend on many factors such as meteorological conditions, soil characteristics, farmer management practices etc. Not all of these factors are taken into account in the estimation of the GNB. The actual risks of N surplus to air and water are better represented by the European Commission agri-environmental indicators 18 "Ammonia emissions", 19 "GHG emissions" and 27.1 "Water quality (Nitrate pollution)". Data on the state and accumulation or depletion of N stocks in the soil are currently not available.

For the ideal methodology the changes in N stock of the soil are accounted in the output side of the budget, see previous paragraph. In that case the GNS consists of N emissions to the air and leaching/run-off to the water and can be split in a part which is definitely emitted to the air, the atmospheric Gross Nitrogen Surplus (aGNS), and a part that is potentially leached and run-off to the water, the hydrospheric Gross Nitrogen Surplus (hGNS).

Equation 1. $\mathbf{GNS = aGNS + hGNS}$

Equation 2. $\mathbf{hGNS = GNS - aGNS}$

Equation 1 describes the relation between GNS, aGNS and hGNS. aGNS can be estimated directly from available data on N emissions, see discussion below. hGNS cannot be estimated directly and is estimated as the result of subtracting aGNS from GNS, see Equation 2.

aGNS is defined as the part of the GNS estimated with the GNB which potentially poses a risk of atmospheric N pollution due to direct and immediate N emissions in reactive form.

Because hGNS is estimated as the result of GNS minus aGNS, it cannot provide an accurate indication of nitrate pollution of water. Currently changes in the stock cannot be estimated; they can therefore not be accounted for in the output side of the budget, and are therefore numerically included in the GNS. As hGNS is estimated as the difference between GNS and aGNS, stock changes in the soil are included in hGNS. Emissions of N to the atmosphere which are not included in aGNS due to technical reasons (availability of methodologies to estimate emissions and data), indirect N emissions after leaching and run-off and immediate and direct emissions of N_2 will also end up in hGNS. hGNS can only be used as an indication of the potential risk of N pollution of waters.

hGNS can be defined as the part of the GNS estimated with the GNB which potentially poses a risk to the aquatic environment due to leaching and run-off and which includes changes to the stock of N in the soil and indirect N emissions to the air after leaching and run-off as well as immediate and direct emissions of N_2.

In the **ideal definition of aGNS** all direct and immediate emissions of NH_3, NO, N_2O from the following emission sources are included:

- animal housing
- manure management
- manure storage
- manure application
- manure dropped on pastures
- application of mineral fertilizers
- application of other organic fertilizers
- crop residues
- field burning of agricultural wastes

Please note that direct N_2O emissions due to the cultivation (drainage/management) of high organic content soils which are estimated for the United Nations Framework Convention on Climate Change (UNFCCC) GHG Inventories following the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines are not taken into account in this definition. The cultivation of high organic content soils leads to enhanced mineralisation of old, N-rich organic matter. As changes of N stocks in the soil are not taken into account in the budget, it seems appropriate not to include emissions from the cultivation of high organic soils either.

N_2O emissions from biological fixation should also be included to be coherent with the GHG Inventories following the revised IPCC 1996 Guidelines. However due to the lack of evidence of significant emissions arising from the fixation process itself (IPCC 2006, Vol. 4, Ch. 11.6); these emissions will no longer be required to be estimated following the IPCC 2006 Guidelines. Therefore they are not included in the definition of aGNS.

A practical implementation of the estimation of aGNS will be discussed in Chapter 3.16.

2.4. The Phosphorus Budget

The Phosphorus Budget (PB) estimates the Phosphorus Surplus (PS). The PS represents an indication of the total potential risk of P agriculture poses to the environment (P leaching and run-off to waters) and depletion/accumulation of P in the soil. A persistent P surplus indicates potential risks of P leaching and run-off to water and increases in the soil stock. This could lead to environmental problems such as phosphate pollution of ground- and surface water. A persistent P deficit indicates a potential risk of decline in soil fertility which can also lead to other soil related problems such as erosion.

It is important to note that the PB can only indicate a potential risk to the environment. The actual risk of P leaching, run-off or changes in soil stocks of P depend on many factors such as meteorological conditions, soil characteristics, farmer management practices etc. Not all of these factors are taken into account in the estimation of the PB. Data on the state and accumulation or depletion of P stocks in the soil are currently not available. Also it should be noted that the accumulation of P over time represent a larger actual risk for the environment than the amount of P which is applied yearly, or the surplus on today’s balance. This is in contrast of N for which the cumulative N Surplus of the past is much less relevant since N hardly accumulates in soils. However, the future risk of P on the environment is strongly influenced by the P surplus of today and the near future, in combination with the capacity of a soil to bind P. This is why the PB on its own is not sufficient to indicate areas at risk of P pollution. Therefore to evaluate risks of P pollution the European Commission is developing an additional indicator to support the evaluation of PB *"Vulnerability to phosphorus leaching/run-off"*[8].

[8] More information on this indicator can be found at the website on Agri-Environmental Indicators of Eurostat: http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/introduction

3. Guidelines to the practical implementation of GNB and PB

3.1. Introduction

Data collection of nutrient budgets in 2010 showed that there is a need to improve data availability and quality for some flows. Resources in countries are however limited. This means that there is not only a need to prioritise new data collection but also existing data collection to create room for new data collection. In this Chapter the ideal GNB and PB are described, as well as guidelines for the practical implementation, which is a compromise between the ideal budgets and what can be reasonably achieved with limited resources.

Though in principle the aim is to include all nutrient flows, problems in data availability and quality have led to exclude certain flows (which ideally should be included in the nutrient budgets) in the described practical implementation of the nutrient budgets, e.g. atmospheric deposition of P, crop residue inputs and BNF by free living organisms.

A further distinction has been made in the practical implementation between flows for which data reporting are obligatory and flows for which data reporting is optional. For obligatory flows of the practical implementation default estimations procedures are established. Some flows are currently optional in the practical implementation because data are not available for all countries and default estimations are difficult to establish, e.g. use of other organic fertilizers, manure treatment and non-agricultural use of manure. For obligatory flows a minimum data reporting requirement is established in the practical implementation to ensure a minimum level of comparability and transparency of GNB and PB estimations across countries. Countries are however encouraged to go beyond this minimum data requirement to provide as much as possible complete information on the flow.

Obviously, the best available estimate is required. If countries are able to estimate one or more flows following the ideal budget, they should do so.

Table 2 shows an overview and the differences between current GNB following the OECD/Eurostat Handbook on Nitrogen Balances (2007) and ideal GNB and practical implementation as described in this Chapter. The ideal GNB includes all flows from and to agricultural soils and estimates total GNS, aGNS and hGNS following the land budget approach for the reference area. The practical implementation is based on discussions with stakeholders, Member States delegates, and results from DireDate etc. The practical implementation of the ideal GNB is represented in the third column of Table 2. In a similarly Table 3 shows an overview and differences between the current PB following the OECD/Eurostat Handbook on Phosphorus Balances (2007) and the ideal and practical implementation of the PB as described in this Chapter.

In subchapter 3.2 to 3.4 the statistical limit of nutrient budgets are defined. In subchapters 3.5 to 3.16 particular flows of the budgets are discussed in more detail, following a common structure:

(1) Definition.

Definitions are provided for terms used.

(2) Description in Ideal and Practical implementation of GNB and PB.

In the box the nutrient flow is defined in the ideal GNB and PB and under its practical implementation.

(3) Guidelines on practical implementation.

Guidelines are provided for the practical implementation and a minimum data requirement is formulated. For some flows the guidelines cannot be considered final as improvements are expected in the future. The actions to improve the flows accounting in the future are listed in the last section of each subchapter. For sections which are likely to be updated in the future this is noted at the beginning of the section.

(4) Discussion.

Differences with the OECD/Eurostat Handbooks 2007 are discussed.

(5) Coherence with UNFCCC/UNECE.

In this section the coherence between the Handbook and the IPCC Guidelines and EMEP/EEA Guidelines are discussed. Due to a difference in definition of agriculture, see subchapter 3.2, between the Handbook and IPCC and EMEP/EEA, for some flows data to be reported in GNB may deviate slightly from data reported to UNFCCC and EMEP/EEA. These deviations are discussed in this section.

(6) Default estimation procedure.

The default estimation procedure is described which will be applied by Eurostat in case that a country cannot submit the required data.

(7) Actions foreseen.

GNB and PB estimations are expected to be improved in the coming years, in terms of improved quality of data, data availability, definitions etc. In this section actions are listed for flows in the budgets for which actions can be expected to lead to an update of the subchapter in the Handbook.

Table 2. Current, ideal and proposed improved Gross Nitrogen Budgets

Current GNB	Ideal GNB	Practical GNB
INPUTS		
N1) Mineral fertilizers	N1) Mineral fertilizers	N1) Mineral fertilizers
N2) Manure production	N2) Manure production	N2) Manure production
N3) Net manure import/export, withdrawals, stocks	N3) Net manure import/export, withdrawals, stocks	N3) Net manure import/export, withdrawals
N4) Other organic fertilizers	N4) Other organic fertilizers	N4) Other organic fertilizers
N5) Biological N fixation	N5) Biological N fixation	N5) Biological N fixation
N6) Atmospheric N deposition	N6) Atmospheric N deposition	N6) Atmospheric N deposition
N7) Seed and planting materials	N7) Seed and planting materials	N7) Seed and planting materials
	N8) Crop residues inputs	
N9) **Total inputs** = sum (N1,N2,N3,N4,N5,N6,N7)	N10) **Total inputs** = sum (N1,N2,N3,N4,N5,N6,N7,N8)	N11) **Total inputs** = sum (N1,N2,N3,N4,N5,N6,N7)
OUTPUTS		
N12) Crop production	N12) Crop production	N12) Crop production
N13) Fodder production	N13) Fodder production	N13) Fodder production
N14) Crop residues outputs	N14) Crop residues outputs	N16) Residues removed /burnt
	N15) Stock changes of N in soil	
N17) **Total outputs** = sum (N12, N13, N14)	N18) **Total outputs** = sum (N12, N13, N14, N15)	N19) **Total outputs** = sum (N12, N13, N16)
SURPLUS		
N20) **GNS** = N9 – N17	N21) **GNS** = N10 - N18	N24) **GNS** = N11 - N19
	N22) **aGNS** = N gas emissions	N22) **aGNS** = N gas emissions
	N23) **hGNS** = N21 – N22	N25) **hGNS** = N24 - N22

Table 3. Current, ideal and proposed improved Phosphorus Budgets

Current PB	Ideal PB	Practical PB
INPUTS		
P1) Mineral fertilizers P2) Manure production P3) Net manure import/export, withdrawals, stocks P4) Other organic fertilizers P6) Atmospheric P deposition P7) Seed and planting materials	P1) Mineral fertilizers P2) Manure production P3) Net manure import/export, withdrawals, stocks P4) Other organic fertilizers P6) Atmospheric P deposition P7) Seed and planting materials P8) Crop residues inputs	P1) Mineral fertilizers P2) Manure production P3) Net manure import/export, withdrawals P4) Other organic fertilizers P7) Seed and planting materials
P9) **Total inputs** = sum (P1,P2,P3,P4,P6,P7)	P10) **Total inputs** = sum (P1,P2,P3,P4,P6,P7,P8)	P11**) Total inputs** = sum(P1,P2,P3,P4,P7)
OUTPUTS		
P12) Crop production P13) Fodder production P14) Crop residues outputs	P12) Crop production P13) Fodder production P14) Crop residues outputs P15) Stock changes of P in soil	P12) Crop production P13) Fodder production P16) Crop residues removed
P17) **Total outputs** = sum(P12, P13, P14)	P18) **Total outputs** = sum(P12, P13, P14, P15)	P19) **Total outputs** = sum(P12, P13, P16)
SURPLUS		
P20) **PS** = P9 – P17	P21) **PS** = P10 - P18	P22) **PS** = P11 - P19

3.2. Agriculture

3.2.1. *Definitions*

Agriculture covers all agricultural holdings within a country. An 'agricultural holding' means a single unit, both technically and economically, which has a single management and which undertakes agricultural activities listed under NACE Rev2 Chapter 01[9], within the economic territory of the country, either as its primary or secondary activity.

3.2.2. *Description in Ideal and Practical implementation of GNB and PB*

Ideal:	The nutrient budget records nutrient flows of agriculture at appropriate regional level.
Practical:	The nutrient budget records nutrient flows of agriculture at NUTS0.

3.2.3. *Guidelines on practical implementation*

Nutrient flows should be reported for all agricultural holdings within a country as defined in section 3.2.1.

3.2.4. *Discussion*

A clear definition was not provided in OECD/Eurostat Handbooks 2007. Agriculture as described in section 3.2.1 provides a narrower description of nutrient flows to be recorded in nutrient budgets than nutrient flows which have been included under agriculture in IPCC Guidelines, European Monitoring and Evaluation Programme (EMEP)/ European Environment Agency (EEA) Guidebook or current draft guidance document of the Gothenburg protocol, see section 3.2.5. In the Working Group meeting on AEI in February 2013 it was decided to use this stricter definition, to better describe risks of nutrient pollution in agriculture. Differences between data reported on flows to UNFCCC, UNECE and in nutrient budgets due to the use of this narrower definition in GNB are noted in the separate subchapters on the different flows of the nutrient budgets (see also section 3.2.5).

3.2.5. *Coherence with UNFCCC/UNECE*

In IPCC Guidelines and EMEP/EEA Guidebook under 'Agriculture' activities leading to NH_3 and GHG emissions are defined. Sometimes these activities are however not solely related to agriculture; e.g. under Revised IPCC 1996 Guidelines all mineral fertilizer use should be reported, also those for non-agricultural uses (city parks, golf courses etc.), whereas in nutrient budgets only mineral fertilizer use by agriculture should be reported. Some countries take into account livestock outside agricultural holdings when estimating excretion and emissions for UNFCCC/UNECE reporting, while in GNB only livestock held on agricultural holdings should be included. Such differences in activity data may also lead to differences in estimated emissions to be taken into account in GNB (see subchapter 3.16) and data reported to UNFCCC/UNECE. Whenever such differences occur, they are described in sections 'Coherence with reporting requirements UNFCCC/UNECE' of the separate subchapters on flows in the nutrient budgets.

3.2.6. *Default estimation procedure*

Not applicable.

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[9] NACE is the statistical classification of economic activities in the European Community.

3.2.7. Actions foreseen

Eurostat is coordinating with EPNB on improving the definition of agriculture in nutrient budgets of Eurostat and the national nitrogen budgets.

3.3. Reference area

3.3.1. Definitions

Utilized Agricultural Area (UAA) is the total area taken up by arable land, permanent grassland, permanent crops and kitchen gardens used by agricultural holdings, regardless of the type of tenure or whether it is used as common land (Regulation **EC No 543/2009**).

3.3.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	Total UAA at appropriate regional level.
Practical:	UAA as reported in Crop Statistics at NUTS0.

3.3.3. Guidelines on practical implementation

This section may be updated in the future, following actions listed in section 3.3.7, see also the discussion in section 3.3.4.

Data on UAA as reported in Crop Statistics at NUTS0 level (Regulation (EC) No 543/2009).

3.3.4. Discussion

In the OECD/Eurostat Handbooks 2007 the following was stated on the reference area: "*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*". From this definition it is not clear how to interpret potentially fertilised UAA, bias and extensive areas. Interpretations therefore varied and some countries excluded certain areas whereas others did not exclude such areas. After several discussions with countries and other stakeholders[10] involved it was agreed to define the reference area as the total UAA.

Arguments for total UAA include:

- Consistency with other indicators: AEI indicators linked to nutrient budgets are based on total UAA (e.g. GHG and NH_3 emissions, crop and livestock patterns). Indicators on agriculture in general refer to UAA.
- UAA covers total agricultural activities on soils.
- Data on UAA of EU countries have been collected annually in Crop Statistics for many years and can be considered of high quality and consistent across countries and time. However certain problems exist, e.g. inconsistencies for some countries with other land use statistics[11]

[10] The reference area in the 2010/2011 data collection was the sum of arable land, permanent grassland and land under permanent crops, see presentation on nutrient balances of WG meeting on AEI March 2011. Discussions in WG meetings and with stakeholders continued on the definition of the reference area, see for example document and MS reactions on reference area WG meeting on AEI February 2012.

[11] See document for Crop statistics WG October 2011.

and coverage of non-grassland grazing areas[12]. The coverage and treatment of extensive grazing areas in the reference area will be addressed in the project on grasslands see section 3.3.7.

It should also be noted that the budgets at national level remain difficult to interpret as they present averages for often very heterogeneous areas and structures of agriculture. To identify areas at risk of nutrient pollution, the indicator needs to be estimated at sufficient low geographical scales. Eurostat is working with JRC on regionalising nutrient budgets with the CAPRI Model[13].

3.3.5. *Coherence with UNFCCC/UNECE*

Not applicable.

3.3.6. *Default estimation procedure*

UAA as reported in Crop Statistics (Eurobase: apro_cpp_luse) at NUTS0.

3.3.7. *Actions foreseen*

Eurostat has signed a contract in October 2012 with duration of 14 months with the objective to define different types of grasslands and their productivity and to describe how data can be collected on these different types of grassland in the EU so that a coherent European data set on grasslands is created[14]. Non-grassland grazing areas are also covered by this project. This action is expected to indicate measures to improve current data on land use and especially grassland and grazing areas and provide recommendations on coverage and treatment of extensive grazing areas in nutrient budgets.

3.4. Reference period

3.4.1. *Definitions*

The **calendar year** covers a period starting on 1 January end ending at 31 December.

A **crop year** is the duration from one year's harvest to the next. Crop years will vary with each different commodity and harvest cycle; it begins 12 months before harvest and ends with harvest.

3.4.2. *Description in Ideal and Practical implementation of GNB and PB*

Ideal:	Calendar year.
Practical:	Calendar year. Data on crop year (t-1/t) can be reported in calendar year t.

3.4.3. *Guidelines on practical implementation*

The calendar year is the reference period for the Nutrient Budgets. Data on crop year (t-1/t) can be reported for calendar year t.

3.4.4. *Discussion*

In the OECD/Eurostat Handbooks 2007 the reference period was not defined explicitly. Budgets have therefore been estimated by countries for different reference periods. Most countries estimate nutrient budgets for calendar years. However some countries estimate nutrient budgets for crop years as they

[12] Examples are areas in Spain, which are used by agriculture during a specific time for grazing of livestock, which are not covered in statistics on UAA.

[13] See presentations by JRC on the pilot projects of regionalising the nutrient budgets with CAPRI at the WG meeting on AEI in 2012, and at the kick-off meeting of the pilot projects on 20 February 2013 in Luxembourg.

[14] See presentation of the project at the WG meeting on AEI February 2013.

consider this reference period more appropriate as the amount of nutrients applied to the soil is particularly linked to the final yield.

In the discussion on the reference period with experts from Member States the following arguments have been mentioned in favour of the calendar year:

- Data on other flows (e.g. livestock, excretion, emissions) are referring to calendar year.
- Coherence and usability of the indicator; all other indicators are based on calendar year, as well as data reported to UNFCCC (GHG Inventory) and UNECE (NH_3, NO emissions).
- From the agronomic point of view it makes sense to report crop statistics by crop year but all decisions on economic and financial impact of farming for the production system, investments, loans to purchase inputs, etc., are independent and are made during the calendar year as other decisions with less impact but also important as daily decisions.
- Impact of nutrients on environment is not confined to crop year, goes beyond crop year.
- If nutrient budgets are estimated for crop year, there will be less data available.
- Comparability across Member States decreases as crop years vary among Member States.

It was concluded that the calendar year is the appropriate reference period for Nutrient budgets.

Though many of the data used in the GNB refer to the calendar year, some data are however often estimated for different periods, e.g.:

- Fertilizer statistics are in some countries estimated per calendar year and in other countries for crop years.
- Crop statistics provide, for a given product, the area, the yield and the production harvested during the crop year at national level. The reference period is the harvest year: 2004 indicates that the data refer to production harvested during the 2004 calendar year.

The impact of these inconsistencies with the reference period and the need for corrections has been discussed with Member States. It was concluded that these inconsistencies will not significantly affect the budget results, and therefore no corrections are needed:

- Crop production statistics refer to crops where harvest begins during the calendar year, input statistics refer to those crops.
- Though data on particular flows may refer to a different period, the data are consistent over time.

3.4.5. *Coherence with UNFCCC/UNECE*

For some flows (e.g. livestock population, crop residues burned) the 1996 Revised IPCC Guidelines (Volume 3, Chapter 4.2.2 and 4.4.3) recommend to use three year averages of activity data if available. This recommendation is however removed in the 2006 Guidelines which aim at the best annual estimates of activity data.

3.4.6. *Default estimation procedure*

Not applicable.

3.4.7. *Actions foreseen*

No actions foreseen.

3.5. Mineral fertilizers

3.5.1. Definitions

'**Inorganic fertilizer**' means a fertilizer in which the declared nutrients are in the form of minerals obtained by extraction or by physical and/or chemical industrial processes. Calcium cyanamide, urea and its condensation and association products, and fertilizers containing chelated or complex micro-nutrients may, by convention, be classed as inorganic fertilizers (Regulation (EC) No 2003/2003).

3.5.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	All mineral fertilizers used in the reference area.
Practical:	Official national statistics of mineral fertilizer use by agriculture at national level.

3.5.3. Guidelines on practical implementation

This section may be updated in the future, following actions listed in section 3.5.7, see also the discussion in section 3.3.4.

Data on mineral fertilizer consumption provided to Eurostat as official statistics. Countries are advised to discuss the data reported to UNFCCC[15] in national discussion groups to ensure and improve coherence and consistency between data reported to UNFCCC on mineral fertilizer use and data reported to Eurostat in nutrient budgets and for fertilizer statistics, see also section 3.5.5.

Data estimated from sales statistics or production and trade statistics in general include non-agricultural uses, whereas data from farm surveys do not. If the estimation of mineral fertilizer use by agriculture is based on trade/production or sales statistics, it is recommended to provide corrections for non-agricultural use, stocks, double-counting of intermediate production etc. It is also recommended to include verification procedures of data, such as crosschecking with other available data sources, expert knowledge etc. DireDate also recommended collection of data at farm level to improve/verify official statistics.

3.5.4. Discussion

Currently different data sources for mineral fertilizer consumption exist and are used by countries for reporting to nutrient budgets, GHG/NH_3 inventories and other policy requirements; farmer surveys, trade/production statistics, sales data, expert judgement/modelling etc. To improve the coherence ("one single official figure") of reporting on mineral fertilizer statistics for the different policies and institutes and to improve the quality and availability of data on mineral fertilizer consumption, DireDate recommended that each Member State establishes a workgroup covering e.g. statistical departments, environmental and agricultural institutes, fertilizer industry, GHG/NH3 inventory compilers etc. This recommendation was discussed in CPSA meetings and countries have been requested to establish such discussion groups[16]. These workgroups should discuss the quality of existing data sources on mineral fertilizer consumption and if needed a strategy to improve or collect data on mineral fertilizer consumption and establish a single official statistic on mineral fertilizer consumption in the short term.

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[15] All countries provide data to UNFCCC. These data can be found in the National Submissions to the GHG Inventory available at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598.php

[16] See CPSA document 649 and first results of national discussion group meetings available at Circabc

Current available data sources include:

- Data reported to UNFCCC

IPCC 2006 Guidelines propose to use country specific data, Fertilizers Europe or FAO data in the case country-specific data are not available, see also section 3.5.5.

- Data reported to UNECEC/CLTRAP

The EMEP/EEA Guidebook propose to use country specific data, and Fertilizers Europe or FAO data in the case country-specific data are not available, see also section 3.5.5.

- Data reported to PRODCOM/COMEXT

Data on production and trade of fertilizers by type are also available in all countries from PRODCOM and COMEXT. Data on production and trade of fertilizers could be used to crosscheck estimations on fertilizer consumption.

- Other data available in countries.

In the short term Eurostat will collect data on mineral fertilizer consumption as discussed in CPSA meetings in 2012[17]. Data collection at farm level may be implemented in the future, see section 3.5.7.

3.5.5. *Coherence with UNFCCC/UNECE*

For this flow in the nutrient budgets data should be provided which are coherent with data reported to UNFCCC. Please note that coherence does not necessarily mean exactly the same data: The Revised 1996 IPCC Guidelines (Vol. 3 Ch. 4.5.2) note as activity data to estimate N_2O emissions from application of mineral fertilizers, total fertilizer consumption per year corrected by that fraction of synthetic fertilizer N applied to soils that volatilises as NH_3 and NO_x. The 2006 IPCC Guidelines require for Tier 1 amounts of applied mineral N fertilizers which is no longer adjusted for amounts of NH_3 and NO_x volatilisation after application to soil (see Vol. 4 Ch. 11.2.1.3). In IPCC 2006 Guidelines and in EMEP/EEA 2009 Guidebook (Vol. 4D Ch. 3.2.3 and 3.3.3) it is recommended that annual amount of synthetic N fertilizer applied to soils is estimated from total amount of synthetic fertilizer consumed annually. Annual fertilizer consumption data may be collected from official country statistics, often recorded as fertilizer sales and/or as domestic production and imports and should not be limited to only agricultural N uses. IPCC 1996 Revised Guidelines are less clear on the inclusion of non-agricultural uses, but NIR reports show that different practices have been used by different countries for instance data sources used include data from agricultural holdings, sales data, data fertilizer industry, etc. In the nutrient budgets should in principle only relate to agriculture. There should however be coherence between estimates of total fertilizer use and fertilizer use by agriculture. Countries are expected to provide information on the coherence of data reported in nutrient budgets and fertilizer statistics and data reported to UNFCCC/UNECE in the metadata.

3.5.6. *Default estimation procedure*

For countries which do not have data available Eurostat will use data reported to UNFCCC in NIR/CRF reports on total N fertilizer consumption for N and data from Fertilizers Europe for P.

3.5.7. *Actions foreseen*

At medium-long term Eurostat intends to implement DireDate recommendations. Discussions are on-going to include variables on mineral fertilizer consumption in FSS 2016 onwards.

[17] See documents CPSA 649 and CPSA 675 available at Circabc

3.6. Manure production

3.6.1. Definitions

The **Annual average population** (AAP) represents the average population of a livestock type present during a year, this includes fall-out (animals which die before coming to production age).

- For livestock types without seasonal variations in the population and empty stable places (e.g. dairy cows) AAP can be considered equal to the population counted at any specific day.
- For livestock types with seasonal variations (e.g. sheep, goats) or occurrence of empty stables the population counted on a specific day or data on animal places need to be corrected for these factors to represent AAP present in a year.
- For livestock types involving multiple production cycles within a year (e.g. broilers) AAP can be derived from slaughter/production statistics corrected for non-sold or non-slaughtered animals (animals dying before production age has been achieved) divided by number of cycles. AAP of livestock types involving multiple production cycles can also be derived from number of animal places corrected for average amount of empty stable places during a year.

Excretion coefficients are factors representing the average amount of nutrients excreted per animal head per year (animal place for animals with multiple production cycles). The excretion coefficient can in specified cases include excretion of offspring and/or males. The excretion coefficient represents the nutrient content of excretion at the time of excretion; i.e. no corrections are made for volatilisation of N during animal housing, storage or with the application to land or for additions of nutrients when manure mixes with other material (e.g. straw). In the case of livestock with several production cycles per year, the production cycles should be directly reflected in the excretion coefficients, instead of in the livestock number. Thus, the excretion coefficient does not necessarily be one that can be measured for individual animals, but is defined such that the product of excretion factor and annual average population yield the total amount of nutrient at the time of excretion without correction (see Equation 5 and Equation 6 below).

Nitrogen use efficiency (NUE) of a livestock type can be defined as how much of Nitrogen consumed ($N_{animalfeed\_i}$) by livestock type *i* is retained in the animal products and in the animal of livestock type *i* ($N_{animalretention\_i}$), see Equation 3.

Phosphorus use efficiency (PUE) of a livestock type can be defined as how much of Phosphorus consumed ($P_{animalfeed\_i}$) by livestock type *i* is retained in the animal products and in the animal of livestock type *i* ($P_{animalretention\_i}$), see Equation 4.

Equation 3. $$NUE_i = N_{animalretention_i}(tonnes\ of\ N) \div N_{animalfeed_i}(tonnes\ of\ N)$$

Equation 4. $$PUE_i = P_{animalretention_i}(tonnes\ of\ P) \div P_{animalfeed_i}(tonnes\ of\ P)$$

Manure: livestock excreta or mixture of litter, urine and excreta, including processed manure.

Liquid manure: Manure from housed livestock that flows under gravity and can be pumped with a dry matter content of less than 5%. There are several different types of liquid manure arising from different types of livestock housing, manure storage and treatment. .

Slurry: Faeces and urine produced by housed livestock, usually mixed with some bedding material and some water during management, with a dry matter content between 5-15%.

Solid manure: Manure from housed livestock that does not flow under gravity, cannot be pumped but can be stacked in a heap. May include manure from cattle, pigs, poultry, horses, sheep, goats and rabbits. Bedding material could be crops residues, compost straw, leaf and other materials. There are several different types of solid manure arising from different types of livestock housing, manure storage and treatment (RAMIRAN, 2011).

Farmyard manure: Faeces and urine mixed with large amounts of bedding (usually straw) on the floors of cattle or pig housing. It may also include horse manure or manure from animals housed in stables and farmyards (RAMIRAN, 2011).

Deep litter: Faeces or droppings and urine mixed with large amounts of bedding (e.g. straw, sawdust, wood shavings) and accumulated over a certain time on the floors of buildings housing any type of livestock or poultry (RAMIRAN, 2011).

Bedding: Material placed on floors of livestock houses with solid floors or partially slatted floors to provide some comfort to the animals and to absorb moisture and urine. Commonly straw, chopped straw, sawdust, wood shavings, sand, peat. Rubber or plastic mats may also be provided.

3.6.2. *Description in Ideal and Practical implementation of GNB and PB*

Ideal: All manure produced in the reference area.

Practical:

- N: Excretion coefficients established for UNFCCC and data on annual average livestock population on agricultural holdings
- P: Excretion coefficients available in country and data on annual average livestock population on agricultural holdings.

3.6.3. *Guidelines on practical implementation*

This section may be updated in the future, following actions listed in section 3.6.7.

Equation 5. $$N_{excretion}(tonnes\ of\ N) = \sum_i \left\{ AAP_i(1000\ heads) \times N_{excretion_{coefficient_i}}\ (kg\ N\ per\ head\ per\ year) \right\}$$

Equation 6. $$P_{excretion}(tonnes\ of\ P) = \sum_i \left\{ AAP_i(1000\ heads) \times P_{excretion_{coefficient_i}}\ (kg\ P\ per\ head\ per\ year) \right\}$$

Manure production in tonnes of nitrogen is estimated by summing up the manure production of different livestock types. For each livestock type *i* manure nitrogen production ($N_{excretion}$) is estimated by multiplying nitrogen excretion coefficients which represent annual average nitrogen excretion per head of animal for livestock type *i* ($N_{excretion\_coefficient\_i}$) with the annual average population (AAP_i) of that livestock type *i* (Equation 5). In a similar way P excretion can be estimated (Equation 6). In principle excretion should be estimated for all livestock-types on agricultural holdings in the country. As a minimum requirement excretion should be estimated for all the livestock types (on agricultural holdings) reported to UNFCCC in the NIR and CRF reports of the country, these include in any case bovine animals (differentiated by dairy and non-dairy), pigs, poultry, sheep, goats and horses[18].

[18] UNFCCC reporting requirements include also camels, llamas, mules and asses. These livestock types are however of low significance in Europe and data on these animal types are often not available.

Estimation of annual average population per livestock category

- In Annex 1 the guidelines for the categorisation of livestock and the estimation of AAP by IPCC and EME/EEA are provided. The project on excretion coefficients see section 3.6.7 will look at the current practices in countries and the existing guidelines in IPCC and EMEP/EEA and provide a recommendation for the categorisation of livestock and the determination of AAP. This section provides an initial guideline on the estimation of AAP.
- For livestock types without seasonal variations in the population and empty stable places the AAP can be considered equal to the population counted at any specific day. The preferred data source is the annual livestock surveys (Regulation (EC) No 1165/2008). For livestock which are counted twice a year, an average of these figures can be used.
- For livestock types with seasonal variations or occurrence of empty stables the population counted on a specific day or from data on animal places need to be corrected for these factors to represent AAP. EMEP/EEA Guidebook provides a guideline for the estimation of AAP based on data of animal places and empty stables (Annex 1, Equation 44).
- For livestock types involving multiple production cycles within a year AAP can be derived from slaughter/production statistics corrected for non-sold or non-slaughtered animals (animals dying before production age has been achieved) divided by number of production cycles. The EMEP/EEA Guidebook provides a guideline for the estimation of the AAP; see Annex 1, Equation 46. The AAP of livestock types involving multiple production cycles can also be derived from the number of animal places corrected for the average amount of empty stable places during a year. The EMEP/EEA Guidebook provides a guideline for the estimation of the AAP (Annex 1, Equation 44 and Equation 45).

The following harmonised data sources are available at EU-level on livestock numbers:

- Annual livestock surveys

  Livestock statistics are collected under Regulation (EC) No 1165/2008. Each Member State shall produce under this regulation statistics on number of bovine animals, pigs, sheep and goats held on agricultural holdings within its territory. Member States conducting sample surveys shall cover sufficient agricultural holdings to account for at least 95 % of the entire population, as determined by the last survey on structure of agricultural holdings. Bovine animals and pigs statistics are produced twice a year, for sheep and goats data are produced once a year. Data refer to a specific reference day.

- Farm structure surveys (FSS)

  Data on the structure of agricultural holdings, including livestock numbers of bovine animals, pigs, sheep, goats, poultry, horses and rabbits, are collected once every 3-4 years. Data refer to a specific reference day. Once every ten years the data are collected from a full census.

- Slaughter/production statistics:

  Slaughter and meat production statistics are collected under Regulation (EC) No 1165/2008. Each Member State shall produce statistics relating to the number and carcass weight of bovine animals, pigs, sheep, goats and poultry slaughtered in slaughterhouses on its territory, whose meat is deemed fit for human consumption. It shall also supply estimates of the extent of slaughtering carried out other than in slaughterhouses, so that the statistics include all bovine animals, pigs, sheep and goats slaughtered on its territory. The statistics on slaughtering in slaughterhouses shall be produced monthly by each Member State. The reference period shall be the calendar month. The statistics on slaughtering carried out other than in slaughterhouses shall be produced annually by each Member State. The reference period shall be the calendar year.

- Economic Accounts for Agriculture:

  To compile Economic Accounts for Agriculture production account countries can use a series of tables which are shown in Annex III of the Manual on Economic Accounts for Agriculture and Forestry 1997 (Rev 1.1). In the first of these tables output (quantities) is calculated from resources and uses of agricultural products (which include livestock, animal products etc.).

- Other data sources may exist in countries.

Country experts on nutrient budgets are advised to discuss the estimation AAP with experts estimating the GHG and NH3 emissions, to ensure a coherent approach. Note however that the AAP estimated for the NB may differ from AAP estimated for GHG and NH_3 emissions reporting as only livestock held on agricultural holdings should be covered, whereas countries may include livestock outside agricultural holdings to UNFCCC/UNECE, see also section 3.6.5.

Estimation of nitrogen and phosphorus excretion coefficients per livestock category:

The excretion coefficient should represent the nutrient content of excretion at the time of excretion; i.e. no corrections are made for volatilisation of N during animal housing, storage or with the application to land or for additions of nutrients when manure mixes with other material (e.g. straw).

N excretion coefficients for specific livestock categories have been determined by countries for the estimation of GHG and NH_3 emissions estimations. Data or a reference on excretion coefficients used for GHG emissions calculations can be found in countries NIR reports[19]. These excretion coefficients should be applied to the AAP of that livestock category, see discussion above, to derive total N excretion per livestock category in a specific year.

Unlike for N, for P there are no official guidelines for the estimation of excretion coefficients. Countries are advised to establish a methodology to estimate P excretion coefficients in close coordination with the establishment of N excretion coefficients used for reporting to UNFCCC.

Actions are undertaken to improve and standardize methodologies to establish excretion coefficients, see section 3.6.7.

3.6.4. Discussion

In the OECD/Eurostat Handbooks 2007, data sources for the underlying data (livestock numbers and excretion coefficients) were not defined. Countries used different sources for the estimation of excretion. These sources are often using different approaches and therefore have different results. Manure production is a significant flow in the nutrient budgets. Therefore it is necessary to ensure a transparent and harmonised approach.

At the moment there are 2 legislative requirements at EU level concerning N excretion coefficients: Nitrates Directive (ND) and UNFCCC. The coefficients used in the estimations under these two obligations often differ. Table 4 provides an overview of some the main differences between these two data sources.

In discussion with Member States and stakeholders[20] it was decided to align the estimation with the estimation for the reporting on GHG (UNFCCC) and NH_3 (UNECE) emissions: there are common guidelines (IPCC), the methodology and data used are reported in the National Inventory Reports (NIR) and the Common Report Format (CRF) reports which are publicly available and it would ensure consistency between GNB, GHG and NH_3 emission estimations.

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[19] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php

[20] First proposal was discussed in a specific Task Force meeting on GNB in 2011. In the WG meeting on AEI in February 2012 countries agreed to report the same figures on excretion as those reported to UNFCCC.

Table 4. Excretion coefficients UNFCCC and Nitrates Directive

UNFCCC excretion coefficients	Nitrates Directive excretion coefficients
Common handbook: (IPCC) guidelines	No common handbook
Excretion coefficients and metadata publicly available: (NIR + CRF)	Underlying data not public available
Consistent with NH3 + GHG emissions	Not consistent with NH3 + GHG emissions

3.6.5. Coherence with UNFCCC/UNECE

AAP is estimated in the nutrient budgets for livestock held on agricultural holdings. This may result in some differences with livestock numbers reported to UNFCCC, as reporting to UNFCCC may include livestock outside agricultural holdings and livestock numbers may be averaged over three years under the IPCC Revised 1996 Guidelines (Vol. 3, Ch. 4.2.2). IPCC 2006 Guidelines (Vol. 4, Ch.10.2.2) require annual activity data. Due to these differences in livestock considered in the nutrient budgets and for the estimation of GHG and NH_3 emissions, the estimated N excretion in the nitrogen budgets may differ from those reported to UNFCCC/UNECE. If data reported in the GNB deviate from those reported to UNFCCC, countries are required to provide a clear explanation of these differences in the metadata file which is required to be provided with the GNB.

3.6.6. Default estimation procedure

If data on N excretion are not available Eurostat will use the data on N excretion as reported to UNFCCC in Table 4.B (b) in the CRF reports[21]. Table 4.B (b) in the CRF reports of a country contains a summary in a common format of the detailed estimation of N excretion which can be found in the National Inventory Reports (NIR), see Table 5.

Although IPCC provides guidance to countries how to estimate N excretion, the approaches taken by countries may still vary significantly according to the Tier-level applied. This can for instance be noted in the detail of the livestock classification for which countries have specified excretion coefficients[22]. As countries apply different Tier levels and therefore different detail of livestock classifications, a common reporting format was established by UNFCCC to summarize the resulting estimated N excretions for livestock types at an aggregate level. The Tier-level applied use some subcategories of livestock such as organic milk cows or different level of milk yield per cow would leads to a range of excretion coefficients and is summed up on an average coefficient for e.g. milk cows. The excretion rates at aggregate level represent therefore a weighted average of the structure of that livestock type.

For countries which do not have data on P excretion available data will be estimated based on coefficients used in comparable countries and data on population from annual livestock statistics.

Note that if countries do not have data available on either N or P manure production, data on livestock in the GNB is taken from the CRF reports, while for the PB livestock numbers are based on the livestock statistics. For the GNB data from the CRF reports are used as this is a data source with a legal basis and can be considered as the best available source on the estimation of N excretion. For P no such data source exists. P excretion coefficients are estimated from data from comparable countries

[21] Countries CRF and NIR reports can be found at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php

[22] Information on excretion coefficients and livestock types specified by countries to estimate the total N excretion can usually be found in the NIR reports

at the most detailed level of livestock categorisation. The best available annual statistics on livestock population are the livestock statistics. Due to this different approach a discrepancy may exist between the livestock numbers used to estimate N excretion and data used to estimate P excretion. Actions are undertaken to improve the availability of data on P excretion coefficients coherent with the estimation of N excretion, see section 3.6.7. This section may therefore be updated in the future.

Table 5. Information GHG Inventories CRF reports Table 4.B(b) year x

GREENHOUSE GAS SOURCE GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION	
	Population size (1000s)	Nitrogen excretion (kg N/head/yr)
Cattle		
Option A:		
Dairy Cattle		
Non-Dairy Cattle		
Option B:		
Mature Dairy Cattle		
Mature Non-Dairy Cattle		
Young Cattle		
Sheep		
Swine		
Poultry		
Buffalo		
Goats		
Camels and Llamas		
Horses		
Mules and Asses		
Other livestock (please specify)		
Other non-specified		
Total per AWMS		

3.6.7. Actions foreseen

The alignment of the estimation of excretion in the nutrient budgets with the estimation for the reporting on GHG (UNFCCC) and NH_3 (UNECE) emissions is a first step in harmonising approaches in countries to estimate excretion. The Commission aims at harmonising the estimation of excretion estimates across different EU and other international policy reporting in the long term, this aim is shared by the OECD, FAO and other stakeholders.

The IPCC uses a Tier-system. Tier 1 is the simplest method, in which default values are applied to readily available activity data in countries. Tier 2 allows estimating technology-specific GHG emission factors and therefore requiring more specific data. Tier 3 allows taking country specific methods into account. Whereas Tier 1 and Tier 2 methods are rather prescribed in the Guidelines, Tier 3 offers possibilities to use country-specific methods. Clearly these 3 different Tier approaches will lead to different estimates of different quality. DireDate recommends estimating the GHG and NH_3 emissions in the short term at Tier 2 for the major livestock types: dairy cattle, beef cattle, sows, fattening pigs, broilers and laying hens. In countries where sheep and goats are of significance it is recommended to estimate the emissions from these livestock as well at Tier 2.

For all other categories Tier 1 is considered sufficient. In the long term DireDate recommends GHG emissions for the major livestock types to be estimated at Tier 3 and NH_3 emissions using a Total Ammonia Nitrogen (TAN) -based approach to catch abatement measures. The additional data needed to achieve these recommendations are listed in DireDate report Task 3, 4 and 5[23].

Eurostat has signed a contract in September 2012 with duration of 18 months. The objective of the project is: "to define and describe how the methodologies for estimating gross N and P excretion coefficients in the EU can be improved in the most effective and efficient way, to provide guidelines for a coherent methodology consistent with IPCC and CLTRP Guidelines and to identify the main components of the calculations of excretion factors and the data requirements". The results of this project are expected to contribute to the set-up of a comparable and transparent system of estimating excretion in EU countries consistent with UNFCCC and CLTRP requirements. A specific task of this project is to develop default P-excretion factors as function of animal type, and in line with the methodology proposed for estimating N excretion coefficients. The livestock categorisation and determination of AAP will also be addressed.

3.7. Manure trade, withdrawal, and treatment.

3.7.1. Definitions

Manure export is all manure (incl. treated/processed), which are exported to another country.

Manure import is all manure (incl. treated/processed), which are imported from another country.

Manure processing/treatment: Manure can be treated on farm or off farm to produce biogas, to reduce odour emissions during storage and/or land spreading, to reduce N content or for marketing of manure compounds and/or easy and safe transportation (BREF intensive rearing of poultry and pigs). In many cases the nutrient amount in the product after treatment is the same as before treatment, in some cases treatment can lead to a reduction or an increase in nutrient amount.

3.7.2. Description in Ideal and Practical implementation of GNB and PB

Ideal: Manure export, manure import, stock changes, non-agriculture use and manure treatment.

Practical:

- Data on manure export and import are required if significant (net import or net export >=5% of manure nutrient production).
- Data on manure treatment are optional, countries are encouraged to report this flow if data are available.
- Data on non-agricultural use are optional.

[23] A summary of the data needs identified by DireDate can also be found in the Working Document for the Task Force on GNB organised in November 2011 and document CPSA/AEI/104 provided at the WG on AEI meeting of February 2012, see circabc.

3.7.3. *Guidelines on practical implementation*

It is advised to coordinate country specific data on manure withdrawals with data reported to UNFCCC, see also section 3.7.5.

Manure imports and exports

Countries with significant export and import (net import or net export>=5% of manure production in nutrients. net export = export – import. net import = import - export) are required to report manure imports and exports. Care should be taken in translating nutrient contents of exported/imported manure; it should represent nutrient contents of the exported/imported manure. If manure is treated (processed) before export (import), it is the nutrient content after treatment (processing) which should be used to convert the amount of manure exported (imported) into nutrient amounts.

Manure exports should be reported as negative values, manure imports as positive values.

Manure treatment

This flow is optional. Countries are however encouraged to report data on this flow if available. Please note that for this flow the positive and negative changes in the nutrient content (expressed in tonnes of nutrient) of the treated manure due to treatment/processing compared to the nutrient content of the original product should be counted, NOT the total amount of nutrient in the treated manure. Also only manure treatments leading to a reduction or an increase of nutrient compared to the untreated manure should be reported for this flow. An example of treatment leading to an increase in N content is co-digestion of manure and other materials to produce biogas. Examples of manure treatment leading to a reduction in N content are techniques to reduce N amount in manure. In many cases manure treatment, e.g. to facilitate transport, do not lead to a change in N amount (expressed in tonnes of N) in comparison to the original product. Note that although such treatments do not affect the total amount of N in the treated product in comparison to the original product, the N content expressed in kg N per tonne can be higher in the treated product in cases the treatment reduces the mass of the original product. However as the total amount of N of the treated product compared to the original product has not changed it should not be reported.

The total change in N content of manure treated ($\Delta N_{content\_treated}$) is estimated as the sum of the changes in N content due to different manure treatments. The change in N content due to a specific manure treatment *i* is estimated by multiplying the amount of manure treated[24] with treatment *i* expressed in tonnes of the original product before treatment ($M_{treated\_i}$) with a N coefficient expressed in kg N per tonne which represents the amount of N lost or added due to treatment *i* in comparison to the original product ($N_{treatment\_coefficient\_i}$), see Equation 7. These N coefficients can be estimated by the total N content expressed in tonnes of N in the manure treated with treatment *i* ($N_{manure\_treated\_i}$) minus the total N content expressed in tonnes of N in the original product before treatment ($N_{manure\_untreated\_i}$) and by dividing this result with the total amount of manure treated with treatment *i* expressed in tonnes of the original product before treatment), see Equation 8. In a similar way the total change in P content of manure treated ($\Delta P_{content\_treated}$) is estimated, see Equation 9 and Equation 10.

Some data on manure treatment may be available in the reporting to UNFCCC see section 3.7.5. It is advised to coordinate country specific data with data reported to UNFCCC.

Non-agricultural use

This flow is optional. Countries with significant disposals of manure outside agriculture can report these data for this flow. However data need to be verifiable, therefore these data need to be accompanied with sufficient scientific/statistical proof.

[24] by a treatment that leads to a reduction or increase of Nutrients

Equation 7. $\Delta\ \mathrm{N}_{\mathrm{content}_{\mathrm{treated}}} = \sum_i \left\{ \boldsymbol{M}_{\boldsymbol{treated}_i} (\mathbf{1000}\ \boldsymbol{tonnes\ of\ original\ product}) \times \boldsymbol{N}_{\boldsymbol{treatment}_{\boldsymbol{coefficient}_i}} (\boldsymbol{kg\ N\ per\ tonne}) \right\}$

Equation 8. $\boldsymbol{N}_{\boldsymbol{treatment}_{\boldsymbol{coefficient}_i}} (\boldsymbol{kg\ N}) = \left(\boldsymbol{N}_{\boldsymbol{manure}_{\boldsymbol{treated}_i}} (\boldsymbol{tonnes\ N}) - \boldsymbol{N}_{\boldsymbol{manure}_{\boldsymbol{untreated}_i}} (\boldsymbol{tonnes\ N}) \right) \div \boldsymbol{M}_{\boldsymbol{treated}_i} (\mathbf{1000}\ \boldsymbol{tonnes\ of\ original\ product})$

Equation 9. $\Delta\ \mathrm{P}_{\mathrm{content}_{\mathrm{treated}}} = \sum_i \left\{ \boldsymbol{M}_{\boldsymbol{treated}_i} (\mathbf{1000}\ \boldsymbol{tonnes\ of\ original\ product}) \times \boldsymbol{P}_{\boldsymbol{treatment}_{\boldsymbol{coefficient}_i}} (\boldsymbol{kg\ P\ per\ tonne}) \right\}$

Equation 10. $\boldsymbol{P}_{\boldsymbol{treatment}_{\boldsymbol{coefficient}_i}} (\boldsymbol{kg\ P\ per\ tonne}) = \left(\boldsymbol{P}_{\boldsymbol{manure}_{\boldsymbol{treated}_i}} (\boldsymbol{tonnes\ P}) - \boldsymbol{N}_{\boldsymbol{manure}_{\boldsymbol{untreated}_i}} (\boldsymbol{tonnes\ P}) \right) \div \boldsymbol{M}_{\boldsymbol{treated}_i} (\mathbf{1000}\ \boldsymbol{tonnes\ of\ original\ product})$

3.7.4. Discussion

In the OECD/Eurostat Handbooks 2007 it was mentioned that ideally the calculation of nutrients in livestock manure input should take into account:

(i) livestock manure not used on agricultural land (incl. national exports, if any),

(ii) change in livestock manure stocks intended for use on agricultural land, and

(iii) national livestock manure imports for use on agricultural land.

These flows were expected to be negligible in most countries.

Manure imports and exports

Manure imports and exports are insignificant in most countries; data collection at European level is therefore not justified. Imports and exports are however significant in certain countries, not including these flows would lead to a significant bias in the estimated budgets of these countries. Countries with significant export and import (net import or net export>=5% of manure production in nutrients. net export = export – import. net import = import - export) are therefore required to report manure imports and exports.

Stocks

Data on changes in manure stocks are currently not available in most countries. It can be assumed that the change in manure stocks is on average zero in the long-term. These data are therefore no longer required or included in the practical implementation of nutrient budgets.

Manure treatment

The Inventory of manure Processing Activities in Europe (DG ENV, 2011) shows that manure processing has reached a level of 6.9% of livestock manure production in EU, with big variations between countries ranging from 0% in BG to 29% in DK. Manure treatment and processing is likely to become of growing importance in the EU-27, for instance for biogas production. Data on manure processing are currently limited available. Data collection 2010/2011 show that the withdrawal of nutrients due to manure processing represents less than 2.5 % of the total N content of manure production in NL and Flanders. Data on this flow is currently not required as data are not sufficient available at EU-level and may not significantly impact the results of the nutrient budgets. Countries are however encouraged to report data on this flow if available.

Non-agricultural use

In some cases manure produced in the country may be disposed within the country outside agriculture. Manure may be used to fertilise non-agricultural land, or it may be disposed through the sewage etc. In many cases non-agricultural uses are insignificant and data are not available.

3.7.5. Coherence with UNFCCC/UNECE

Some countries report data on manure export and import in NIR reports to UNFCCC. IPCC Revised 1996 Guidelines require the fraction of manure used for fuel to be determined to estimate emissions from application of manure to soils (Vol. 3 Ch. 4.5.2). If data are not available the fraction is assumed zero. IPCC Good Practice Guidance describe a Tier 1b approach where additional to the fraction of manure used for fuel, fractions of manure for feed and for construction are additionally required. If data are not available the fraction is assumed zero. The Guidance notes that amounts of animal manure used for purposes other than fertilizer can be obtained from official statistics or a survey of experts. IPCC 2006 Guidelines also require determination of fractions of manure used for feed, fuel and construction (Vol. 4 Ch.11.2.1.3). If data are not available the fraction is assumed zero.

3.7.6. Default estimation procedure

No estimations are made in case countries do not have data available, as a default estimation procedure is difficult to establish without country-specific data and the omission of this flow is considered to have little impact on the estimated nutrient surplus. Manure withdrawals are likely to be of significance in a few countries with a high production of manure.

3.7.7. Actions foreseen

No actions foreseen.

3.8. Other organic fertilizers

3.8.1. Definitions

Other organic fertilizers are organic fertilizers not originating from livestock excretion; they include compost, sewage sludge, residues from biogas plants using crops, crops residues or grassland silage**,** industrial waste and other organic products containing nutrients used in agriculture as fertilizer or soil amendment.

(Sewage) sludge:

(i) residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters;

(ii) residual sludge from septic tanks and other similar installations for treatment of sewage;

(iii) residual sludge from sewage plants other than those referred to in (i) and (ii).

Sludge shall be treated before being used in agriculture. Member States may nevertheless authorize, under conditions to be laid down by them, the use of untreated sludge if it is injected or worked into the soil. **Treated sludge** means sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use (Directive 86/278/EEC).

Compost is the solid particulate material that is the result of composting and which has been sanitised and stabilised. **Composting** is a process of controlled decomposition of biodegradable materials under managed conditions, which are predominantly aerobic and which allow the development of temperatures suitable for thermophilic bacteria as a result of biologically produced heat (IPTS, 2011).

A wide range of materials may be composted, but they must consist of principally organic components (e.g. yard trimmings, wood chips, vegetable scraps, paper products, sorted municipal solid waste, animal carcasses, manures and wastewater sludge). In the context of this Handbook products resulting from composting manure and sewage sludge are not considered as compost.

Sometimes **industrial wastes** other than compost are used in agriculture as fertilizer or soil amendments (e.g. organic left overs of food industry, digestate from biogas plants).

3.8.2. Description in Ideal and Practical implementation of GNB and PB

Ideal: All other organic fertilizers used in the reference area.

Practical:

- Data on sewage sludge are required.
- Data on other organic fertilizers are optional.

3.8.3. Guidelines on practical implementation

Equation 11. $$N_{orgfert}(tonnes\ of\ N) = \sum_i \left\{F_{org_i}(1000\ tonnes) \times N_{orgfert_{coefficient_i}}(kg\ N\ per\ tonne)\right\}$$

Equation 12. $$P_{orgfert}(tonnes\ of\ P) = \sum_i \left\{F_{org_i}(1000\ tonnes) \times P_{orgfert_{coefficient_i}}(kg\ P\ per\ tonne)\right\}$$

Total N amount of other organic fertilizers applied to agricultural soils ($N_{orgfert}$) is estimated by summing up the different applications of other organic fertilizers to agricultural soils. The N amount of other organic fertilizer *i* applied to agricultural soils is estimated by multiplying the amount of organic fertilizer *i* (F_{org_i}) with data on N content of organic fertilizer *i* ($N_{orgfert\_coefficient\_i}$), see Equation 11. In a similar way the total P amount of other organic fertilizers applied to agricultural soils ($P_{orgfert}$) is estimated (Equation 12).

Data is only required for sewage sludge. Data on sewage sludge used in agriculture and its nutrient contents is required by the Sewage Sludge Directive 86/278/EEC. Data on sewage sludge application and N contents are also requested as activity data to estimate N_2O emissions from managed soils under IPCC Guidelines and NH_3emissions from managed soils following EMEP/EEA Guidebook see section 3.8.5.Countries are advised to check data they have on sewage sludge applications with those reported to the Commission under the Sewage Sludge Directive and to UNFCCC.

If countries have data available on other organic fertilizers these can be reported. A possible source for data on compost could be ECN[25].

Please note that applications of composted manure or digestate from anaerobic digestion of manure should not be reported here; manure and manure products are taken into account under the flows manure production and manure trade, withdrawals and treatment.

[25] See Barth et al, 2008. This report includes a list of consulted experts in Annex 6.

3.8.4. Discussion

OECD/Eurostat Handbooks 2007: *'Other organic fertilizers 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 fertilizers 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*'.

Data collection in 2010/2011 showed that data on other organic fertilizers are available in only a limited amount of countries (Austria, Belgium, Germany, Spain, Finland, Ireland, Netherlands, Sweden, United Kingdom, Czech Republic, Hungary, Slovakia and Switzerland). Data from these countries show that other organic fertilizers are currently not very significant in the GNB (on average 2005-2008 <3% of total N inputs). Organic fertilizers are of some significance in some countries for P (>5% of total phosphorus inputs). For the phosphorus budget, the effect of missing data on organic fertilizers may therefore be significant in some countries.

The European Commission is currently assessing whether the current Directive should be reviewed. For its assessment, the Commission has launched a study to gather existing information on environmental, economic, and social as well as health impacts of present practices of sewage sludge use on land. This study will also assess risks and opportunities that can be foreseen in coming years. Some data on the application of sewage sludge incl. N and P contents can also be found in the reports of this study (Milieu Ltd, WRc and RPA, 2008. Part I, Part II, Part III). The study noted that the use of sewage sludge in EU is relatively small compared to other organic and inorganic fertilizers: sludge contributes less than 5% of total amount of organic manure used on land (most of which is of farm animal origin), and sludge is applied to less than 5% of agricultural land in EU. The analysis considered that the use of sludge on land in EU-15 will not change dramatically over the next 5 years and increase in the 12 other Member States, in particular in those where it is currently little practiced.

3.8.5. Coherence with UNFCCC/UNECE

In the revised IPCC 1996 Guidelines (Vol. 3 Ch.4.5.2) and IPCC Good Practice (Ch. 4.7.1.4) other organic fertilizers taken into account include only sewage sludge. In the IPCC 2006 Guidelines other organic fertilizers applied to agricultural soils include sewage sludge, compost and other organic amendments used as fertilizer (Vol.4 Ch.11.2.1.3). In the CRF reports some countries have reported data on the application of sewage sludge to UNFCCC/UNECE. In the EMEP/EEA Guidebook 2009 also only sewage sludge is mentioned as activity data (Vol. 4D Ch. 3.2.3). Data should be checked for consistency with data reported to UNFCCC and UNECE.

3.8.6. Default estimation procedure

If countries do not have data available on the application of sewage sludge data reported under the Sewage Sludge Directive will be used, or if not available data reported to UNFCCC.

As data sources on the use of other organic fertilizers (excl. sewage sludge) are not available and the use of these fertilizers may vary significantly across countries no default estimation procedure can be established and no estimations for other organic fertilizers (than sewage sludge) are made.

3.8.7. Actions foreseen

No actions foreseen.

3.9. Biological Nitrogen fixation (BNF)

3.9.1. *Definitions*

Nitrogen is fixed in the soil by:

(1) **BNF by leguminous crops** through the action of bacteria which live symbiotically in root nodules of leguminous crops. **Leguminous crops** include leguminous plants, beans, soya bean, pulses etc. **Leguminous plants** are defined in Crop Statistics as leguminous plants[26] grown and harvested green as the whole plant, mainly for forage. Mixtures of predominantly leguminous (normally >80%) forage crops and grass plants, harvested green or as dried hay. This group of plants are often perennial on the field (< 5years) and a real N input occurs at the end of the period by ploughing the field. IPCC Guidelines 2006 therefore portioned N-input between the years of growing.

(2) **BNF by grass-legume mixtures**. Part of the area counted under temporary and permanent grassland can be mixed with leguminous forage crops. These areas can be grazed, harvested green or as dried hay.

(3) **BNF by free living soil organisms**. Some diazotrophs (N-fixing bacteria), fix N in association with plants, e.g. with leguminous crops, while others fix N in a free-living state. Free-living organisms in agricultural systems include cyanobacteria (most prominent in rice fields), heterophic diazotrophic bacteria and autotrophic bacteria

3.9.2. *Description in Ideal and Practical implementation of GNB*

Ideal: BNF by leguminous crops, in grass-legume mixtures and by free living organisms in the reference area.

Practical:

- BNF by leguminous crops is required based on Crop Statistics regulation (EC) No 543/2009 and country-specific coefficients.
- Biological N fixation in grass – legume mixtures.

3.9.3. *Guidelines on practical implementation*

This section may be updated in the future, following actions listed in section 3.9.7, see also the discussion in section 3.9.4..

Leguminous crops

Equation 13. $$N_{fix_{legumes}}(tonnes\ of\ N) = \sum_i \left\{ A_{legumes_i}(1000\ ha) \times N_{fix_{legumes_{coefficient_i}}}(kg\ N\ per\ ha) \right\}$$

[26] Handbook Crop Statistics: The various species of clovers, annual or perennial, such as crimson (Trifolium incarnatum L.), red (T. pratense L.), white (T. repens L.), Egyptian (T. alexandrinum), of Persia (T. resupinatum). Different types of lucerne, such as Medicago sativa L., M. falcata L. and its hybrids, are included here. Other leguminous plants grown mainly for fodder can include sainfoin (Onobrychis viciifolia Scop.), sweet clover (Lotus corniculatus L.), vetches (Vicia sativa, villosa, panonica), vetch (Lathyrus sativus), trefoil (Medicago lupulina L.), melilot (Melilotus alba Lam.), sweet lupins (Lupinus albus, angustifolius, luteus), serradella (Ornithopus sativus), fenugreek (Trigonella foenum-graecum), sulla (Hedysarium coronarium).

BNF by leguminous crops ($N_{fix\_legumes}$) is estimated by summing up BNF of different leguminous crops. BNF of leguminous crop type *i* is estimated by multiplying area of leguminous crop *i* ($A_{legumes\_i}$**)** by the fixation coefficient of leguminous crop *i* ($N_{fix\_legumes\_coefficient\_i}$) (Equation 13).

BNF is at minimum required to be estimated for following crop types collected in crop statistics: dried pulses (C1300), soya bean (C1470), leguminous plants (C2670) and pulses (C1885).

Data on areas and production of leguminous plants are annually available from Crop Statistics (regulation (EC) No 543/2009), countries should use these data to estimate BNF by leguminous crops, see also section 3.9.4**.**.

Currently a harmonised methodology across Europe to estimate BNF coefficients does not exist and actions to improve the situation are not foreseen in the short term, see also section 3.9.7. Although in principle the aim is to provide coherent estimations with GHG Inventories countries for this flow an exception is made, see section 3.9.5 and country-specific data are preferred. Care should be taken that the estimation of BNF by leguminous crops takes into account the belowground fixation. If country-specific methodologies are based on a biomass approach, Equation 14 can be used to determine the fixation coefficient per ha; the estimated BNF by a leguminous crop *i* is divided by the area of leguminous crop *i*.

Equation 14. $$N_{fix_{coefficient_i}}(kg\ Nitrogen\ per\ ha) = N_{fix_{legumes_i}}(tonnes\ of\ Nitrogen) \div A_{legumes_i}(1000\ ha)$$

The comparability and transparency of the estimation of BNF by leguminous crops could be improved if a set of common guidelines on the estimation method and update frequency were established. In the short term such a study is not foreseen, see also section 3.9.7.

Grass-legume mixtures

This flow is obligatory, as even though data availability is low and default estimation procedures have not yet been established, ignoring this flow would lead to a significant bias of the N-budgets. Countries which have country-specific data available on BNF in legume-grass pastures can report data on areas concerned and coefficients to estimate total amounts of N fixed in these areas. Countries are encouraged to establish methodologies and data collection on this topic. Care should be taken that belowground fixation is taken into account as well.

The comparability and transparency of the estimation of BNF in forage/fodder legumes and legume-grass mixtures could be improved if a set of common guidelines on the estimation method and update frequency were established. Currently a study is undertaken in which a specific task is to establish such guidelines, see section 3.9.7. The recommendations are expected in the beginning of 2014.

Free-living organisms

This flow has been excluded from the practical implementation of nutrient budgets due to uncertain quality of data and very limited availability of estimates on this flow, see section 3.9.4.

3.9.4. Discussion

OECD/Eurostat Handbook 2007 included BNF of leguminous crops and free-living organisms.

Leguminous crops

In the OECD/Eurostat Handbooks 2007 the BNF by leguminous crops is determined by multiplying the area covered by leguminous crops with a fixation coefficient. As countries have provided data in previous GNB editions on BNF relating to area units, it has been decided to continue this practice in this Handbook.

Leguminous plants, especially those planted specifically for N fixation, are often grown as secondary crops. Data on areas of leguminous plants are available from FSS and Crop Statistics. Data from FSS refer to main areas and are only collected once every 3 or 4 years. The preferred data source is therefore Crop Statistics. The following data is required by Crop Statistics:

- Areas under cultivation[27] of leguminous plants. This is an aggregated category covering i) clovers and mixtures, ii) lucerne and iii) other legumes for fodder. It may be difficult to establish coefficients for this broad category. However as in previous regulations this category was broken down to the classes mentioned before, countries may still have data available on the distribution of areas between these different types of leguminous crops which can be used to provide a more accurate estimation of BNF by these crops.
- Areas under cultivation and harvested production of dried pulses and protein crops for production of grain (incl. seed and mixtures of cereals and pulses). Data is further differentiated into field peas, broad and field beans, sweet lupins, other dried pulses n.e.c.
- Areas under cultivation and harvested production of soya.
- Harvested area[28] and harvested production of pulses.
- Harvested area and harvested production of beans.
- Different methodologies exist to estimate BNF, e.g. Herridge et al, 2008 and Unkovich et al. 2008. Some methodologies provide estimates on an area basis. More recent techniques however provide estimates on the percentage of total N[29] of the plant that is derived from BNF.
- IPCC Revised 1996 Guidelines estimate BNF based on above ground biomass of N-fixing plants (Annex 2).
- BNF rates are dependent upon many environmental factors, and can be greatly influenced by farm management practices (Peoples et al. 1995). Factors influencing biological fixation can be found in the Technical Paper 2 on Biological Fixation of the FAO. This is also reflected in the large range of measured values of biological fixation; see for example Table 6 which shows a review of the variation in measured values of BNF by Unkovich et al. 2008.

Table 6. Variation in BNF measurements (kg N per ha per year) (M. Unkovich. 2008)

	Measured variation	Most commonly observed
Green manure crops	5-325	50-150
Pasture/forage legumes	1-680	50-250
Crop legumes	0-450	30-150

Herridge et al, 2008 and Unkovich et al. 2008 note that many estimates of BNF are too low as often only above ground biological fixation is taken into account in estimation of BNF. Published values for below ground N fixation as a percentage of total plant N are 22-68% for pulse and oilseed legumes, soybean, beans and peas and 34%-68% for pasture/fodder legumes. Care should be taken that belowground fixation is also taken into account in the estimation of BNF.

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[27] See for a definition section 3.13.1.

[28] See for a definition section 3.13.1.

[29] Including below ground biomass

Table 7 shows the variation in estimated rates of BNF in kg N per ha per year for different crops collected from the countries during 2010-2011. A wide variation can be noted especially for leguminous plants. It should also be noted that most countries use a fixed rate across time, as BNF is very much depending on environmental (e.g. climate) and farmer practices (e.g. fertilizer use) which may change over time, regular updating of such coefficients is advised.

Table 7. Variation in country estimated BNF rates GNB data collection 2010/2011

	Kg N per ha per year
Dried pulses	6-280
Soya bean	20-135
Pulses, peas, beans	24-125
Green fodder	10-190
Leguminous plants	55-500
Pasture	5-153

Grass-legume mixtures

The estimation of BNF in forage/fodder legumes and legume-grass pastures within the UAA is difficult because it is difficult to determine the productivity and areas of these legumes. Parts of Permanent and Temporary Grassland can be mixed with legumes. Grass-legume mixtures contribute significantly to BNF. Data on areas covered with grass-legume mixtures are however not available as European statistics on land use do not distinguish between areas of grass-legume mixtures and pure grass areas. The proportion of legumes in grass needs to be identified as well to estimate the amount of N fixed in grass-legume mixed areas. The level of fixation in grass-legume mixed areas is also depending on grassland management and fertilisation. Care should be taken that belowground fixation is taken into account as well.

DireDate has made several recommendations concerning improving data on BNF:

- Countries should establish a national workgroup of experts (agronomists) to establish a methodology for the derivation of BNF by clover in grasslands on a regional level. The procedures and methodologies should be reviewed.
- Workshop at EU-27 level with scientists and agronomists involved, in order to discuss and approve methodologies and to derive best estimates of BNF by clover on regional level.
- The best estimate of BNF by clover can be made from local experts with knowledge of the grasslands and management of grassland. The amount of BNF by clover is difficult to estimate, because both the estimate of the average share of clover in grassland in a region and the amount of N fixed by clover are uncertain. It depends on the standing biomass of clover in the sward, which may vary throughout the year. Large amounts of N can be fixed in clover grassland (>200 kg N per ha in the year of ploughing in) and care should be taken to identify these grasslands and estimate its BNF. If clover is grown on soils that contain mineral N (e.g. because of N fertilizer or manure application), clover can use this N and may not or only slightly fix atmospheric N.

Denmark has also described in its pilot project on GNB a model to estimate BNF in grasslands, which is also used by Sweden. Denmark recommends reviewing the coefficients used by countries and comparing them with coefficients calculated with an empirical model.

Free living organisms

Equation 15. $N_{fix_{free}}\ (tonnes\ of\ Nitrogen) = A_{UAA}\ (1000\ ha) \times N_{fix_{free_{coefficient}}}\ (kg\ Nitrogen\ per\ ha)\ )$

In OECD/Eurostat Gross Nitrogen Balances Handbook 2007 BNF by free living soil organisms (N_{fix_free}) was calculated by multiplying area (A_{UAA}) with a N fixation coefficient for the area ($N_{fix\_free\_coefficient}$), see Equation 15.

Crop residues left or returned to the soil provide energy to asymbiotic diazotroph bacteria for BNF. Heterotrophic free-living N_2 fixers utilising plant residues such as straw and leaf litter appear to contribute only small amounts of N to dry land agriculture (according to Unkovich et al. 2008 mostly <5 kg N/ha per year). N-fixation by cyanobacteria and photosynthetic bacteria inhabiting the floodwater and soil surface of rice fields might contribute as much as 30 kg N/ha according to Firth et al, 1973. Unkovich et al. note that there are few conclusive data to indicate that agronomical significant amounts of N are fixed by bacteria associated with non-legumes in temperate agriculture, but studies (e.g. Boddey et al, 1995) have demonstrated measurable inputs of fixed N with tropical grasses such as sugarcane, in the order of 10–65 kg N/ha per year.

DireDate recommended to drop this flow as scientific and quality data to estimate N fixed by free living soil bacteria is limited available in countries and the amount of N fixed by free living soil bacteria is generally small, i.e. < 5 kg N per ha per year (see e.g. Paul et al, 1996. Unkovich et al 2008. Beriner et al, 1984. Vitousek et al, 2002). A review by Herridge et al, 2008 note that amounts of N fixed by free-living bacteria are very difficult to estimate, if not impossible. Unkovich, et al. 2008 note that for quantifying associative N_2 fixation the methods available may not always provide reliable estimates, or even unequivocal evidence, of N_2 fixation activity, because these methods have particular limitations at low rates of N_2 fixation,. In their opinion the question of whether there are significant inputs of biologically fixed N to such associations remains controversial (e.g. Giller and Merckx 2003), and claim that thus often much more rigorous experimental protocols are necessary than in the case of nodulated legumes. Because of the inherent uncertainties of current methodologies, they argue that defensible proof of N_2 fixation by associative N_2-fixing systems may need to be established along with quantification.

3.9.5. Coherence with UNFCCC/UNECE

IPCC Revised 1996 Guidelines provide some guidelines on estimation of BNF, which are summarised in Annex 2. Although in principle the aim is to provide coherent estimations with GHG Inventories countries for this flow an exception is made. It has been noted that applying IPCC Tier1 methodology results in relative high estimations of N fixation in comparison to estimates of countries which have invested in country-specific approaches.

Due to lack of evidence of significant emissions arising from the fixation process itself (IPCC 2006, 11.6), it should be noted that data on N_2O emissions from BNF and underlying data to estimate these emissions will no longer be required to be reported to UNFCCC when the 2006 Guidelines become applicable which is expected in 2015. However N_2O emissions from crop residues of N-fixing crops are still required, which are depending on the amount of N fixed.

Because of the rough estimation under the Revised 1996 IPCC Guidelines and the removal of the estimation of N_2O emissions from BNF in the 2006 Guidelines, countries are advised to establish country-specific estimates of BNF of leguminous crops.

3.9.6. *Default estimation procedure*

BNF of leguminous crops is a considerable source of N input in many countries (data collection in 2010/2011 shows rates ranging from 0% to 12% in total N inputs).

Countries which do not have country-specific coefficients available to estimate BNF of leguminous crops can use the default estimation procedure in IPCC Good Practice Guidance (Tier 1a or Tier 1b), see Annex 2, to estimate BNF by leguminous crops. Equation 47 or Equation 48 and Equation 50 could be applied to data on production of leguminous crops available from Crop Statistics with default values for $x_{res\_above\_legumes\_i}$, $x_{above\_dry\_i}$, and $N_{legumes\_coefficient\_kg\_dry\_i}$ provided in Table 15. If residue N content is needed for a crop type for which a value is not provided in Table 15, the non-crop specific default value 0.03 kg N / kg dry matter can be used.

It is however recognized that the default estimation procedure by IPCC Guidelines may only provide a rough indication of BNF. Estimations based on IPCC Guidelines can be compared to estimations of comparable countries which have country-specific data available. In bilateral cooperation between Eurostat and the country, it can be decided that country-specific coefficients used by comparable countries reflect the situation in the country better than estimation based on IPCC Guidelines.

It is more difficult to establish default estimations for BNF in legume-grass pastures, as basic data on areas and productivity of these areas are not available and are likely to vary significantly across countries. If possible Eurostat will, based on intermediate results of the grassland project see section 3.9.7 and bilateral consultations with countries, provide default estimations for countries which have no country-specific data available.

3.9.7. *Actions foreseen*

A project on grasslands has been signed by Eurostat in September 2012 with duration of 14 months. The objective is: "*to define different types of grasslands and their productivity and to describe how data can be collected on these different types of grassland in the EU so that a coherent European data set is created*". Task 2 of this contract is concerned with methodologies to estimate biological fixation in grasslands. The recommendations mentioned in the previous paragraph will be taken into account in this project. This project will provide a first step towards a harmonised classification of grasslands, estimation of grassland production and BNF, follow-up actions may be needed.

For the establishment of a common methodology or a common set of guidelines for estimation of BNF of leguminous crops no actions are currently planned in short term, however it is recognized that improvements in this area are highly needed, and may be foreseen in medium to long term.

3.10. Atmospheric deposition

3.10.1. *Definitions*

Atmospheric nitrogen deposition is the process by which N airborne particles and gases are deposited to soils, vegetation, waters, and other surfaces, either through precipitation (rain, snow, clouds, and fog), known as **wet nitrogen deposition** or as a result of complex atmospheric processes such as settling, impaction, and adsorption, known as **dry nitrogen deposition**. Emissions of ammonia (in the forms NH_3 and NH_4^+), mainly agriculture, lead to **deposition of reduced nitrogen** in the form of NH_4^+ in precipitation, and in the form of particulate NH_4^+ and NH_3 when dry deposited. Emissions of nitrogen oxides (NO and NO_2) emissions, mainly industry and cars/trucks, lead to **deposition of oxidized nitrogen** in the form of HNO_3 and NO_3^- in precipitation, and in the form of HNO_3 and particulate NO_3^- when dry deposited.

Atmospheric phosphorus deposition is the process by which P airborne particles are deposited to soils, vegetation, waters, and other surfaces, either through precipitation (rain, snow, clouds, and fog), known as **wet phosphorus deposition** or as the gravitational settling of large particles not associated with falling precipitation, known as **dry phosphorus deposition**

3.10.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	Atmospheric deposition on the reference area.
Practical:	N: Estimation of atmospheric N deposited on reference area based on country specific data or EMEP data. P: Atmospheric deposition of P is not included in the practical implementation.

3.10.3. Guidelines on practical implementation

Equation 16. $N_{deposition}\ (tonnes\ of\ Nitrogen) = A_{UAA}\ (1000\ ha) \times N_{deposition_{coefficient}}\ (kg\ Nitrogen\ per\ ha)\ )$

All oxidized and reduced N deposited by dry and wet deposition processes on the reference area regardless of the source should be included in the land budget approach as it is a real input to the soil. The sources of N volatilisation to NH_3 and NO_x gases and deposition of these gases and their products NH_4^+ and NO_3^- onto soils and surface of lakes and other waters are not confined to agricultural fertilizers and manures, but also include fossil fuel combustion, biomass burning and processes in chemical industry.

Atmospheric deposition varies by location. Precise data on atmospheric deposition on the reference area are generally not available. An approximation of N deposited on the reference area ($N_{deposition}$) could be derived by multiplying a national average deposition rate ($N_{deposition\_coefficient}$) per ha with the reference area (A_{UAA}) (see subchapter 3.3), assuming that the average deposition rates is equal for agricultural and non-agricultural soils, see Equation 16.

Data may be available from:

- Country-specific data sources.
- UNFCC:

  Data on atmospheric deposition of N emissions originating from the application of inorganic fertilizers and manure and the manure deposited by grazing animals on pasture, range and paddock is reported to UNFCCC under the IPCC Revised 1996 Guidelines, see section 3.10.5.
- The European Monitoring and Evaluation Programme (EMEP) of CLTRAP:

  EMEP models total N deposition at NUTS0 level and at grid level in a harmonised way for signatories of CLTRAP. EMEP makes use of national expertise and research.

3.10.4. Discussion

OECD/Eurostat Handbook 2007 recommended correcting atmospheric deposition of N for N-deposits resulting from domestic agriculture as N surplus includes emissions of NH_3 and NO which would lead to double counting. This view is however not correct as all atmospheric deposition regardless of the source are a true input of N to the soil and therefore should be counted at the input side of the budgets. NH_3 and NO emissions are a true part of the surplus (posing a potential risk to the environment), therefore there is no double counting and all deposition should be included at the input side.

3.10.5. Coherence with UNFCCC/UNECE

IPCC Revised 1996 Guidelines describe in Chapter 4.5.4 the estimation of indirect N emissions from agricultural soils due to atmospheric deposition of N emissions originating from application of inorganic fertilizers and manure and manure deposited by grazing animals on pasture, range and paddock. Note that only agricultural sources of N are considered in Revised 1996 Guidelines, whereas nutrient budgets require data on all deposition on agricultural soils.

IPPC 2006 Guidelines include guidance for estimating N_2O emissions resulting from N deposition of all anthropogenic sources of NO_x and NH_3. Specific guidance on estimating N_2O emissions from that portion of N compounds associated with volatilisation of NO_x and NH_3 from manure management systems are provided in Section 10.5 and from synthetic and organic N input to managed soils, and urine and dung N deposited by grazing animals in Section 11.2.2 of Volume 4. In section 7.3 of Volume 1 guidance is provided on estimating N_2O emissions from the atmospheric deposition of N.

3.10.6. Default estimation procedure

Equation 17. $$N_{deposition_{coefficient}}(kg\ N\ per\ ha) = \left(N_{deposition_{oxidized}}(tonnes\ of\ N) + N_{deposition_{reduced}}(tonnes\ of\ N)\right) \div A_{total}\ (1000\ ha)$$

If countries do not have country-specific data available, data from EMEP will be used to estimate deposition. Data on atmospheric N deposition at NUTS0 level in Gg can be found at http://webdab.emep.int/Unified_Model_Results/ by selecting the country, years of interest and total deposition of oxidized N and total deposition of reduced N. Data can be converted to tonnes by multiplying data in Gg with 1 000. An approximation of the average deposition rate in kg N per ha can be calculated by aggregating oxidised ($N_{deposition\_oxidized}$) and reduced N ($N_{deposition\_reduced}$) and dividing the result by total land area (A_{total}) (L0008 in Crop Statistics)[30], see Equation 17. N deposition on the reference area is estimated by multiplying the estimated coefficient with the reference area.

3.10.7. Actions foreseen

No actions foreseen.

3.11. Seeds and planting materials

3.11.1. Definitions

Cropped area is defined in Eurostat Crop Statistics as the area that corresponds to the total sown area for producing a specific crop during a given year.

Area under cultivation is defined in Eurostat Crop Statistics as the area that corresponds to total sown area, but after harvest it excludes ruined areas (e.g. due to natural disasters). If the same land parcel is used twice in the same year for different crops, the area of this parcel can be counted twice.

3.11.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	All seeds and planting material on the reference areas are included.
Practical:	At minimum seeds for cereal crops and potatoes are included.

[30] Countries are no longer obliged to report data on total land area with Crop Statistics; however countries may report these data on a voluntary base.

3.11.3. Guidelines on practical implementation

This section may be updated in the future, following actions listed in section 3.11.7, see also the discussion in section 3.11.4.

Equation 18. $$N_{seed}\ (tonnes\ of\ N) = \sum_i \left\{ C_{seed_i}\ (tonnes) \times N_{seed_{coefficient_i}}\ (kg\ N\ per\ tonne) \right\}$$

Equation 19. $$P_{seed}\ (tonnes\ of\ P) = \sum_i \left\{ C_{seed_i}\ (tonnes) \times P_{seed_{coefficient_i}}\ (kg\ P\ per\ tonne) \right\}$$

Equation 20. $$C_{seed_i}\ (tonnes) = A_{crop_i}\ (1000\ ha) \times SR_i\ (kg\ seed\ per\ ha)$$

The N amount of seeds input to agricultural soils (N_{seed}) is estimated by summing up the N seed inputs of the different crops. The N seed input of crop *i* is estimated by multiplying the amount of seeds used for crop *i* (C_{seed_i}) with a coefficient to convert to nutrient contents ($N_{seed\_coefficient\_i}$), see Equation 18. In a similar way the P amount of seeds input to agricultural soils (P_{seed}) can be estimated with Equation 19. The amount of seeds used of crop *i* can be derived from data on sowing rates of crop *i* (SR_i) and cropped areas of crop *i* (A_{crop_i}), see Equation 20. If data on cropped areas are not available data on the area under cultivation can be used as an approximation.

In principle countries should provide estimates on seed nutrient inputs for all crops cultivated on the reference area. However as data are in most countries limited available the minimum reporting requirement are data on seed input of cereal crops and potatoes, see section 3.11.4.

Data may be available from country specific data sources or from e.g. Economic Accounts for Agriculture.

3.11.4. Discussion

Data collection in 2010/2011 showed that data on seeds and planting material:

- are not available from all countries (19 countries reported seeds),
- are often only available for a limited number of crops,
- are often based on standard or assumed seeding rates,
- country-specific data on nutrient contents were often not available,
- seeds and planting material were <2% of nutrient input in most countries for which data was available, in Hungary, Poland and Slovakia seeds and planting materials are of minor importance for P (2-5% of total P inputs).
- Data were provided on amount of seeds in tonnes and nutrient contents of seeds.
- After several discussions in WG meetings on AEI[31] it was agreed to keep this flow in the practical implementation of the budget but require data for only a selected group of crops. Data collected in 2010/2011 from show that cereals and potatoes accounted for more than 90% of total seed input reported in 15 of the 19 countries, see Annex 3.

3.11.5. Coherence with UNFCCC/UNECE

Not applicable

[31] Responses countries and discussions WG meetings in 2010, 2012 and 2013

3.11.6. *Default estimation procedure*

In case countries do not have data available, Eurostat will estimate nutrient seed input by applying default values mentioned in Table 8 to areas under cultivation from crop statistics (apro_cpp_crop). More information on these default values can be found in Annex 3.

Table 8. Default nutrient seed input rates per ha

	kg N per ha	kg P per ha
Wheat	4	0.7
Other cereals	3	0.6
Potatoes	8	1.3

3.11.7. *Actions foreseen*

Currently some pilot-projects on nutrient contents of crops are carried out. These actions may provide some improvement in data availability on seeds and nutrient contents.

3.12. Crop residues inputs

3.12.1. *Definitions*

The main purpose of agricultural cultivation of plants is crop and fodder production. A (fodder) **crop** is the part of the plant cultivated by agriculture which is harvested and processed as main purpose for food, fodder or industrial production (e.g. grain, sugar beets, potatoes etc.).

Crop residues (Equation 21) are:

i) Residues of the plant which remain after harvest of the (fodder) crop (e.g. stalks and stubble) (C_{res_left}). Crop residues may remain above ($C_{res\_left\_above}$) or below ($C_{res\_left\_below}$) ground (Equation 22).

ii) Residues which are harvested as by-product with the fodder (crop) (e.g. straw) and can be used as feed for animals, bedding material or other purposes ($C_{res\_harvest}$). Some of these residues may be removed completely from agriculture (C_{res_remove}) and some (C_{res_return}) may return to the field at a later stage (e.g. in litter) (Equation 23).

iii) Residues of the plant which are burned on the field (C_{res_burnt}). A part of N is lost (volatilises) with burning of crop residues ($C_{res\_volatilised}$), a part is returned to the soil with the ashes (C_{res_ash}) (Equation 24). It is assumed that there are no losses of P with burning of crop residues, all P in the burned crop residue remains in the ashes.

Equation 21. $$C_{res} = C_{res_{left}} + C_{res_{harvest}} + C_{res_{burnt}}$$

Equation 22. $$C_{res_{left}} = C_{res_{left_{above}}} + C_{res_{left_{below}}}$$

Equation 23. $$C_{res_{harvest}} = C_{res_{remove}} + C_{res_{return}}$$

Equation 24. $$C_{res_{burnt}} = C_{res_{volatilised}} + C_{res_{ash}}$$

3.12.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	All nutrients incorporated into the soil with crop residues left on the field, returned to the soil and ashes of burned crop residues on the reference area are included.
Practical:	Crop residues are not accounted in the input side of the practical implementation.

3.12.3. Guidelines on practical implementation

Crop residues are not accounted in the input side of the practical implementation.

3.12.4. Discussion

In the ideal budget all nutrient flows to and from the soil should be included. In the ideal budget the different flows from crop residues to and from the soil would need to be clearly distinguished. In the ideal budget the crop residues left (C_{res_left}), returned to the field (C_{res_return}) and the ashes of burned crop residues (C_{res_ash}), should be counted at the input-side of the budget and all crop residues (C_{res_left}, $C_{res\_harvest}$ and C_{res_burnt}) at the output-side of the budget see Table 1. Including all crop residues at the output side of the budget is to be able to estimate correct nutrient use efficiencies. The difference with regards of the treatment of crop residues in the ideal budget and the practical implementation is the effect on the estimated nutrient use efficiencies. Nutrient use efficiencies are estimated as Inputs/Outputs. Nutrient use efficiencies estimated with the ideal budget increase if the share of crop residues which are left on the field increases (cet. par.). Nutrient use efficiencies estimated with the practical implementation of the budget do not take into account the beneficial effect of crop residues left on the field.

The estimated surplus from crop residue input and output in the practical implementation of the nitrogen budget approaches the surplus estimated with the ideal approach if the majority of N is lost (volatilization) with burning of crop residues, see Table 9 and Table 10 in subchapter 3.15.

Following a written consultation with members of the Eurostat Working Group on AEI, it was concluded not to include crop residues at the input side of the nutrient budgets to reduce data requirements and at the same time improve the estimated surplus by including certain crop residues at the output side of nutrient budgets in the practical implementation. See for a further discussion on crop residues subchapter 3.15.

3.12.5. Coherence with UNFCCC/UNECE

The IPCC Guidelines estimate GHG emissions for the (net) crop residue input, see Annex 5. In the nutrient balances the net removal of crop residues is taken into account.

3.12.6. Default estimation procedure

Not applicable.

3.12.7. Actions foreseen

Inclusion of data on crop residue input in the nutrient budgets is not foreseen in the short term.

3.13. Crop production

3.13.1. Definitions

See also section 3.11.1.

Crops cultivated by agricultural holdings on the UAA include crops listed in Regulation (EC) No 543/2009. Other crops cultivated by agricultural holdings not mentioned in Regulation (EC) No 543/2009 (e.g. ornamental plants) may also be included. Fodder crops such as plants harvested green

(C2610), temporary (C2680) and permanent grassland (C0002) are not considered in this subchapter, they are discussed in subchapter 3.14 on Fodder production.

Harvested crop-production is defined in Eurostat Crop Statistics (regulation (EC) No 543/2009), as the production including on-holding losses and wastage, quantities consumed directly on the farm and marketed quantities, indicated in units of basic product weight. By-products and crop residuals are excluded under this definition.

Harvested area is defined in Eurostat Crop Statistics as the part of the cropped area that is harvested. It can, therefore, be equal to or less than the cropped area.

Yield is defined in Eurostat Crop Statistics as the harvested production per area under cultivation.

Main area of a given parcel is defined in Eurostat Crop Statistics as the area where the parcel has been used only once during a given crop year, and which is unequivocally defined by that use.

3.13.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	All crop products harvested on the reference area are included.
Practical:	Estimation based on country specific nutrient coefficients and crop production data reported to Eurostat with Crop production statistics.

3.13.3. Guidelines on practical implementation

This section may be updated in the future, following actions listed in section 3.13.7, see also discussion in section 3.13.4.

Equation 25. $$N_{crop}\,(tonnes\ of\ N) = \sum_i \left\{ C_{crop_i}\,(tonnes) \times N_{crop_{coefficient_i}}\,(kg\ N\ per\ tonne) \right\}$$

Equation 26. $$P_{crop}\,(tonnes\ of\ P) = \sum_i \left\{ C_{crop_i}\,(tonnes) \times P_{crop_{coefficient_i}}\,(kg\ P\ per\ tonne) \right\}$$

N removal with crop production (N_{crop}) is estimated by summing up N removal of different crops. N removal with crop production of crop type *i* is estimated by multiplying crop production of crop *i* (C_{crop_i}) with a coefficient ($N_{crop\_coefficient\_i}$) to convert tonnes into N amount, see Equation 25. In a similar way P removal with crop production (P_{crop}) can be estimated (Equation 26). Annual data on crop production are available from Crop Statistics (regulation (EC) No 543/2009). This is the designated data source for countries to use to estimate nutrient removed by harvested crops for all crop production reported under this regulation. In principle countries should report data on all crop products harvested on the reference area. The minimum data requirement is nutrient removal of crops for following crops under regulation 543/2009: cereals (C1040), dried pulses (C1300), root crops (C1350), industrial crops (C1400), vegetables (C1600) and fruit (C2009). Plants harvested green (C2610), temporary (C2680) and permanent grassland (C0002) are considered in subchapter 3.14.

Coefficients to translate crop production in nutrient amounts are available in some countries. Care should be taken that coefficients refer to the harvested crop. For some crops only a part of the crop is harvested, and nutrient contents of the harvested and non-harvested plants may vary. The coefficient should also refer to the unit in which the production is measured. Crop production can be reported as field-dry or fresh weight or in dry matter. A correction factor can be applied to production in field-dry or fresh weight to derive dry matter yields.

3.13.4. *Discussion*

Annual data on production of most crops cultivated on UAA are available from Crop Statistics (regulation (EC) No 543/2009). Some crops which are part of UAA are however not covered by Crop Statistics (e.g. ornamental plants and flowers, nurseries, seed and seedlings). Data from the 2010/2011 data collection show that these crops are only reported by a few countries (Netherlands, Spain, Belgium, Poland, France, United Kingdom and Switzerland) and are negligible (<1% of total nutrient removed with the harvest of crops in 2006) in all of these countries except the Netherlands. If flowers and other crops not included in Crop Production Statistics cover more than 1% of UAA, countries should estimate and report nutrient removal of these areas, unless nutrient removal of these crops is below 1% of total nutrient removal of crops. Data on minor crops may also be available from Economic Accounts for Agriculture.

3.13.5. *Coherence with UNFCCC/UNECE*

Not applicable

3.13.6. *Default estimation procedure*

There is little data available on crop nutrient contents. Differences in coefficients used by countries can partly be explained by differences in farmer practices, climate, soil etc. Data collection in 2010/2011 however also showed very large differences between neighbouring countries, this suggests that a part of the variation may be due to differences in methodologies used to estimate crop nutrient contents. There is a need to improve coefficients used by countries to estimate nutrient contents of harvested crops, to establish guidelines for the estimation of such coefficients, to benchmark coefficients and to develop default values, see also section 3.13.7. At present default values could not be established. As this is a major flow in the nutrient budgets, the flow cannot be ignored. As an intermediate solution, until default values are established, Eurostat will estimate coefficients for countries which do not have country-specific data available from data of comparable countries. Data on crop production will be derived from crop statistics.

3.13.7. *Actions foreseen*

There is a need to improve coefficients used by countries to estimate nutrient contents of harvested crops, to establish guidelines for the estimation of such coefficients, to benchmark coefficients and to develop default values. In 2012 Eurostat started pilot projects with a few countries to improve or establish such coefficients. These pilot studies could be a first step towards establishing default values, estimation guidelines and verification procedures. Other actions in medium and long term may follow.

3.14. Fodder production

3.14.1. *Definitions*

See also section 3.13.1.

Gross grassland production: The total amount of biomass (in tonnes of nutrients) produced on grasslands. This is the potential amount of biomass available for harvesting and/or grazing.

Net grassland production: The total amount of biomass (in tonnes of nutrients) removed from grasslands. Not the entire potential amount of biomass is removed by harvesting and/or grazing, a part flows back to the soils. For instance not all of the biomass produced on grazed grasslands is actually grazed by animals; a part of the biomass gets trampled and is therefore not grazed by grazing animals. Other losses occur during harvesting, conservation of hay and silage and with the feeding of animals with fresh grass, hay and silage. The net grassland production is calculated from the gross grassland production corrected for these losses.

3.14.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	All fodder harvested and grazed on the reference area are included.
Practical:	Estimation based on country specific nutrient coefficients and crop production data reported to Eurostat with Crop production statistics and country estimations on fodder production.

3.14.3. Guidelines on practical implementation

This section may be updated in the future; following actions listed in section 3.14.7 see also discussion in section 3.14.4.

Annual plants harvested green

For some fodder crops data on production is available from annual Crop Statistics (Regulation (EC) No 543/2009):

Annual plants harvested green (area under cultivation and production) (C2611).

– Green maize (area under cultivation, production and yield)

– Cereals harvested green (area under cultivation and production)

Together with coefficients on crop nutrients, nutrients removed by the harvest of these fodder crops can be estimated (Equation 25 and Equation 26). Coefficients to translate fodder production in nutrient amounts are available in some countries. Care should be taken that established coefficients refer to the harvested fodder crop. For some crops only a part of the crop is harvested, and nutrient contents of the harvested and non-harvested plants may vary. Coefficients should also refer to the unit in which production is measured. Crop production can be reported as field-dry, fresh weight or in d.m. A correction factor can be applied to production in field-dry or fresh weight to derive d.m. yields.

Minimum data requirement: nutrient removal of Annual plants harvested green (C2611).

Leguminous plants

Data on production of leguminous plants such as clover and lucerne are currently not available from Eurostat statistics. Some countries however estimate N removal by harvest and or grazing of leguminous crops by applying coefficients to data on production (harvested and grazed) as is presented in Equation 25. In other countries a coefficient is applied to the area under cultivation (A_{crop_i}), see Equation 27. In these cases a constant yield over time has been assumed. The same applies for P (Equation 28).

Equation 27. $$N_{crop}\ (tonnes\ of\ N) = \Sigma i \left\{ A_{crop_i}\ (1000\ ha) \times N_{crop_{coefficient_{ha_i}}}\ (kg\ N\ per\ ha) \right\}$$

Equation 28. $$P_{crop}\ (tonnes\ of\ P) = \Sigma i \left\{ A_{crop_i}\ (1000\ ha) \times P_{crop_{coefficient_{ha_i}}}\ (kg\ P\ per\ ha) \right\}$$

Data on areas are available from annual Crop Statistics (Regulation (EC) No 543/2009):

- Leguminous plants (area under cultivation) (C2670)

Data on main areas of these fodder crops are also available from FSS. Countries which have country-specific data available on this flow can report these data.

Minimum data requirement: Nutrient removal of Leguminous plants (C2670)

Grassland

Data on the gross and net production of grasslands are currently not available from Eurostat statistics. Some countries however have established methods to estimate the gross and net nutrient removal by the harvest and or grazing of grasslands, see also discussion in section 3.14.4. Countries which have country-specific data available on this flow can report these data.

Minimum data requirement is nutrient removal of (gross and net production) of following crops under regulation 543/2009: Temporary grasslands (C2680) and Permanent grasslands (C0002).

3.14.4. Discussion

Data on production of grasslands are currently not available from Eurostat statistics. Data on areas are available from annual Crop Statistics (Regulation (EC) No 543/2009):

- Temporary grasses and grazing (area under cultivation)
- Permanent grassland (main areas, also at regional level: NUTS2, UK and DE at NUTS1)

Data on main areas of these fodder crops are also available from the Farm Structure Survey.

Some countries may have established methods to estimate the nutrient removal by the harvest and or grazing of grasslands: applying a yield-factor to the grassland area based on scientific research, surveying farmers, measurements in a selected sample of farms, modelling etc. Countries which have data available on this flow can report these data.

The approach used has a significant impact on estimated removal of nutrients by harvest and grazing of grasslands, and as in most countries grasslands cover a major part of UAA the approach used to estimate removal of nutrients by harvest and grazing of grasslands has a considerable impact on the outcome of the budget. Grass yield estimations from research farms are generally higher than from a farm survey, due to the fact that research farms are often more intensive and productive than the average farm. Methods used by the farmer also determine the accuracy of the result; are the products harvested weighed to determine the amount, or is the harvest estimated from average height of grass in a field etc. Some methodologies (e.g. constant per ha rates) do not capture changing farmer practices. Reducing grazing livestock will normally lead to a lower grassland production; this is not taken into account when constant rates are used. The Netherlands and Switzerland estimate grassland production with a fodder balance: consumption of grass grazed is the balancing item of the equation with on the left side animal energy requirements and on the right side intake from grass grazed and other feed. This approach has the advantage that it reflects changes in farmer practices. Results in Netherlands for the period 1990-2002 showed a decreasing trend in grassland N removal following decreasing N inputs from manure and fertilizers[32]. The fodder balance is also used as an input in the estimation of excretion coefficients. A participant in the Task Force meeting on Gross Nutrient Balances held in November 2011 mentioned the opposite approach: to estimate fodder N intake from excretion. N excreted by livestock type *i* ($N_{excretion\_i}$) in a year must equal the amount of N consumed by livestock type *i* in a year ($N_{animalfeed\_i}$) minus amount of N retained in the animal and animal products of livestock type *i* ($N_{animalretention\_i}$), see Equation 29. If excretion rates are known or established the N removal with animal feed can be estimated by summing up N excretion and N retention in the animal and animal products of different livestock types, see Equation 30. However this approach is less sensitive to farmer changes as fixed excretion coefficients are used.

In a similar way P in fodder ($P_{animalfeed\_i}$) can be estimated from Equation 31 and Equation 32.

[32] See http://www.cbs.nl/en-GB/menu/themas/landbouw/publicaties/artikelen/archief/2005/2005-1625-wm.htm?Languageswitch=on

Equation 29. $N_{excretion_i}(tonnes\ of\ N) = N_{animalfeed_i}(tonnes\ of\ N) - N_{animalretention_i}(tonnes\ of\ N)$

Equation 30. $N_{animalfeed_i}\ (tonnes\ of\ N) = \sum_i \{N_{excretion_i}\ (tonnes\ of\ N) + N_{animalretention_i}\ (tonnes\ of\ N)\}$

Equation 31. $P_{excretion_i}(tonnes\ of\ P) = P_{animalfeed_i}(tonnes\ of\ P) - P_{animalretention_i}(tonnes\ of\ P)$

Equation 32. $P_{animalfeed_i}\ (tonnes\ of\ P) = \sum_i \{P_{excretion_i}\ (tonnes\ of\ P) + P_{animalretention_i}\ (tonnes\ of\ P)\}$

The Guidelines (2012) for the Economy Wide Material Flow Accounts (EW-MFA) suggest 2 approaches to estimate harvested fodder and biomass grazed when national data are not available: a supply-side approach or a demand-side approach. In the EW-MFA the supply-side approach attempts at closing gaps in production data for individual fodder crop categories. The demand-side approach takes the annual fodder requirement of the existing livestock as the starting point for estimating the total production of fodder crops; see Annex 4.

DireDate recommendations with regard to estimation of grassland production and nutrient removal:

- Install a Working Group with scientists, agronomists, and statisticians of different Member States to develop a methodology to estimate grassland yields taking different management types into consideration (rough grazing, extensively managed, and intensively managed).
- Estimates of the area and yields of different types of grasslands are needed.
- Estimations may be based on empirical data (field experiments), results of crops models, expert estimates and feed balances of dairy cattle (i.e. feed N intake can be estimated from milk yield). The model MITERRA-EUROPE (Velthof et al, 2009) is one example of possible methodologies, another one is the study of Aarts et al. 2008 in the Netherlands, in which the grassland yield was estimated on farm level using data on milk production, energy requirements, feed composition, and maize yields. Grassland yield was the output of a balance calculation. Such a calculation can be also made on a regional level, but a methodology must be derived. Evidently, these mean yield estimates should have a firm and scientifically sound underpinning.
- Introduce control measures. Once satisfactory NUEs and PUEs for livestock have been established (see Equation 3 and Equation 4 in paragraph 3.6.1), feed N ($N_{animalfeed}$) and P intake ($N_{animalfeed}$) can be calculated from Equation 30 and Equation 32. Feed N intake ($N_{animalfeed}$) consists of N in animal feed produced at farms ($N_{animalfeed\_farm}$) (grass, maize etc.) and N in animal feed products from industry ($N_{animalfeed\_import}$) (concentrates etc.), see Equation 33. $N_{animalfeed\_farm}$ can be estimated with Equation 34. Validation can be made with statistics on land use areas and fodder production. In a similar way P in animal feed produced at farms ($P_{animalfeed\_farm}$) can be estimated with Equation 35 and Equation 36.

Equation 33. $\boldsymbol{N_{animalfeed}\ (tonnes\ of\ N) = N_{animalfeed_{farm}}\ (tonnes\ of\ N) + N_{animalfeed_{import}}\ (tonnes\ of\ N)}$

Equation 34. $\boldsymbol{N_{animalfeed_{farm}}\ (tonnes\ of\ N) = N_{animalfeed}\ (tonnes\ of\ N) - N_{animalfeed_{import}}\ (tonnes\ of\ N)}$

Equation 35. $\boldsymbol{P_{animalfeed}\ (tonnes\ of\ P) = P_{animalfeed_{farm}}\ (tonnes\ of\ P) + P_{animalfeed_{import}}\ (tonnes\ of\ P)}$

Equation 36. $\boldsymbol{P_{animalfeed_{farm}}\ (tonnes\ of\ P) = P_{animalfeed}\ (tonnes\ of\ P) - P_{animalfeed_{import}}\ (tonnes\ of\ P)}$

The Eurostat Task Force meeting on Gross Nutrient Balances in November 2011 in Luxembourg discussed EW-MFA and DireDate recommendations. Following recommendations were made:

- The method to estimate grassland production and nutrient removal should be able to capture changes in farmer practices, and data should be estimated at an annual rate.
- Ideally both demand-side and supply side should be combined to crosscheck results.
- Grassland production needs to be estimated for different types of grasslands and at regional level. Grassland output is depending on fertilizer inputs, grazing/mowing practices, intensity of farming etc. These factors vary across different grasslands systems and perhaps yields may also vary between regions due to climate differences etc. One suggestion would be to classify grasslands according to their production potential (fertilizer inputs, grazing/mowing practices, intensity of farming etc.). Grasslands could also be classified according to their environmental potential (High Nature Value grassland, rotational grasslands, and other less biologically valuable grasslands). Classification could be linked to the frequency of grassland cut (the more cuts, the more intensive). Classifying grasslands as intensive or extensive is a politically sensitive question.

Equation 37. $\boldsymbol{N_{grass_{net}}\ (tonnes\ of\ N) = N_{grass_{gross}}\ (tonnes\ of\ N) \times \left(1 - \left(x_{grass_{tramp}} + x_{grass_{harvest_{loss}}} + x_{grass_{conserv}} + x_{grass_{feeding}}\right)\right)}$

Equation 38. $\boldsymbol{P_{grass_{net}}\ (tonnes\ of\ P) = P_{grass_{gross}}\ (tonnes\ of\ P) \times \left(1 - \left(x_{grass_{tramp}} + x_{grass_{harvest_{loss}}} + x_{grass_{conserv}} + x_{grass_{feeding}}\right)\right)}$

Not all of the produced grass is removed from agricultural soils. The N removal with the gross production of grassland (N_{grass_gross}) needs to be corrected to determine the N removal with the net production of grassland (N_{grass_net}), see Equation 37. In a similar way the P removal with the net production of P in grassland (P_{grass_net}) is estimated from the P removal with the gross production (Equation 38):

- A part of grass produced on grazed grasslands is not consumed by grazing animals, due to trampling of grass by grazing animals. Total grassland production (in tonnes of Nutrients) therefore needs to be corrected for this share (x_{grass_tramp}).
- During harvesting of grass, losses may occur. These losses remain on field. Total grassland production (in tonnes of Nutrients) needs to be corrected for this share ($x_{grass\_harvest\_loss}$).
- During conservation of hay or silage losses may occur due to volatilization of N and leaching of N and P. It is assumed that the nutrients leached return to the soil. N volatilization is included in total GNS. Total grassland production (in tonnes of Nutrients) therefore needs to be corrected for this share ($x_{grass\_conserv}$).
- During feeding of fresh grass, hay and silage to animals, losses may occur. It is assumed that these nutrients return to the soil through the litter. Total grassland production (in tonnes of Nutrients) therefore needs to be corrected for this share ($x_{grass\_feeding}$).

Data from other data sources may also be helpful in providing estimates of fodder production, e.g. Economic Accounts for Agriculture.

3.14.5. Coherence with UNFCCC/UNECE

Not applicable

3.14.6. Default estimation procedure

Data on production is available for annual plants harvested green from crop statistics. Some countries may have provided data on leguminous plants production with crop statistics. However for some countries such data will not be available from crop statistics. Data on grassland production is neither available, see section 3.14.7. The removal of nutrients with the harvest and/or grazing of leguminous plants and grasslands will in these cases be estimated with a coefficient relating to area units and data on land use from crop statistics.

There is little data available on coefficients of crop nutrient contents of annual plants harvested green and leguminous plants and coefficients relating to area units to estimate removal of nutrients with harvest and/or grazing of leguminous plants and grasslands. Differences in coefficients used by countries can partly be explained by differences in farmer practices, climate, soil etc. Data collected in 2010/2011 showed very large differences between neighbouring countries, suggesting that a part of the variation may be due to differences in methodologies used to estimate coefficients. There is a need to improve coefficients used by countries to estimate nutrient removal of harvested and grazed fodder crops, to establish guidelines for the estimation of such coefficients, to benchmark coefficients and to develop default values, see section 3.13.7. At present default values could not be established. As this is a major flow in the nutrient budgets, the flow cannot be ignored. As an intermediate solution, until default values for coefficients are established, Eurostat will estimate coefficients for countries which do not have country-specific data available from data on coefficients of comparable countries.

3.14.7. Actions foreseen

To improve data on grassland statistics, incl. land use, the estimation of grassland production and biological fixation, Eurostat has issued a tender on grassland statistics. The project was signed in September 2012 and a kick-off meeting has been organised at the beginning of October 2012. The contract has duration of 14 months. The objective of the project is: *'to define different types of grasslands and their productivity and to describe how data can be collected on these different types of grassland in the EU so that a coherent European data set is created*".

This project will provide a first step towards a harmonised classification of grasslands and the estimation of grassland production and biological fixation. Follow-up actions may be needed.

3.15. Crop residues outputs

3.15.1. Definitions

See section 3.12.1.

3.15.2. Description in Ideal and Practical implementation of GNB and PB

Ideal:	All nutrients in crop residues of the reference area are included.
Practical:	N: N removal with crop residues removed from the soil (N_{res_remove}) and burned (N_{res_burnt}) estimated from country-specific data or if not available default estimation procedure described in Annex 5 with IPCC default values mentioned in Table 21 and default recovery rates of EW-MFA Guidelines (Table 23). P: P removal with crop residues removed from the soil (P_{res_remove}) estimated from country-specific data.

3.15.3. Guidelines on practical implementation

Equation 39. $$N_{res_{remove}}\ (tonnes\ of\ N) = \sum_i \left\{ C_{res_{remove_i}}\ (tonnes) \times N_{res_{remove_{coefficient_i}}}\ (kg\ N\ per\ tonne) \right\}$$

Equation 40. $$P_{res_{remove}}\ (tonnes\ of\ P) = \sum_i \left\{ C_{res_{remove_i}}\ (tonnes) \times P_{res_{remove_{coefficient_i}}}\ (kg\ P\ per\ tonne) \right\}$$

Equation 41. $$N_{res_{burnt}}(tonnes\ of\ N) = \sum_i \left\{ C_{res_{burnt_i}}\ (tonnes) \times N_{res_{burnt_{coefficient_i}}}(kg\ N) \right\}$$

The (net) N removal of crop residues from the field (N_{res_remove}) can be estimated by summing up the (net) N removals of crop residues for different crops. The (net) N removal of crop residues from the field of crop *i* is estimated by multiplying the (net) amount of crop residues removed of crop *i* ($C_{res\_remove\_i}$) with a coefficient on the residue N content ($N_{res\_remove\_coefficient\_i}$), see Equation 39. In a similar way the (net) P removal of crop residues from the field (P_{res_remove}) can be estimated with Equation 40. If data are not available on the net removal of crop residues of crop *i* (C_{res_remove}), see Equation 23, countries may report total crop residues harvested from the field for crop *i* ($C_{res\_harvest\_i}$) as an approximation. Data on nutrient contents of crop residues may be available in some countries. Coefficients should refer to the content of the residue and the unit in which the residue is measured (dry weight, fresh content, m.c. etc.).

In principle data on all (net) crop residue removals should be included. Minimum requirement is the (net) removal of crop residues of cereal crops, rapeseed, soybean and sugar beet.

The N removal with crop residues burned on the field (N_{res_burnt}) can be estimated by summing up the N removals with burning of crop residues of different crops. The N removal with crop residues burned on the field of crop *i* is estimated by multiplying the amount of residues of crop *i* burned ($C_{res\_burnt\ \_i}$) with a coefficient on the residue N content of crop *i* ($N_{res\_burnt\_coefficient\_i}$), see Equation 41.

It is advised to coordinate country specific data on crop residues removals and burning with data reported to UNFCCC, see also section 3.15.5 UNECE.

3.15.4. Discussion

In the GNB N with crop residues removed (N_{res_remove}) and burned (N_{res_burnt}) will be included at the output-side in the practical implementation, see Table 9. If the majority of N is lost (volatilization) with burning of crop residues the surplus estimated with the practical implementation will approach the surplus estimated with the ideal approach (ceteris paribus).

Table 9. Crop residues in ideal and practical implementation of GNB

	Ideal budget	Practical implementation
Inputs	Crop residues left on the field (N_{res_left}) Crop residues returned to the field (N_{res_return}) Crop residues ashes (N_{res_ash})	
Outputs	Crop residues (N_{res_left} + $N_{res\_harvest}$ + N_{res_burnt})	Crop residues removed (N_{res_remove}) Crop residues burnt (N_{res_burnt})
Surplus	$\mathbf{(N_{res\_left} + N_{res\_return} + N_{res\_ash}) - (N_{res\_left} + N_{res\_harvest} + N_{res\_burnt}) = - (N_{res\_remove} + N_{res\_volatilised})}$	$\mathbf{= - (N_{res\_remove} + N_{res\_burnt})}$

In PB only nutrient removal with crop residues removed (P_{res_remove}) will be included at the output-side in the practical implementation, see Table 10. As it is assumed that with burning of crop residues no P is lost only crop residues removed (P_{res_remove}) will be included at the output-side of the budget in the practical implementation of PB.

Table 10. Crop residues in ideal and practical implementation of PB

	Ideal budget	Practical implementation
Inputs	Crop residues left on the field (P_{res_left}) Crop residues returned to the field (P_{res_return}) Crop residues burned (P_{res_burnt})	
Outputs	Crop residues (P_{res_left} + $P_{res\_harvest}$ + P_{res_burnt})	Crop residues removed (P_{res_remove})
Surplus	$\mathbf{(P_{res\_left} + P_{res\_return} + P_{res\_burnt}) - (P_{res\_left} + P_{res\_harvest} + P_{res\_burnt}) = - (P_{res\_remove})}$	$\mathbf{= - (P_{res\_remove})}$

In the ideal budget the estimated N surplus from crop residues is N removal with the net removal of crop residues ($-N_{res\_remove}$), see Table 9. For P it is P removal with the net removal of crop residues ($-P_{res\_remove}$), see Table 10. The amount of crop residues removed completely from agriculture (C_{res_remove}) can be estimated by subtracting crop residues which were harvested from the field but at a later stage later reapplied to the field (e.g. in compost or litter) (C_{res_return}) from total crop residues harvested ($C_{res\_harvest}$). Data on reapplication of crop residues is however often not available in countries. Also some countries may currently count reapplication of crop residues under other flows of the budget; e.g. nutrients in straw used for bedding may have been taken into account in estimation of excretion. Crop residues reapplied to the soil may also have been reported under other organic fertilizers. Therefore in the practical implementation of the budget countries may report the total N (respectively P) removal with crop residues harvested from the field, $N_{res\_harvest}$ (respectively $P_{res\_harvest}$) as an approximation of the net N (respectively P) removal of crop residues, N_{res_remove} (respectively

P_{res_remove}). When the fraction of harvested crop residues which are removed completely from agriculture is large $N_{res\_harvest}$ (respectively $P_{res\_harvest}$) will approach N_{res_remove} (respectively P_{res_remove}).

A description in the IPCC Guidelines and EMEP/EEA Guidebook on the estimation of crop residues is included in Annex 5, see also section 3.15.5.

The Guidelines (2012) for the Economy Wide Material Flow Accounts (EW-MFA) also provide some guidelines on the estimation of the amount of crop residues removed from the field, see Annex 5. The amount of crop residues for a crop is estimated by multiplying data on the main production of the crop with a harvest factor (ratio between main crop and residue). The fraction of crop residues removed from the field is subsequently estimated by multiplying the total crop residues with the recovery rate. The main crops which provide crop residues are listed in Table 23. Data on the main production of these crops are available from Eurostat Crop Statistics.

Data on harvested crop residues may also be available from other data sources such as Economic Accounts for Agriculture.

3.15.5. Coherence with UNFCCC/UNECE

IPCC 1996 Guidelines (Tier1a) estimate incorporation of crop residues by determining total amount of crop residue N produced and adjusting it for the fraction that is burned in the field when residues are burned during or after harvest. It does not include removal of crop residues for other purposes. However IPCC Good Practice Guidance (Tier1b) proposes to adjust the calculation by accounting removal of crop residues for fuel, construction material and fodder. This requires however country-specific data, if country-specific data are not available no removal is assumed. IPCC 1996 Revised Guidelines (Volume 3, Chapter 4.4.3) recommends using three year averages for activity data. IPCC 2006 Guidelines describe the estimation of the amount of N in crop residues (above-ground and below-ground), including N-fixing crops, returned to soils annually. It is estimated from crop yield statistics and default factors for above-/belowground residue: yield ratios and residue N contents. In addition, the method accounts for the effect of residue burning or other removal of residues. Again country-specific data on fraction of crop residues removed is needed else no removal is assumed. If country-specific data are available it is possible to estimate the total N in crop residues which consist of the part of N in residues which is **left on** the field ($N_{res\_left\_kg}$) and the part of N in residues which is **harvested from** the field ($N_{res\_harvest\_kg}$)[33]. IPCC 2006 Guidelines (Volume 4, Chapter 11.2.1) is based on annual activity data. See for more details on the IPCC Guidelines on crop residue input Annex 5.

It is advised to coordinate country specific data on crop residues removals and burning with data reported to UNFCCC, see also section 3.15.5 UNECE. Whereas data are reported to UNFCCC (following IPCC 1996 Guidelines) are based on three-year averages countries are recommended to provide annual data in the Nutrient Budgets if available.

3.15.6. Default estimation procedure

Countries which do not have data available on crop residues removed from the field can as an approximation estimate the nitrogen amount of crop residues harvested from the field with the procedure coherent with IPCC Guidelines described in Annex 5 and recovery rates mentioned in the guidelines of the EW-MFA. For phosphorus Eurostat will apply the same procedure to estimate the amount of above ground residues harvested and multiply this with available data on coefficients from comparable countries. For countries which have no data available on burning of crop residues on the field, no burning will be assumed

[33] $N_{res\_left} = F_{CR}$ and $N_{res\_harvest} = F_{CR-REMOVED}$ in IPCC Guidelines.

3.15.7. Actions foreseen

The different flows of crop residues need to be more clearly distinguished in the budget in the future. A first step in this direction is the inclusion of a separate sheet on crop residues in the excel worksheets. The project on the estimation of excretion mentioned in section 3.6.5 aims at a harmonised methodology to estimate excretion; this may include guidelines on how to deal with for instance bedding material. Bedding material could perhaps in the future be included as a separate flow in the sheet on crop residues. Reporting of compost is currently done as a voluntary requirement under the flow "other organic fertilizers", it may however in the future be considered whether this flow would be better suited in a separate excel sheet on crop residues.

The grants on crop nutrient contents mentioned in section 3.13.7 may also provide some information on the estimation of crop residues or nutrient contents of crop residues.

Other actions are currently not foreseen.

3.16. Emissions

3.16.1. Definitions

Nitrogen emissions can be differentiated with regards to their gaseous forms:

- **Inert nitrogen (N_2).** N_2 is the most abundant element in the earth's atmosphere but, in this form, is almost wholly unusable by the vast majority of living organisms. N in this form does not pose a risk to the environment.
- **Reactive nitrogen**: all other forms of N such as NH_3, NO[34] etc. which are biologically functional and can pose a risk to the environment.

3.16.2. Description in Ideal and Practical implementation of GNB

Ideal and Practical: NH_3, NO, N_2O from

- animal housing,
- manure storage,
- manure application,
- manure dropped on pastures,
- application of mineral fertilizers,
- application of other organic fertilizers,
- crop residues, and
- field burning of agricultural wastes[35].

3.16.3. Guidelines on practical implementation

The following emissions are included in the practical implementation of the GNB: Note that the data can be obtained from the reporting to UNFCCC and UNECE-CLTRAP. Emissions expressed in NO can be transformed to N content by multiplying with 14/30, N_2O by multiplying with 28/44, or NH_3

[34] In this subchapter NO is used to refer to NO, NO_2, NO_x emissions

[35] This can include emissions due to co-burning of other wastes with agricultural residues.

by multiplying with 14/17. Currently the 1996 Guidelines are applicable. As soon as the 2006 Guidelines are applicable this section will be revised to follow the 2006 Guidelines.

- **NH_3 and N_2O emissions from animal housing.**

Data on NH_3 are required for CLTRAP. Emission factors are calculated by animal type following the EMEP/EEA emission guidebook 2009. Data are reported under NFR code 4B. Data on N_2O are required for UNFCCC GHG Inventories. Emission factors are calculated by animal type following the IPCCC 1996 Guidelines. Data are reported in Table 4B (b) in the CRF reports.

There are currently no guidelines established for NO emissions from animal housing; NO emissions from animal housing are therefore not considered.

- **NH_3, NO, N_2O emissions from manure storage.**

Data on NH_3 and NO are required for UNECE CLTRAP. Emission factors are calculated by animal type following the EMEP/EEA emission Guidebook 2009. The Guidebook also describes the estimation of N_2O and N_2 emissions from storage which is required to be able to estimate NH_3 emissions from manure application. Though data on N_2O are not reported to UNECE, they should be available in countries, see for further information Chapter 4B in the Guidebook and Annex 4B[36] . Description of countries methodologies and data sources used can be found in the countries IIR reports. Data on NH_3 and NO are reported under NFR code 4B[37].

Data on N_2O are required for UNFCCC GHG Inventories. Emission factors are calculated by animal type following the IPCCC 1996 Guidelines. Description of countries methodologies and data sources used can be found in the countries NIR reports. Data are reported in table 4B (b) in the CRF reports[38].

- **NH_3, NO, N_2O emissions from manure application.**

Data on NH_3 and NO are required for CLTRAP. Emission factors are calculated by animal type following the EMEP/EEA emission guidebook 2009. Data are reported under NFR code 4B.

Data on N_2O are required for UNFCCC GHG Inventories. Data are reported in table 4Ds1 under direct soil emissions. The IPCC 1996 method for calculating direct N_2O emissions from soils is based on the assumption that 1.25% of all N inputs to agricultural soils are emitted in the form of N_2O (expressed as N). In this method, N inputs are corrected for gaseous losses through volatilization of NH_3 and NO_x.

- **NH_3, NO, N_2O emissions from manure dropped on pastures.**

Data on NH_3 and NO are required for the CLTRAP. Emission factors are calculated by animal type following the EMEP/EEA emission guidebook 2009. Data should in principal be reported under NFR code 4D2c; however data are often reported under NFR code 4B.

Data on N_2O are required for UNFCCC GHG Inventories. Emission factors are calculated by animal type following the IPCCC 1996 Guidelines. Data are reported in Table 4Ds1 under pasture, range and paddock manure.

- **NH_3, NO and N_2O emissions from soils due to the application of mineral fertilizers.**

Data on NH_3 and NO are required for CLTRAP. Emission factors are calculated by fertilised area and fertilizer type following the EMEP/EEA Guidebook 2009. Data are reported under NFR code 4D1.

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36 Available at http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/

37 IIR and NFR reports can be found at: http://www.ceip.at/overview-of-submissions-under-clrtap/

38 NIR and CRF reports can be found at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php

Data on N_2O are required for UNFCCC GHG Inventories. IPCC 1996 method for calculating direct N_2O emissions from soils is based on the assumption that 1.25% of all N inputs to agricultural soils are emitted in the form of N_2O (expressed as N). Data are reported in Table 4Ds1 under direct soil emissions.

- **NH_3, NO and N_2O emissions from soils due to the application of other fertilizers (e.g. sewage sludge).**

EMEP/EEA Guidebook 2009 does refer to estimation of NH_3 and NO emissions due to the application of other fertilizers. However this is not a key source and default values are not established. Some countries do report data in the NFR reports under NFR Codes 4D2a or 4G.

The Revised IPCC 1996 Guidelines refer to the estimation of N_2O emissions from the application of other fertilizers (sewage sludge, Chapter 4.5.2), but do not require the estimation as data are considered insufficient available or the emissions are considered insignificant. Some countries include sewage sludge in the IPCC 1996 method for calculating direct N_2O emissions from soils based on the assumption that 1.25% of all N inputs to agricultural soils are emitted in the form of N_2O (expressed as N). Some countries report data in Table 4Ds1 under direct soil emissions or other emissions.

- **NO and N_2O emissions from crop residues.**

EMEP/EEA Guidebook 2009 does refer to estimation of NO emissions from crop residues. However this is not a key source and default values are not established. Some countries do report data in the NFR reports under NFR Codes 4D2a or 4G.

Data on N_2O are required for UNFCCC GHG Inventories. IPCC 1996 method for calculating direct N_2O emissions from soils is based on the assumption that 1.25% of all N inputs to agricultural soils are emitted in the form of N_2O (expressed as N). Data are reported in Table 4Ds1 under direct soil emissions.

- **NH3, NO and N_2O emissions from field burning of agricultural wastes.**

Data are required for the CLTRAP. Emission factors are calculated following the EMEP/EEA Guidebook 2009. Description of countries methodologies and data sources used can be found in the countries IIR reports, data are reported in the NFR reports under NFR Codes 4F.

Data on N_2O are required for UNFCCC GHG Inventories. Emission factors are calculated following the IPCC 1996 Guidelines. Data are reported in Table 4F in the CRF reports.

3.16.4. Discussion

The Handbook follows the IPCC Guidelines and EMEP/EEA Guidebook which are applicable at the time. Any revision of the IPCC Guidelines or the EMEP/EEA Guidebook will also apply to the guidelines mentioned here.

3.16.5. Coherence with UNFCCC/UNECE

For this flow of the nutrient budgets data should be provided which are coherent with data reported to UNFCCC/UNECE. Please note that coherence does not necessarily mean exactly the same data. Emissions estimated and reported to UNFCCC may overestimate the emissions occurring by the agricultural sector. For instance under the IPCC guidelines the GHG emissions from the application of mineral fertilizer use are based on activity data which should refer to the total mineral fertilizer consumption (not only agriculture), see section 3.5.5. should include non-agricultural use whereas data reported in the nutrient budgets should in principle only relate to agriculture. There should however be coherence between estimates of total fertilizer use and fertilizer use by agriculture. Countries are expected to provide information on the coherence of data reported in nutrient budgets and fertilizer statistics and data reported to UNFCCC in the metadata.

3.16.6. *Default estimation procedure*

If data on N emissions are not available Eurostat will use data on N emissions as reported to UNFCCC in the CRF reports and to UNECE/CLTRAP in the NFR reports.

3.16.7. *Actions foreseen*

No actions foreseen.

4. References

OECD/Eurostat Gross Nitrogen Balances Handbook (2007)

OECD/Eurostat Gross Phosphorus Balances Handbook (2007).

DireDate, reports available at cicabc and http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/publications.

COM(2006)508final. Communication from the Commission to the Council and the European Parliament, 2006. "Development of agri-environmental indicators for monitoring the integration of environmental concerns into the common agricultural policy".

Chapter 1

AgSource Harris, 2012. "Soil Phosphorus Reactions" Cooperative Resources International.

Bomans E., Fransen K., Gobin A., Mertens J., Michiels P.,Vandendriessche H., Vogels N. 2005. "Addressing phosphorus related problems in farm practice ". Final report to the European Commission. Soil Service of Belgium.

Busman, L. et al, 2002. "The nature of Phosphorus in soils". University of Minnesota.

Espinoza, L, 1914. "The Nitrogen and Phosphorus Cycle in Soils". Volume 2148 van FSA (University of Arkansas (System). Cooperative Extension Service)) Agriculture and natural resources.

Haes de. U. H. A et al, 2009. "Phosphate – from surplus to shortage. Policy memorandum of the Steering Committee for Technology Assessment of the Ministry of Agriculture", Nature and Food Quality, Utrecht.

Harrison, J.A. Ph.D, 2003. "The Nitrogen Cycle: Of Microbes and Men" Vision learning Vol. EAS-2 (4), 2003.

Hyland, C, 2005. "Phosphorus Basics – The Phosphorus Cycle". Fact Sheet 12 Agronomy Fact Sheet Series. Cornell University Cooperative Extension.

Morgan, M.A., 1997. " The behaviour of soil and fertilizer phosphorus ". In: Tunney, H., Carton, O., Brookes, P. and Johnston, A. (eds.) Phosphorus loss from soil to water. CAB International, Oxon, UK

Pidwirny, M, 2006. "The Nitrogen Cycle". Fundamentals of Physical Geography, 2nd Edition.

Ruttenberg, K.C, 2003. "The Global Phosphorus Cycle". University of Hawaii at Manoa, Honolulu, HI, USA.

Smit, A.L. et al, 2009. "Phosphorus in agriculture: global resources, trends and developments: report to the Steering Committee Technology Assessment of the Ministry of Agriculture, Nature and Food Quality", The Netherlands, PRI Wageningen.

Tiessen H. ed., 1995. "Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management", Wiley, U.K. 480 pp.

UNEP and WHRC, 2007. "Reactive Nitrogen in the Environment: Too Much or Too Little of a Good Thing". United Nations Environment Programme, Paris.

Chapter 2

Bach, M., Frede, H.-G., 2005. "Assessment of Agricultural Nitrogen Balances for Municipalities e Example Baden-Wuerttemberg (Germany)". European Water Association (EWA).

Bouwman, A.F., Beusen, A.H.W., Billen, G., 2009. Human alteration of the global nitrogen and phosphorus soil balances for the period 1970e2050. Global Biogeochemical Cycles 23, GB0A04

DireDate task 3 report, "Analysis of methodologies for calculating greenhouse gas and ammonia emissions and nutrient balances".

Leip, A., et al., "Farm, land, and soil nitrogen budgets for agriculture in Europe calculated with CAPRI", Environmental Pollution (2011).

Nevens, F., Verbruggen, I., Reheul, D., Hofman, G., 2006. "Farm gate nitrogen surpluses and nitrogen use efficiency of specialized dairy farms in Flanders: evolution and future goals". Agricultural Systems 88, 142e155.

Oenema, O., Kros, H., de Vries, W., 2003. "Approaches and uncertainties in nutrient balances: implications for nutrient management and environmental policies". European Journal of Agronomy 20, 3e16.

Özbek, F.S. et al, 2013. "Estimation of National and Regional Nitrogen Budgets for Agriculture in Turkey". In preparation.

Schröder, J.J., Scholefield, D., Cabral, F., Hofman, G., 2004. "The effects of nutrient losses from agriculture on ground and surface water quality: the position of science in developing indicators for regulation". Environmental Science & Policy 7, 15e23.

Chapter 3

Aarts, H.F.M, C.H.G. Daatselaar & G. Holshof, 2008. "Bemesting, meststofbenutting en opbrengst van productiegrasland en snijmaïs op melkveebedrijven". Rapport 208, Plant Research International.

Barth, J., Amlinger, F., Favoino, E., Siebert, S., Kehres4, Gottschall, R., Bieker, M., Löbig, A., Bidlingmaier, W., 2008. "Compost production and use in the EU". Final Report. Annexes. 2007/S 013-014117. On behalf of European Commission, DG Joint Research Centre/ITPS. Seville.

Beriner, J. E. and P. R. Hirsch. 1984. Genetic Engineering and Nitrogen Fixation. Biotechnology and Genetic Engineering Reviews Volume 1, February 1984.

BMVEL. (2001): Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepublik Deutschland. Landwirtschaftsverlag, Münster-Hiltrup.

Boddey R.M., de Oliveira O., Urquiaga S., Reis V., Olivares F., Baldani V. and Dobereiner J. 1995. Biological nitrogen fixation associated with sugarcane and rice: contributions and prospects for improvement. Plant and Soil 174, 195–209

Buchgraber, K., A. Deutsch, and G. Gindl, 1994. Zeitgemässe Grünland-Bewirtschaftung. Stocker Verlag, Graz, Stuttgart.

Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture

DireDate task 4 & 5 report, "Agri-environmental indicators: recommendations for priority data collection and data combination".

DG Environment, 2011. "Manure Processing Activities in Europe". - Project reference: ENV.B.1/ETU/2010/0007. Inventory of manure processing activities in Europe.

EMEP/EEA Guidebook 2009

European Commission, 2003. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs.

Eurostat, 1997 Manual on the Economic Accounts for Agriculture and Forestry 1997 (Rev 1.1)

Eurostat, 2008. NACE Rev. 2 - Statistical classification of economic activities

Eurostat, 2012. Economy-wide Material Flow Accounts (EW-MFA) Compilation Guide 2012.

Firth P., Thitipoca H., Suthipradit S., Wetselaar R. and Beech D.F. 1973. "Nitrogen balance studies in the central plain of Thailand". Soil Biology and Biochemistry 5, 41–46.

Giller K.E. and Merckx R. 2003. "Exploring the boundaries of N2 fixation in cereals and grasses: a hypothetical framework". Symbiosis 35, 3–17.

Herridge, D. F., Peoples, M. B., & Boddey, R. M. 2008 "Global inputs of biological nitrogen fixation in agricultural systems". Plant Soil 311, 1-18 (2008).

Hohenecker, J. 1981. "Entwicklungstendenzen bei der Futterversorgung Österreichs, dargestellt am Beispiel ausgewählter Jahre. Die Bodenkultur". Austrian Journal of Agricultural Research 32, 163-187.

IPCC 1996 Revised Guidelines

IPCC 2006 Guidelines

IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories

IPTS, 2011. "Technical report for End-of-waste criteria on Biodegradable waste subject to biological treatment".

Milieu Ltd, WRc and RPA, 2008. "Environmental, economic and social impacts of the use of sewage sludge on land". Final Report. Part I: Overview Report. Part II: Report on Options and Impacts. Part III: Project Interim Reports. Study Contract DG ENV.G.4/ETU/2008/0076r. On behalf of the European Commission, DG Environment.

Peoples M.B., Ladha J.K. and Herridge D.F. 1995. "Enhancing legume N2 fixation through plant and soil management". Plant and Soil 174, 83–101.

RAMIRAN, 2011. "Glossary of terms on livestock manure management 2011", Second edition, Compiled and edited by: Brian Pain and Harald Menzi.

Regulation (EC) no 1165/2008 of the European Parliament and of the Council of 19 November 2008 concerning livestock and meat statistics

Regulation (EC) No 2003/2003 of the European Parliament and of the Council of 13 October 2003 relating to fertilizers

Regulation (EC) No 543/2009 of the European Parliament and of the Council of 18 June 2009 concerning crop statistics

Paul, E.E., and F.E. Clark. 1996. "Soil microbiology and biochemistry". 2nd ed. Academic Press, San Diego, CA.

Roper, M.M, Ladha, J. K., 1995. "Biological N2 fixation by heterotrophic and phototrophic bacteria in association with straw". Plant and Soil. July 1995, Volume 174, Issue 1-2, pp. 211-224.

Unkovich, M. D. Herridge, M. Peoples, et al. 2008. "Measuring plant-associated nitrogen fixation in agricultural systems". Australian Centre for International Agricultural Research.

Velthof GL, D Oudendag, HP Witzke, WAH Asman, Z Klimont and O Oenema, 2009. "Integrated Assessment of Nitrogen Losses from Agriculture in EU-27 using MITERRA-EUROPE". Journal of Environmental Quality 38: 402-417.

Vitousek P.M, Cassman K, Cleveland C, Crews T, Field CB, Grimm NB, Howarth RW, Marino R, Martinelli L, Rastetter EB, Sprent JI. 2002. "Towards an ecological understanding of biological nitrogen fixation". Biogeochemistry 57–58:1–45.

Wheeler, R.O., G.L. Cramer, K.B. Young, and E. Ospina, 1981. "The World Livestock Product, Feedstuff, and Food Grain System: An Analysis and Evaluation of System Interactions Throughout the World, With Projections to 1985". Winrock International, Morrilton.

Wirsenius, S., 2000. " Human Use of Land and Organic Materials. Modelling the Turnover of Biomass in the Global Food System ". Doktorsavhandlingar vid Chalmers Tekniska Högskola 1574, 1-255.

Annexes

Anon, 1997. "Danish feeding standards". Danish Agricultural Advisory Centre, Aarhus, Denmark.

Davies, M.G., Smith, K.A. and Vinten, A.J.A., 2001. "The mineralisation and fate of N following ploughing of grass and grass-clover swards". Biology and Fertility of Soils, 33, 423-434.

EMEP/EEA Guidebook 2009

FAO, 1990. "Fertilizer Yearbook". Volume 43. FAO statistics series No. 94. FAO, Rome

Hall, S.J., Matson, P.A., Roth, P.M. 1996. "NOx Emissions From Soil: Implications for Air Quality Modelling in Agricultural Regions", Annual Review of Energy and the Environment, Vol. 21, pp. 311–346.

IPCC 1996 Revised Guidelines

IPCC 2006 Guidelines

IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories

van der Weerden, T.J., Sherlock, R.R., Williams, P.H. and Cameron, K.C, 1999. "Nitrous oxide emissions and methane oxidation by soil following cultivation of two different leguminous pastures". Biology and Fertility of Soils, 30, 52-60.

ANNEX 1 LIVESTOCK POPULATION IN IPCC AND EMEP/EEA GUIDELINES

Revised 1996 Guidelines (Volume 3, Chapter 4.2.3-5)

Tier 1

Livestock categorisation

The *average annual population* of livestock is required for each of the livestock categories listed in Table 11.

The dairy cattle population is estimated separately from other cattle. Dairy cattle are defined in this method as mature cows that are producing milk in commercial quantities for human consumption. This definition corresponds to the dairy cow population reported in the FAO Production Yearbook. In some countries the dairy cattle population is comprised of two well-defined segments:

(1) high-producing "improved" breeds in commercial operations;
(2) and low-producing cows managed with traditional methods.

These two segments can be combined, or can be evaluated separately by defining two dairy cattle categories. However, the dairy cattle category does not include cows kept principally to produce calves or to provide draft power. Low productivity multi-purpose cows should be considered as non-dairy cattle.

Table 11. Table 4-1 revised 1996 IPCC Guidelines

TABLE 4-1
DOMESTIC LIVESTOCK INCLUDED IN THE METHODS

Livestock	Recommended Emissions Inventory Methods	
	Enteric Fermentation	Manure Management
Dairy Cattle	Tier 2[a]	Tier 2[a]
Non-dairy Cattle	Tier 2[a]	Tier 2[a]
Buffalo	Tier 1	Tier 2[a]
Sheep	Tier 1	Tier 1
Goats	Tier 1	Tier 1
Camels	Tier 1	Tier 1
Horses	Tier 1	Tier 1
Mules and Asses	Tier 1	Tier 1
Swine	Tier 1	Tier 2[a]
Poultry	(Not Estimated)	Tier 1

[a] The Tier 2 approach is recommended for countries with large livestock populations. Implementing the Tier 2 approach for additional livestock subgroups may be desirable when the subgroup emissions are a large portion of total methane emissions for the country.

Average Annual Population

In some cases the population fluctuates during the year. For example, a census done before calving will give a much smaller number than a census done after calving. A representative average of the population is therefore needed. In the case of poultry and swine, the number of animals *produced* each year exceeds the annual average population (AAP) because the animals live for less than 12 months. The population data can be obtained from the FAO Production Yearbook or similar country-specific livestock census reports.

Tier 2

Livestock categorisation

To develop precise estimates of emissions, cattle should be divided into categories of relatively homogeneous groups. For each category a representative animal is chosen and characterised for the purpose of estimating an emission factor. Table 12 presents a set of recommended representative cattle types. Three main categories, Mature Dairy Cattle, Mature Non-dairy Cattle, and Young Cattle, are recommended as the minimum set of representative types. The subcategories listed should be used when data are available. In particular, the sub-population of cows providing milk to calves should be identified among non-dairy cattle because the feed intake necessary to support milk production can be substantial. In some countries the feedlot category is needed so that the implications of the high-grain diets can be incorporated.

Table 12. Table 4-7 revised 1996 IPCC Guidelines

TABLE 4-7
RECOMMENDED REPRESENTATIVE CATTLE TYPES

Main Categories	Subcategories
Mature Dairy Cattle	Dairy Cows used principally for commercial milk production
Mature Non-dairy Cattle	Mature Females: •Beef Cows: used principally for producing beef steers and heifers •Multiple-Use Cows: used for milk production, draft power, and other uses Mature Males: •Breeding Bulls: used principally for breeding purposes •Draft Bullocks: used principally for draft power
Young Cattle	Pre-Weaned Calves Growing Heifers, Steers/Bullocks and Bulls Feedlot-Fed Steers and Heifers on High-Grain Diets

IPCC 2006 guidelines (Vol. 4, Ch. 10.2)

Tier 1

Livestock categorisation

A complete list of all livestock populations that have default emission factor values must be developed (see Table 13) if these categories are relevant to the country. More detailed categories should be used if the data are available. E.g. more accurate emission estimates can be made if poultry populations are further subdivided (e.g., layers, broilers, turkeys, ducks, and other poultry), as the waste characteristics among these different populations varies significantly.

Table 13. Table 10.1 IPCC 2006 Guidelines

TABLE 10.1 REPRESENTATIVE LIVESTOCK CATEGORIES[1,2]	
Main categories	**Subcategories**
Mature Dairy Cow or Mature Dairy Buffalo	• High-producing cows that have calved at least once and are used principally for milk production • Low-producing cows that have calved at least once and are used principally for milk production
Other Mature Cattle or Mature Non-dairy Buffalo	Females: • Cows used to produce offspring for meat • Cows used for more than one production purpose: milk, meat, draft Males: • Bulls used principally for breeding purposes • Bullocks used principally for draft power
Growing Cattle or Growing Buffalo	• Calves pre-weaning • Replacement dairy heifers • Growing / fattening cattle or buffalo post-weaning • Feedlot-fed cattle on diets containing > 90 % concentrates
Mature Ewes	• Breeding ewes for production of offspring and wool production • Milking ewes where commercial milk production is the primary purpose
Other Mature Sheep (>1 year)	• No further sub-categorisation recommended
Growing Lambs	• Intact males • Castrates • Females
Mature Swine	• Sows in gestation • Sows which have farrowed and are nursing young • Boars that are used for breeding purposes
Growing Swine	• Nursery • Finishing • Gilts that will be used for breeding purposes • Growing boars that will be used for breeding purposes
Chickens	• Broiler chickens grown for producing meat • Layer chickens for producing eggs, where manure is managed in dry systems (e.g., high-rise houses) • Layer chickens for producing eggs, where manure is managed in wet systems (e.g., lagoons) • Chickens under free-range conditions for egg or meat production
Turkeys	• Breeding turkeys in confinement systems • Turkeys grown for producing meat in confinement systems • Turkeys under free-range conditions for meat production
Ducks	• Breeding ducks • Ducks grown for producing meat
Others (for example)	• Camels • Mules and Asses • Llamas, Alpacas • Fur bearing animals • Rabbits • Horses • Deer • Ostrich • Geese
[1] Source IPCC Expert Group [2] Emissions should only be considered for livestock species used to produce food, fodder or raw materials used for industrial processes.	

Dairy cows and milk production: The dairy cow population is estimated separately from other cattle (see Table 13). The description in the IPCC 2006 Guidelines is the same as in the Revised 1996 Guidelines. Dairy buffalo may be categorized in a similar manner to dairy cows.

Average Annual Population (AAP)

If possible, inventory compilers should use population data from official national statistics or industry sources. FAO data can be used if national data are unavailable. Seasonal births or slaughters may cause the population size to expand or contract at different times of the year, which will require the population numbers to be adjusted accordingly. It is important to fully document the method used to estimate the annual population, including any adjustments to the original form of the population data as it was received from national statistical agencies or from other sources.

AAP are estimated in various ways, depending on the available data and the nature of the animal population. In the case of static animal populations (e.g., dairy cows, breeding swine, layers), estimating AAP may be as simple as obtaining data related to one-time animal inventory data. However, estimating annual average populations for a growing population (e.g., meat animals, such as broilers, turkeys, beef cattle, and market swine) requires more evaluation. Most animals in these growing populations are alive for only part of a complete year (t_{alive_i}).

Equation 42 estimates the AAP of livestock *i* with multiple production cycles by dividing the number of animals produced annually of livestock *i* ($NAPA_i$) with the number of growing cycles per year for livestock *i* ($n_{growing\_cycle\_i}$). Animals should be included in the populations regardless if they were slaughtered for human consumption or die of natural causes.

Equation 42. $$AAP_i\ (1000\ heads) = t_{alive_i}\ (days) \times\ (NAPA_i (1000\ heads) \div 365) = n_{growing_{cycle_i}} \times NAPA_i\ (1000\ heads)$$

Equation 43. $$n_{growing_{cycle_i}} = t_{alive_i}\ (days)\ \div\ 365$$

Tier 2

Livestock categorisation

The livestock characterisation requires detailed information on:

- Definitions for livestock subcategories;
- Livestock population by subcategory, with consideration for estimation of annual population as per Tier 1;
- Feed intake estimates for the typical animal in each subcategory.

The livestock population subcategories are defined to create relatively homogenous sub-groupings of animals. By dividing the population into these subcategories, country-specific variations in age structure and animal performance within the overall livestock population can be reflected. The Tier 2 characterisation methodology seeks to define animals, animal productivity, diet quality and management circumstances to support a more accurate estimate of feed intake for use in estimating methane production from enteric fermentation. The same feed intake estimates should be used to provide harmonised estimates of manure and nitrogen excretion rates to improve the accuracy and consistency of CH_4 and N_2O emissions from manure management.

It is good practice to classify livestock populations into subcategories for each species according to age, type of production, and sex. Representative livestock categories for doing this are shown in Table 13. Further subcategories are also possible:

- Cattle and buffalo populations should be classified into at least 3 main subcategories: mature dairy, other mature and growing cattle. Depending on the level of detail in the emissions estimation method, subcategories can be further classified based on animal or feed characteristics. E.g. fattening cattle could be further subdivided into t cattle that are fed a high-grain diet and housed in dry lot vs. cattle that are grown and finished solely on pasture.

- Subdivisions similar to those used for cattle and buffalo can be used to further segregate the sheep population in order to create subcategories with relatively homogenous characteristics. For example, growing lambs could be further segregated into lambs finished on pasture vs. lambs finished in a feedlot. The same approach applies to national goat herds.
- Subcategories of swine could be further segregated based on production conditions. For example, growing swine could be further subdivided into growing swine housed in intensive production facilities vs. swine that are grown under free-range conditions.
- Subcategories of poultry could be further segregated based on production conditions. E.g. poultry could be divided on the basis of production under confined or free-range conditions.

For large countries or for countries with distinct regional differences, it may be useful to designate regions and then define categories within those regions. Regional subdivisions may be used to represent differences in climate, feeding systems, diet, and manure management. However, this further segregation is only useful if correspondingly detailed data are available on feeding and manure management system usage by these livestock categories.

EMEP/EEA 2009 Guidebook (Vol. 4B, Ch. 3.2.3):

Tier 1

Livestock categorisation

Data are required on animal numbers for each of the categories listed in Table 14. An annual national agricultural census can supply these data. Otherwise, statistical information from Eurostat or the FAO of the United Nations Production Yearbook can be used.

Average Annual Population

The AAP, can be obtained by a number of methods. If the number of animals present on a particular day does not change over the year, a census of the animals present on a particular day will give the AAP_i. However, if the number of animals present varies over the year, e.g. because of seasonal production cycles, it may be more accurate to base the AAP_i on a census of the number of animal places, the average capacity for livestock type *i* in the animal housing that is usually occupied (n_{places_i}). If this is done, see Equation 44, allowance has to be made for the time that the animal place is empty the average duration during the year when the animal place for livestock type *i* is empty (in days) (t_{empty_i})

There can be a number of reasons why the animal place may be empty for part of the year, but the most common are that the production is seasonal or because the building is being cleaned in preparation for the next batch of animals. Where the duration of an animal life or the time that animals remain within a category is less than one year, it will be common to have more than one production cycle per year. In this situation, t_{empty_i} will be the product of the average number of production cycles or rounds for livestock type *i* ($n_{growing\_cycle\_i}$) per year and the duration per round of the period when the animal place for livestock type *i* is empty e.g. for cleaning ($t_{cleanse\_i}$) (Equation 45). A third method of estimating AAP_i is to use statistics recording the number of animals produced per year of livestock type *i* ($NAPA_i$) corrected to include the proportion of animals that die and are not sold (x_{ns_i}), see Equation 46.

Equation 44. $AAP_i\ (1000\ heads) = n_{places_i}\ (1000\ places) \times (1 - t_{empty_i}\ (days) \div 365)$

Equation 45. $t_{empty_i}\ (days) = n_{growing_{cycle_i}} \times \mathbf{t}_{\mathbf{cleanse_i}}\ (days)$

Equation 46. $AAP_i\ (1000\ heads) = NAPA_i\ (1000\ heads) \div \left(n_{growing_{cycle_i}} \times (1 - x_{ns_i})\right)$

Table 14. Table 3-1 EMEP/EEA 2009 Guidebook

Table 3-1 Default Tier 1 EF (EF_{NH3}) for calculation of NH_3 emissions from manure management. Figures are annually averaged emission kg AAP^{-1} a^{-1} NH_3, as defined in subsection 3.3.1 of the present chapter.

SNAP	Livestock	Manure type	EF_{NH3} (kg a^{-1}. AAP^{-1} NH_3)
100901	Dairy cows	slurry	39.3
100901	Dairy cows	solid	28.7
100902	Other cattle (including young cattle, beef cattle and suckling cows)	slurry	13.4
100902	Other cattle	solid	9.2
100903	Fattening pigs	slurry	6.7
100903	Fattening pigs	solid	6.5
100904	Sows	slurry	15.8
100904	Sows	solid	18.2
100904	Sows	outdoor	7.3
100905 +100911	Sheep (and goats)	solid	1.4
100906 +100912	Horses (and mules, asses)	solid	14.8
100907	Laying hens (laying hens and parents)	solid	0.48
100907	Laying hens (laying hens and parents)	slurry	0.48
100908	Broilers (broilers and parents)	litter	0.22
100909	Other poultry (ducks)	litter	0.68
100909	Other poultry (geese)	litter	0.35
100909	Other poultry (turkeys)	litter	0.95
100910	Fur animals		0.02
100913	Camels	solid	10.5
100914	Buffalo	solid	9.0

Sources: Default grazing periods for cattle were taken from Table 10A 4-8 of IPCC chapter 10: Emissions from Livestock and Manure Management, default N excretion data for Western Europe from Table 10.19, also given in Table 3-8, together with the housing period on which these EFs are based.

Annex 2 Biological Nitrogen Fixation in IPCC Guidelines

Data on biological N fixation is required by the revised IPCC 1996 Guidelines for UNFCCC GHG Inventories to estimate direct N_2O emissions from the fixation process. Countries may use default values or country-specific data. Currently the 1996 Guidelines are applicable, the UNFCCC is considering implementing the 2006 Guidelines in 2015. The IPCC 2006 Guidelines no longer require data on emissions due to biological N fixation due to lack of evidence of N_2O emissions arising from the fixation process. Biological fixation will be accounted differently (included in the crop residues).

Revised IPCC 1996 Guidelines

The 1996 Revised Guidelines (Volume 3 Chapter 4.5.2) describe a default estimation of nitrogen fixed by N-fixing crops in a country per year ($N_{fix\_legumes\_kg}$) (Tier 1a). Only soya bean and pulses are included ($C_{legumes\_kg}$ is the seed yield of pulses and soybeans in a country). Tier 1a is based on the assumption that the amount of N contained in the aboveground plant material (crop product plus residues) is a reasonable proxy for the total amount of N fixed by the crop. Tier 1a is described by Equation 47[39], it assumes that total crop biomass is about twice the mass of edible crop (FAO, 1990), and a certain nitrogen content of nitrogen fixing crop ($N_{legumes\_coefficient\_kg\_dry}$). The default value of $N_{legumes\_coefficient\_kg\_dry}$ is 0.03 kg N / kg d.m. A residue/crop ratio of 1 is assumed (i.e. the total aboveground plant biomass is 2 times the crop product). For specific crops, ratios can be obtained from Table 20 (See Annex 5). This crop production is defined in FAO crop data bases as pulses and soybeans. Countries can also apply country-specific data if available.

Equation 47. $$N_{fix_{legumes_{kg}}}\ (kg\ N) = 2 * C_{legumes_{kg}}\ (kg) \times N_{legumes_{coefficient_{kg_{dry}}}}\ (kg\ N / kg\ d.m.)$$

IPCC Good Practice Guidance

The *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Chapter 4.7.1.1) describe several ways to modify the approach suggested in the *IPCC Guidelines* to estimate more accurately the total mass of aboveground crop residue and product nitrogen (Tier 1b), this approach is shown in Equation 48 and Equation 49[40]:

- Equation 47 uses a default value of 2 to convert $C_{legumes\_kg}$ to total aboveground crop residue and product. This factor is too low for some pulses and soybeans, and may result in underestimating the total aboveground crop residue and product. The default value of '2' is replaced by the term "(1 + $x_{res\_above\_legumes\_i}$) * $x_{above\_dry\_i}$". Residue to crop product mass ratio for each crop type *i* ($x_{res\_above\_legumes\_i}$) are presented in Table 15. As the ratio of aboveground biomass to crop product mass varies among crop types, more accurate estimates can be developed if crop specific values are used.
- Dry matter fraction in the aboveground biomass of each crop type *i* ($x_{above\_dry\_i}$) also need to be incorporated into the equation so that adjustments are made for moisture contents. Note that it is assumed that the dry matter content of the residue and product are equal so only one dry matter variable is included in the equation. Countries may have dry matter contents specific to the product and the residue – these should be used if the additional effort is warranted by increased accuracy.

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[39] $N_{fix\_legumes\_kg} = F_{BN}$ and $C_{legumes\_kg} = Crop_{BF}$ and $N_{legumes\_coefficient\_kg\_dry} = Frac_{NCRBF}$ in IPCC Guidelines..

[40] $C_{res\_above\_legumes\_kg\_i} = Res_{BFi}$ and $x_{above\_dry\_i}$ is $Frac_{DMi}$ in IPCC Good Practice Guidance

- In addition, $C_{legumes\_kg}$ should be defined so that it is representative of the products of all N-fixing crops, not just the seed yield of pulses and soybeans. In particular, N-fixing forage crops such as alfalfa should be included in the calculations. $C_{legumes\_kg\_i}$ should be defined as the 'production of N-fixing crops.' In the case of N-fixing forage crops such as alfalfa, $x_{res\_above\_legumes\_i}$ will equal 0, and Equation 48 becomes Equation 50 (N fixed by N-fixing forage crops).

Equation 48. $$N_{fix_{legumes_{kg}}}\ (kg\ N) = \sum_i \left\{ C_{legumes_{kg_i}}(kg) \times \left(1 + x_{res_{above_{legumes_i}}}\right) \times x_{above_{dry_i}} \times N_{legumes_{coefficient_{kg_{dry_i}}}}\ (kg\ N / kg\ d.m.) \right\}$$

Equation 49. $$x_{res_{above_{legumes_i}}} = C_{res_{above_{legumes_{kg_i}}}}\ (kg) \div C_{legumes_{kg_i}}\ (kg)$$

Equation 50. $$N_{fix_{legumes_{kg}}}\ (kg\ N) = \sum_i \left\{ C_{legumes_{kg_i}}\ (kg) \times x_{above_{dry_i}} \times N_{legumes_{coefficient_{kg_{dry_i}}}}\ (kg\ N\ /\ kg\ d.m.) \right\}$$

Table 15. Table 4.16 IPCC Good Practice Guidance

TABLE 4.16

SELECTED CROP RESIDUE STATISTICS

Product	Residue/Crop Product Ratio	Dry Matter Fraction	Carbon Fraction	Nitrogen Fraction
Wheat	1.3	0.82-0.88	0.4853	0.0028
Barley	1.2	0.82-0.88	0.4567	0.0043
Maize	1.0	0.70-0.86	0.4709	0.0081
Oats	1.3	0.92		0.0070
Rye	1.6	0.90		0.0048
Rice	1.4	0.82-0.88	0.4144	0.0067
Millet	1.4	0.85-0.92		0.0070
Sorghum	1.4	0.91		0.0108
Peas	1.5	0.87		0.0142
Beans	2.1	0.82-0.89		
Soybeans	2.1	0.84-0.89		0.0230
Potatoes	0.4		0.4226	0.0110
Feedbeet	0.3		0.4072[a]	0.0228[a]
Sugarcane tops		0.32	0.4235	0.0040
Sugarcane leaves		0.83	0.4235	0.0040
Jerusalem artichoke	0.8			
Peanuts	1.0	0.86		0.0106

[a] These figures are for beet leaves.

Source: All data from Strehler and Stützle (1987), except sugarcane data (Turn *et al.*, 1997), dry matter and nitrogen fraction data for oats, rye, sorghum, peas, and peanuts (Cornell, 1994), and nitrogen fraction data for millet and soybeans (Barnard and Kristoferson, 1985).

Note that if inventory agencies use Equation 50 to estimate the amount of N fixed by N-fixing crops, and if any of the residues of these crops are burned in the field, they should use the same values for $C_{legumes\_kg}$, $x_{res\_above\_legumes\_i}$, and $x_{above\_dry\_i}$ that are used in estimating emissions from agricultural residue burning. The values used for $N_{legumes\_coefficient\_kg\_dry\_i}$, should also be consistent with N/C ratios used in estimating emissions from agricultural residue burning. *Good practice* default values for $x_{res\_above\_legumes\_i}$, $x_{above\_dry\_i}$, and $N_{legumes\_coefficient\_kg\_dry\_i}$, for some crop types, are presented in Table 15.

ANNEX 3 DEFAULT VALUES SEEDS

In 2010/2011 19 countries reported data on seed input. Most of these countries reported data on cereals, dried pulses, root crops and industrial crops, only a very few countries reported data on other crops such as vegetables, fruits and fodder crops. Table 16 and Table 17 show some results based on the collected data form the 19 countries for available data between 2000 and 2010. Cereals and potatoes accounted for more than 90% of total seed input in 15 of the 19 countries, and at minimum 65% of total seed input. Figure 1 shows boxplots for the average share of N seed input in N crop production for the countries which had data available. Figure 2 shows boxplots for the average rates of N seed input per ha. The average rate of N seed input per ha was estimated from reported data on total N seed input and data on annual areas of production[41] from crop production statistics. Figure 3 and Figure 4 show the same for P. The rates per ha do not vary much for most cereal crops. The difference between the first and the third quartile is around 1 kg N per ha or less than ¼ kg P per ha. For potatoes the difference is larger for Nitrogen between the first and third quartile (3.5 kg N per ha)

Table 16. Analysis data on N seed input 19 countries (2000-2010)

Crop	Obs	% in N seed input			% in N crop production		Kg N per ha harvested area	
		avg	min	max	avg	median	avg	median
Cereals	19	79%	37%	95%				
Wheat	19	39%	21%	56%	4.3%	4.6%	4.0	4.0
Barley	19	25%	3%	44%	4.7%	4.4%	3.0	3.2
Rye	18	3%	0%	11%	5.5%	5.0%	2.7	2.9
Oats	17	7%	0%	29%	5.6%	5.5%	3.0	2.9
Grain maize	12	5%	0%	17%	3.2%	0.6%	4.4	0.9
Triticale	11	4%	1%	13%	4.8%	3.8%	3.2	3.5
Dried pulses	11	3%	0%	8%	7.6%	7.8%	6.2	6.0
Root crops	19	14%	2%	42%				
Potatoes	18	14%	2%	42%	10.5%	9.4%	8.6	8.2
Industrial crops	17	2%	0%	5%				
Oilseed crops	17	1%	0%	5%	0.5%	0.5%	0.4	0.4

[41] As an approximation of the sown area.

Figure 1. **Average share of N seed input in N crop production 2000 - 2010 by crop type**

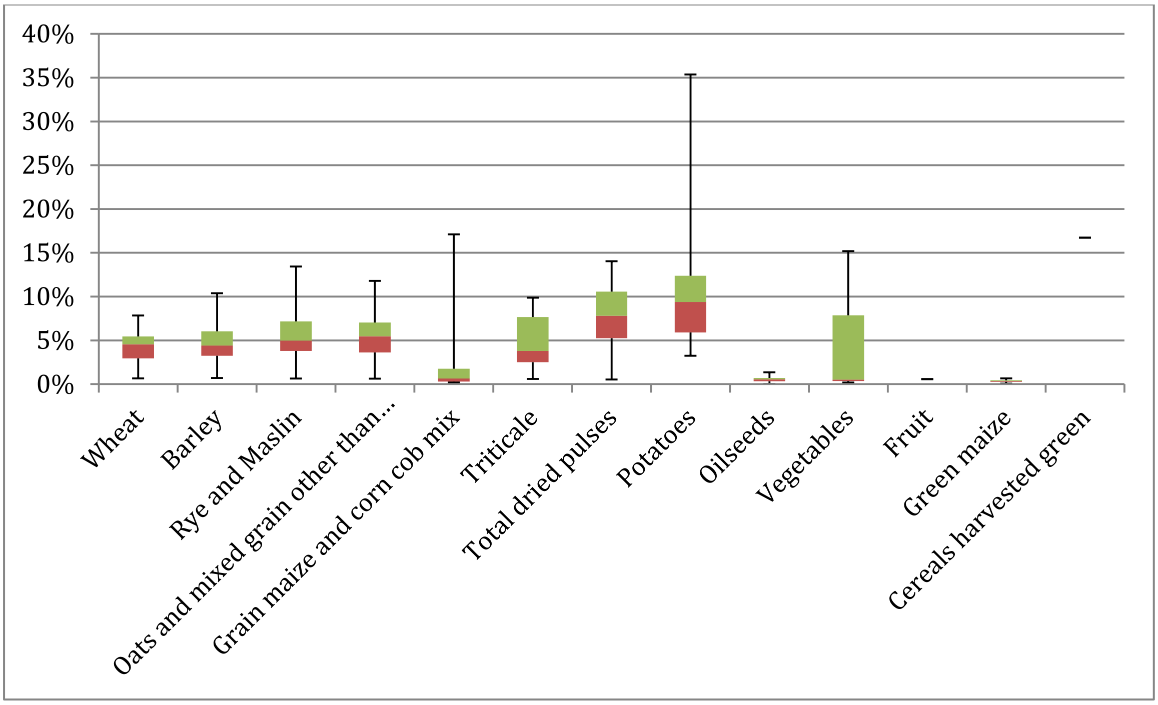


Figure 2. **Average rate of N seed input per ha between 2000 and 2010 by crop type**

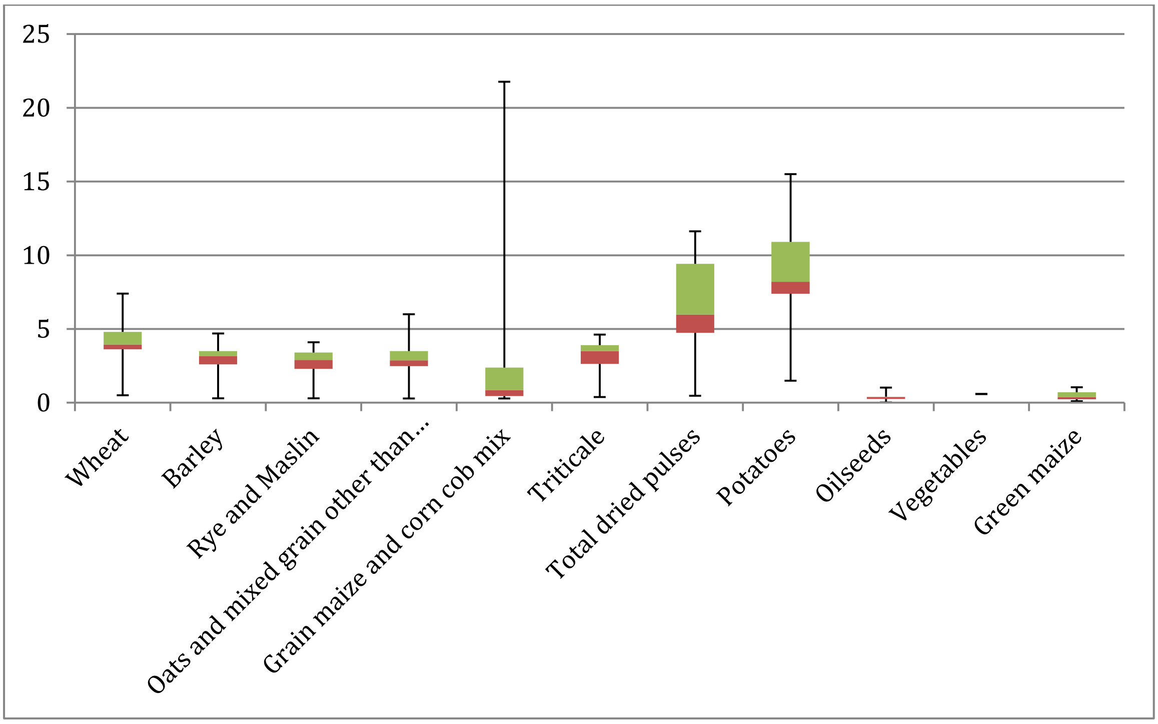


Table 17. Analysis data on P seed input 19 countries (2000-2010)

Crop	Obs	% in P seed input			% in P crop production		Kg P per ha harvested area	
		avg	min	max	avg	median	avg	median
Cereals	18	82%	54%	96%				
Wheat	18	38%	19%	56%	4.2%	4.1%	0.7	0.7
Barley	18	27%	7%	50%	4.4%	4.3%	0.6	0.6
Rye	17	3%	0%	12%	5.0%	4.6%	0.6	0.6
Oats	16	8%	1%	30%	5.2%	5.5%	0.6	0.6
Grain maize	11	5%	1%	18%	3.3%	0.9%	1.1	0.3
Triticale	9	4%	1%	13%	4.8%	4.9%	0.6	0.7
Dried pulses	10	2%	0%	6%	7.9%	9.5%	0.8	0.9
Root crops	17	11%	3%	35%				
Potatoes	16	11%	3%	35%	9.9%	8.3%	1.4	1.3
Industrial crops	14	1%	0%	3%				
Oilseed crops	15	1%	0%	3%	0.5%	0.4%	0.7	0.7

Figure 3. Average share of P seed input in P crop production 2000 - 2010 by crop type

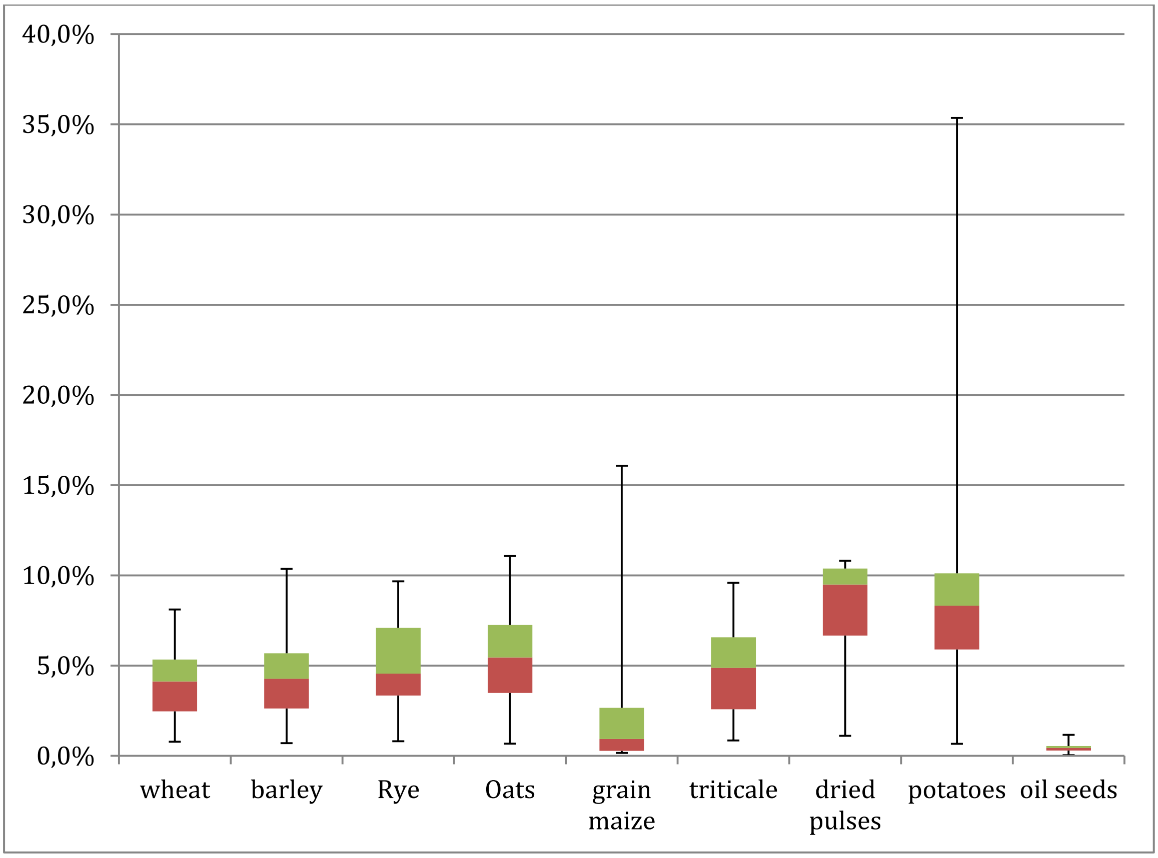
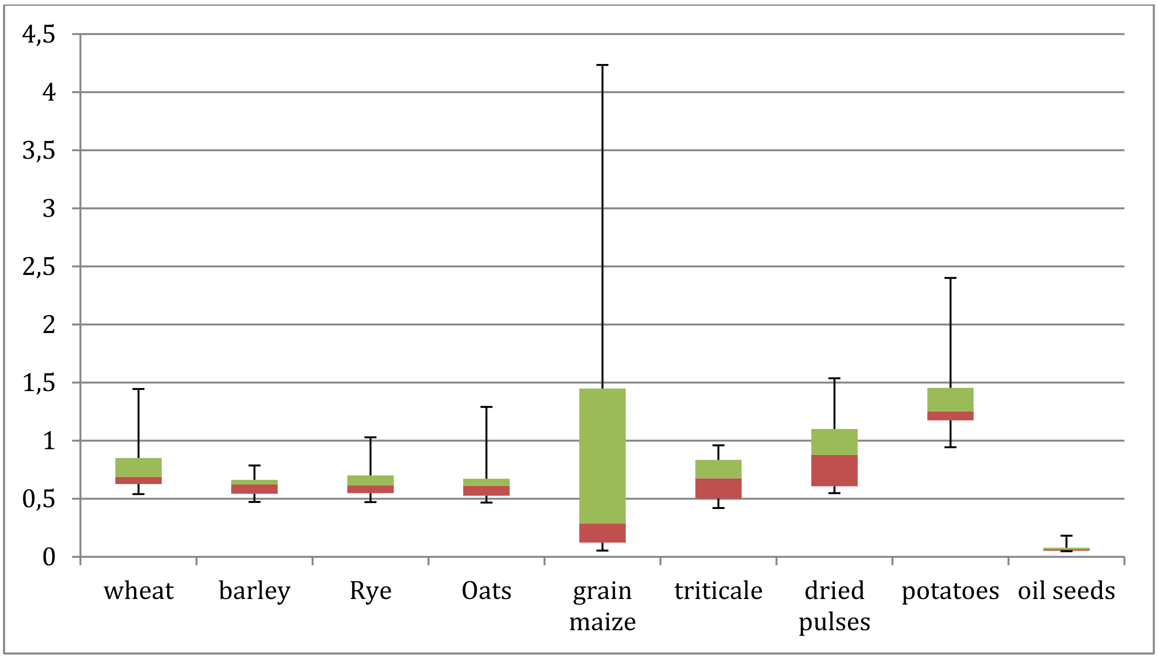


Figure 4. Average rate of P seed input per ha between 2000 and 2010 by crop type



ANNEX 4 ESTIMATION OF FODDER PRODUCTION IN EW-MFA

Supply-side approach:

<u>Fodder crops</u>:

If data for item A.1.2.2.1 *fodder crops (incl. biomass harvested from grassland)* are missing in crop statistics one should try to refer to internal estimates of Economic Accounts for Agriculture (EAA) where *fodder crops (including harvest from grassland)* have to be completely covered in monetary terms. The underlying physical data or models of EAA calculations could also be used for closing those gaps. As far as grass type fodder crops are concerned it has to be noted that data have to be reported in dry weight (15 % m.c.). If data from the original sources (like national agricultural statistics, data from Eurostat's reference database, or from other sources) are reported in wet weight they have to be converted accordingly.

<u>Grazed biomass</u>:

A significant amount of fodder is directly taken up by animals from pastures (*grazed biomass*). Grazed biomass is regarded as domestic extraction according to EW-MFA conventions. However, in Eurostat's crop production database data on uptake of biomass from pastures is reported only for a few countries. In some cases, information on grazing is available from national feed balances or from agricultural experts. These data can be used for EW-MFA. If necessary, quantities given in other units (e.g. dry weight or specific feed units) have to be converted into air dry weight (15% m.c.) with support of expert knowledge. For countries with no or with incomplete direct data on extraction of grazed biomass supply-side estimate via grazed area and information on area yield can possibly be applied. Often, statistical offices and Eurostat's reference database provide data on the extent of grazing land (often differentiated by quality or intensity) in their agricultural or land use statistics. Based on information on extent of pastures (A_{grass}) and typical area yields ($Y_{grass\_gross\_kg}$), biomass taken up by grazing, grazing potential (C_{grass_gross}), can be calculated, see Equation 51 . Country or region specific area yields of pastures and rangelands can be estimated based on different sources. Eurostat's reference database reports for some countries the actual uptake of grass per hectare. For countries with no direct data it could be considered to estimate the uptake of grazed biomass by utilizing information on area yields (kg per hectare) from other countries or a mix of other countries with similar natural conditions.

Equation 51. $$\boldsymbol{C_{grass_{gross}}\ (tonnes\ at\ 15\%\ m.c.) = A_{grass}\ (1\,000\ ha) \times Y_{gras_{gross_{kg}}}\ (kg\ at\ 15\%\ m.c.\ per\ ha)}$$

Those calculation results should be cross-checked as far as possible with expert knowledge and literature data. Table 18 provides information on typical grazing yields potential (in tonnes at 15% m.c. per ha) for different quality types of pastures in Central Europe (based on data for Austria).

Table 18. Typical area yield of permanent pastures

	Yield range [t at 15%mc / ha]	**Average yield** [t at 15%mc / ha]
Rough grazing, alpine pasture	<1	0.5
Extensive pasture	1-5	2.5
Improved pasture	5-10	7.0

Source: The values are derived from data for Austrian grassland systems given in Buchgraber et al, 1994 and can be assumed typical for Central Europe.

Demand-side approach:

The demand for roughage biomass ($C_{roughage\_demand}$) can be estimated by summing up the demands of ruminants and other grazing animals. The demand for roughage of livestock type *i* is estimated by multiplying the roughage requirements of livestock type (RR_i) with the number of livestock (AAP_{graz_i}), see Equation 52. Daily biomass intake by grazing depends on the live weight of the animal, animal productivity (e.g., weight gain, milk yield), and the feeding system (e.g., share of concentrate), and may vary considerably within one species. This method is based on European average values and allows a rough estimation of biomass uptake by grazing.

Equation 52. $$C_{roughage_{demand}}\,(\text{tonnes at }15\%\text{ m.c.}) = \sum_i \left\{ AAP_{graz_i}\,(\text{heads}) \times RR_i\,(\text{tonnes at }15\%\text{ m.c. per head per year}) \right\}$$

European average factors for roughage uptake by livestock species are provided in Table 19. The values are given in air dry weight (i.e. 15% m.c.) and take into consideration that the share of market feed in feed ratios ranges between 5 and 20% (d.m. basis, average across all species).

Table 19. Typical roughage intake by grazing animals in Europe

	Daily intake (range) [kg/head and day]	Annual intake (range)[t/head and year]	Annual intake (average)[t/head and year]
Cattle (and buffalo)	10-15	3.6-5.5	4.5
Sheep and goats	1-2	0.35-0.7	0.5
Horses	8-12	2.9-4.4	3.7
Mules and asses	5-7	1.8-2.6	2.2

Sources: The values are typical for industrialised livestock production systems and derived from national feed balances and literature (Wirsenius 2000; Hohenecker 1981; Wheeler et al. 1981; BMVEL 2001).

Roughage uptake may be covered from grass type fodder crops, hay or silage, or from grazing. To estimate biomass uptake by grazing (C_{grass_grazed}), total roughage uptake has to be reduced by the amount of available fodder crops ($C_{roughage\_foddercrops}$) and biomass harvest from grassland ($C_{grass\_harvested}$), see Equation 53.

Equation 53. $$C_{grass_{grazed}}\,(\text{tonnes at }15\%\text{ m.c.}) = C_{roughage_{demand}}\,(\text{tonnes at }15\%\text{ m.c.}) - C_{grass_{harvested}}\,(\text{tonnes at }15\%\text{ m.c.}) - C_{roughage_{foddercrops}}\,(\text{tonnes at tonnes at }15\%\text{ m.c.})$$

If results from the supply-side approach for grazed biomass are available they should be used for crosschecking the outcome of the demand-side approach. If the results do not match, the underlying assumptions should be reviewed, which may after expert consultation lead to an adaptation of the estimates. Reasons for differences may be an exceptionally high share of market feed and feed concentrate in feed ratios, overgrazing of pasture resources or significant grazing on areas other than those reported as pasture in land use statistics (woodlands, waste lands etc.).

ANNEX 5 CROP RESIDUES IN INTERNATIONAL GUIDELINES

IPCC Guidelines include estimation of N_2O emissions from decomposition of crop residues left or returned to the soil and from burning of crop residues on agricultural soils. To estimate these emissions activity data on amount of crop residues incorporated in the soil, removed and burned, as well as N contents of crop residues are needed. Revised IPCC 1996 Guidelines (Tier1a) (Volume 3, Chapter 4.4.3) estimate incorporation of crop residues by determining total amount of crop residue N produced and adjusting it for the fraction that is burned in the field when residues are burned during or after harvest. It does not include removal of crop residues for other purposes. However IPCC Good Practice Guidance (Tier1b) (Chapter 4.7.1.1) proposes to adjust the calculation by accounting removal of crop residues for fuel, construction material and fodder. This requires however country-specific data, if country-specific data are not available no removal is assumed. IPCC 2006 Guidelines (Volume 4 Chapter 11.2.1.3) describe the estimation of the amount of N in crop residues (above-ground and below-ground), incl. N-fixing crops, returned to soils annually. It is estimated from crop yield statistics and default factors for above-/belowground residue: yield ratios and residue N contents. In addition the method accounts for the effect of residue burning or other removal of residues. Again country-specific data on the fraction of crop residues removed is needed else no removal is assumed. If country-specific data are available it is possible to estimate total N in crop residues which consist of the part of N in residues which is left on the field ($N_{res\_left\_kg}$) and the part of N in residues which is harvested from the field ($N_{res\_harvest\_kg}$)[42].

EMEP/EEA 2009 Guidebook includes the estimation of NO_x and NH_3 emissions from burning of crop residues on agricultural soils. Activity data required are the amount of crop residues burned.

The EW-MFA Guidelines (2012) provide some guidelines on the estimation of the amount of crop residues removed from the field. The amount of above ground crop residues for a crop is estimated by multiplying data on the main production of the crop with a residue factor (ratio between total above ground residue and main crop product). The fraction of crop residues removed from the field is subsequently estimated by multiplying the total crop residues with the recovery rate. The main crops which provide crop residues are listed in Table 23.

Revised IPCC 1996 Guidelines

Tier 1a

Equation 54. $$N_{res_{left_{above_{kg}}}}\,(kg\,N) = N_{res_{above_{kg}}}\,(kg\,N) \times \left(\left(1 - x_{harvest}\,(kg\,N\,/\,kg\,crop - N)\right) \times \left(1 - x_{res_{above_{burn}}}\right)\right)$$

Equation 55. $$N_{res_{above_{kg}}}\,(kg\,N) = 2 \times \left(C_{crop_{kg_i}}\,(kg) \times N_{crop_{coefficient_{kg_{dry_i}}}}\,(kg\,N\,/kg\,d.m.) + C_{legumes_{kg_i}}\,(kg) \times N_{legumes_{coefficient_{kg_{dry_i}}}}\,(kg\,N\,/kg\,d.m.)\right)$$

In the Revised 1996 IPCC Guidelines (Volume 3 Chapter 4.5.2) (Tier 1a), the amount of nitrogen incorporated in the soil with crop residues ($N_{res\_left\_above\_kg}$) is estimated by determining the amount of nitrogen in total above ground biomass (N_{above_kg}) and then adjusting for the amount of total

42 $N_{res\_left\_above\_kg} = F_{CR}$ and $N_{res\_harvest\_kg} = F_{CR\text{-}REMOVED}$ in IPCC Guidelines.

aboveground crop biomass that is removed from the field as product ($x_{harvest}$)[43] and above ground residues burned ($x_{res\_above\_burn}$) (Equation 54)[44]. The amount of nitrogen in total above ground biomass (N_{above_kg}) is estimated by multiplying annual crop production of N-fixing crops ($C_{legumes\_kg\_i}$) and other crops ($C_{crop\_kg\_i}$)[45] by their respective N contents ($N_{crop\_coefficient\_kg\_dry\_i}$) and $N_{legumes\_coefficient\_kg\_dry\_i}$), summing these two nitrogen values, and multiplying by a default value of 2 (to convert edible crop production to total aboveground crop biomass) (Equation 55) [46].

IPCC default value for $x_{res\_above\_burn\_i}$ is 0.10 kg N / kg crop – N, for $x_{harvest\_i}$ 0.45 kg N / kg crop – N, $N_{legumes\_coefficient\_kg\_dry\_i}$ 0.03 kg N /kg d.m. and $N_{crop\_coefficient\_kg\_dry\_i}$ 0.015 kg N /kg d.m. The default values and Tier 1a result in out of total crop-N being produced during the season, a default of 45% in the harvested part, <=10% loss by agricultural waste burning, leaving 50-55% of N originally present in plat tissue.

Crop residues only apply to dead biomass, rest of biomass of annual crops which is left to decay with nitrogen mineralizing into ammonia and nitrate susceptible to take-up by next year's crop. The situation is different with living biomass in perennial crops or grassland, that biomass will remain biomass and is not considered residue (also as N in plant material will not be released).

Different practice in individual countries may affect the real factor quite a bit. If straw is not used in a specific country and left on fields, and if it is burnt in another country; or if grazing is the dominant form of land use - all of that does make a difference.

Tier 1b

The IPCC Good Practice Guidance (Chapter 4.7.1) presents several ways to modify Tier 1a to estimate more accurately the amount of crop residue nitrogen that is incorporated into soils:

- Equation 55 uses a default value of 2 to convert $C_{crop\_kg\_i}$ and $C_{legumes\_kg\_i}$ to total aboveground crop residue and product (N_{above_kg}). As previously mentioned with $N_{fix\_legumes\_kg}$ (see Annex 2), this factor is too low for some pulses and soybeans, and may result in underestimating the total aboveground crop residue and product. In addition, this factor of 2 is inconsistent with the default value for $x_{harvest}$ presented in the IPCC Guidelines[47]. Equation 57 estimates the total nitrogen content in aboveground residue biomass $N_{res\_above\_crop\_kg\_i}$ for crop type *i* by determining the total aboveground residue biomass from crop production with the residue to crop product mass ratio ($x_{res\_above\_crop\_i}$), the dry matter content of the aboveground biomass ($x_{above\_dry\_i}$) and the nitrogen content of aboveground dry matter biomass ($N_{crop\_coefficient\_kg\_dry\_i}$). In a similar way the total nitrogen content in aboveground residue biomass ($N_{res\_above\_legumes\_kg\_j}$) for leguminous crop type *j* is determined (Equation 58). The residue to crop product mass ratio $x_{res\_above\_crop\_i}$ can be estimated with Equation 49 and $x_{res\_above\_legumes\_j}$ with Equation 61.
- $C_{legumes\_kg}$ should be defined so that it is representative of the products of all N-fixing crops, not just seed yield of pulses and soybeans.

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[43] *IPCC Good Practice Guidance:* The *IPCC Guidelines* define $Frac_R$ as the 'fraction of crop residue that is removed from the field as crop.' However, this variable, as it is currently used, is instead the 'fraction of total *aboveground crop biomass* that is removed from the field as crop.'

[44] $x_{res\_above\_burn}$ = $Frac_{BURN}$ and $x_{harvest}$ = $Frac_R$ in IPCC Guidelines.

[45] These data are available from Crop Statistics (regulation (EC) No 543/2009)

[46] $C_{crop\_kg\_i}$ = $Crop_O$ and $C_{legumes\_kg\_i}$ = $Crop_{BF}$, $N_{crop\_coefficient\_kg\_dry\_i}$ = $Frac_{NCR0}$ and $N_{legumes\_coefficient\_kg\_dry\_i}$ = $Frac_{NCRBF}$ in IPCC Guidelines.

[47] *IPCC Good Practice Guidance*: The *IPCC Guidelines* present a default value for $Frac_R$ of 0.45 that is not consistent with the default value presented for aboveground crop residue and product. If $Frac_R$ = 0.45, then 55% of the residue plus crop product mass equals residue. However, if residue plus crop product mass equals 2 times the crop product, then 50% of the residue plus crop product mass equals residue.

- Dry matter fractions ($x_{above\_dry\_i}$ and $x_{above\_dry\_j}$) need to be incorporated into the equation so that adjustments are made for moisture contents.
- The equation should be modified to account for additional uses of above ground crop residues ($x_{res\_above\_harvest\_i}$ and $x_{res\_above\_harvest\_j}$): the fraction of residue used as fuel ($x_{res\_above\_fuel\_i}$ and $x_{res\_above\_fuel\_j}$), the fraction of residue used for construction ($x_{res\_above\_construct\_i}$ and $x_{res\_above\_construct\_j}$) and the fraction of residue used as fodder ($x_{res\_above\_\_fodder\_i}$ and $x_{res\_above\_fodder\_j}$) (Equation 59 and Equation 60).
- These modifications are shown in Equation 56 (Tier 1b)[48]:

Equation 56. $$N_{res_{left_{above_{kg}}}}\ (kg\ N) = \sum_i \left\{ N_{res_{above_{crop_{kg_i}}}}\ (kg\ N) \times \left(1 - x_{res_{above_{burn_i}}} - x_{res_{above_{harvest_i}}}\right)\right\} + \sum_j \left\{ N_{res_{above_{legumes_{kg_j}}}}\ (kg\ N) \times \left(1 - x_{res_{above_{burn_j}}} - x_{res_{above_{harvest_j}}}\right)\right\}$$

Equation 57. $$N_{res_{above_{crop_{kg}}}}\ (kg\ N) = \sum_i \left\{ C_{crop_{kg_i}}\ (kg) \times x_{res_{above_{crop_i}}} \times x_{above_{dry_i}} \times N_{crop_{coefficient_{kg_{dry_i}}}}\ (kg\ N\ /kg\ of\ d.m.)\right\}$$

Equation 58. $$N_{res_{above_{legumes_{kg}}}}(kg\ N) = \sum_j \left\{ C_{legumes_{kg_j}}\ (kg) \times x_{res_{above_{legumes_j}}} \times x_{above_{dry_j}} \times N_{legumes_{coefficient_{kg_{dry_j}}}}\ (kg\ N\ /\ kg\ d.m.)\right\}$$

Equation 59. $$x_{res_{above_{harvest_i}}} = x_{res_{above_{fuel_i}}} + x_{res_{above_{construct_i}}} + x_{res_{above_{fodder_i}}}$$

Equation 60. $$x_{res_{above_{harvest_j}}} = x_{res_{above_{fuel_j}}} + x_{res_{above_{construct_j}}} + x_{res_{above_{fodder_j}}}$$

Equation 61. $$x_{res_{above_{crop_i}}} = C_{res_{above_{kg_i}}}\ (kg) \div C_{crop_{kg_i}}\ (kg)$$

Good practice default values for $x_{res\_above\_crop\_i}$, $x_{above\_dry\_i}$, and $N_{crop\_coefficient\_kg\_dry\_i}$, for some crop types, are presented in Table 20. Inventory agencies may use these values if country-specific data are not available. If default residue nitrogen content is needed for a crop type for which a value is not provided in Table 20, the non-crop specific default values for N-fixing and Non-N-fixing crops can be used (0.03 and 0.015 kg N / kg dry matter, respectively).

[48] $C_{res\_above\_kg\_i} = Res_{Oi}$, $x_{res\_above\_fuel\_i} = Frac_{FUEL-Cri}$, $x_{res\_above\_construct\_i} = Frac_{CNST-Cri}$ and $x_{res\_above\_fodder\_i} = Frac_{FODi}$ in IPCC Guidelines

Table 20. Default values Table 4-16 IPCC Good Practice Guidance

TABLE 4.16 SELECTED CROP RESIDUE STATISTICS				
Product	Residue/Crop Product Ratio	Dry Matter Fraction	Carbon Fraction	Nitrogen Fraction
Wheat	1.3	0.82-0.88	0.4853	0.0028
Barley	1.2	0.82-0.88	0.4567	0.0043
Maize	1.0	0.70-0.86	0.4709	0.0081
Oats	1.3	0.92		0.0070
Rye	1.6	0.90		0.0048
Rice	1.4	0.82-0.88	0.4144	0.0067
Millet	1.4	0.85-0.92		0.0070
Sorghum	1.4	0.91		0.0108
Peas	1.5	0.87		0.0142
Beans	2.1	0.82-0.89		
Soybeans	2.1	0.84-0.89		0.0230
Potatoes	0.4		0.4226	0.0110
Feedbeet	0.3		0.4072[a]	0.0228[a]
Sugarcane tops		0.32	0.4235	0.0040
Sugarcane leaves		0.83	0.4235	0.0040
Jerusalem artichoke	0.8			
Peanuts	1.0	0.86		0.0106

[a] These figures are for beet leaves.

Source: All data from Strehler and Stützle (1987), except sugarcane data (Turn *et al.*, 1997), dry matter and nitrogen fraction data for oats, rye, sorghum, peas, and peanuts (Cornell, 1994), and nitrogen fraction data for millet and soybeans (Barnard and Kristoferson, 1985).

IPCC 2006 Guidelines

Tier 1

In the 2006 IPCC Guidelines (Volume 4, Chapter 11.2.1.3) Tier 1 approach the term $N_{res\_left\_kg}$ refers to the amount of N in crop residues above-ground ($N_{res\_above\_left\_kg}$) and below-ground ($N_{res\_below\_left\_kg}$) (Equation 62), including N-fixing crops, returned to soils annually[49]. It also includes the N from N-fixing and non-N-fixing forages mineralised during forage or pasture renewal[50].

Equation 62. $$N_{res_{left_{kg}}}\ (kg\ N) = N_{res_{above_{left_{kg}}}}\ (kg\ N) + N_{res_{below_{left_{kg}}}}\ (kg\ N)$$

[49] The equation to estimate F_{CR} has been modified from the previous *1996 IPCC Guidelines* to account for the contribution of the below-ground nitrogen to the total input of nitrogen from crop residues, which previously was ignored in the estimate of F_{CR}. As a result, F_{CR} now represents a more accurate estimate of the amount of nitrogen input from crop residue, which makes it possible to assess the contribution to residue nitrogen arising from the growth of forage legumes such as alfalfa, where the harvesting of virtually all the above-ground dry matter results in no significant residue except the root system

[50] The inclusion of nitrogen from forage or pasture renewal is a change from previous *1996 IPCC Guidelines*.

Equation 63. $N_{res_{above_{left_{kg}}}}\ (kg\ N)\ =$

$$\sum_i \left\{ Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha) \times \left(A_{crop_{ha_i}}\ (ha) - A_{burnt_{ha_i}}\ (ha) \times C_f\right) \times x_{renew_i} \times x_{res_{above_i}}\ (kg\ d.m./\ kg\ d.m.) \times N_{res_{above_{coefficient_{kg_{dry_i}}}}}\ (kg\ N\ /\ kg\ d.m.) \times \left(1 - x_{res_{above_{harvest_i}}}\ (kg\ N\ /\ kg\ cropN)\right) \right\}$$

Equation 64. $Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha) = Y_{crop_{kg_i}}\ (kg\ fresh\ weight\ /\ ha) \times x_{dry_i}\ (kg\ d.m./\ kg\ fresh\ weight)$

Equation 65. $x_{res_{above_i}}\ (kg\ d.m./\ kg\ d.m.) = Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m./\ ha) \times 1\,000 \div Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha)$

Equation 66. $Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m\ /\ ha) = \left(Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha) \div 1\,000\right) \times \alpha_i + \beta_i$

Equation 67. $N_{res_{below_{left_{kg}}}}\ (kg\ N) =$

$$\sum_i \left\{ Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha) \times \left(A_{crop_{ha_i}}\ (ha) - A_{burnt_{ha_i}}\ (ha) \times C_f\right) \times x_{renew_i} \times x_{res_{below_i}}\ (kg\ d.m./\ kg\ d.m.) \times N_{res_{below_{coefficient_{kg_{dry_i}}}}}\ (kg\ N\ /\ kg\ d.m.) \right\}$$

Equation 68. $x_{res_{below_i}}\ (kg\ d.m./\ kg\ d.m.) = x_{res_{below_{above_i}}} \times \left(\left(Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m./\ ha) \times 1\,000 + Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha)\right) \div Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha)\right)$

Equation 69. $N_{res_{left_{kg}}}\ (kg\ N) = \sum_i \Bigg\{ \left(A_{crop_{ha_i}}\ (ha) - A_{burnt_{ha_i}}\ (ha) \times C_f\right) \times x_{renew_i} \times$

$$\left(Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m./\ ha) \times 1\,000 \times N_{res_{above_{coefficient_{kg_{dry_i}}}}}\ (kg\ N/\ kg\ d.m.) \times \left(1 - x_{res_{above_{harvest_i}}}\ (kg\ N\ /\ kg\ cropN)\right) + \left(Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m./\ ha) \times 1\,000 + Y_{crop_{kg_{dry_i}}}\ (kg\ d.m./\ ha)\right) \times x_{res_{below_{above_i}}} \times N_{res_{below_{coefficient_{kg_{dry_i}}}}}\ (kg\ N\ /\ kg\ d.m.) \right) \Bigg\}$$

To estimate the amount of N in crop residues above-ground incorporated in the soil ($N_{res\_above\_left\_kg}$) (Equation 63)[51], data are needed on:

(i) Crop yield and area statistics

$Y_{crop\_kg\_dry\_i}$ is the harvested annual dry matter yield for crop *i* and $A_{crop\_ha\_i}$ is the total annual area harvested of crop *i*. Data on crop yield statistics (yields and area harvested, by crop) are available from Crop Statistics. Since yield statistics for many crops are reported as field-dry or fresh weight ($Y_{crop\_kg\_i}$), a correction factor (x_{dry_i}, the dry matter fraction of harvested crop *i*) can be applied to estimate dry matter yields ($Y_{crop\_kg\_dry\_i}$) where appropriate (Equation 64). The proper correction to be used is dependent on the standards used in yield reporting, which may vary between countries. Alternatively default values for d.m. content in Table 21 may be used.

(ii) Area of residue burnt

$A_{burnt\_ha\_i}$ is the annual area of crop *i* burnt. C_f is the combustion factor, the proportion of pre-fire fuel biomass consumed, for which default values can be found in IPCC 2006 Guidelines Volume 4 Chapter 2 Table 2.6, see Table 22.

(iii) Forage and pasture renewal

x_{renew_i} is the fraction of total area under crop *i* that is renewed annually[52]. For countries where pastures are renewed on average every X years, $x_{renew\_i} = 1/X$. For annual crops $x_{renew\_i} = 1$.

(iv) above-ground residue/yield ratios

$x_{res\_above\_i}$ is the ratio of above-ground residues d.m. yield ($Y_{res\_above\_tonnes\_dry\_i}$) to harvested d.m. yield for crop *i* ($Y_{crop\_kg\_dry\_i}$). $x_{res\_above\_i}$ can be estimated from Equation 65[53]. If data are not available on the ratio of above-ground residues d.m. yield the regression equation in Table 21 (Equation 66) may be used to calculate the total above-ground residue dry matter ($Y_{res\_above\_tonnes\_dry\_i}$).

(v) N contents of above-ground and belowground residues

$N_{res\_above\_coefficient\_kg\_dry\_i}$ is the N content (dry matter) of above-ground residues for crop *i*. . Default values can be found in Table 21.

(vi) removal of residues

$x_{res\_above\_harvest\_i}$ is the fraction of above-ground residues of crop *i* removed annually for purposes such as feed, bedding and construction. Survey of experts in country is required to obtain data. If data for $x_{res\_above\_harvest\_i}$ are not available, no removal is assumed.

To estimate the amount of N in crop residues below-ground ($N_{res\_below\_left\_kg}$) is estimated in a similar way to above-ground residues see Equation 67[54]. If data are not available on the belowground residue/yield ratios ($x_{res\_below\_i}$) these may be calculated by multiplying the ratio of belowground residues to above-ground biomass ($x_{res\_above\_below\_i}$ in Table 21) by the ratio of total above-ground biomass to crop yield, see Equation 68[55]. $Y_{res\_above\_tonnes\_dry\_i}$ can be calculated from the information in

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[51] $Y_{crop\_kg\_dry\_i}$ = Crop(*T*), $A_{crop\_ha\_i}$ = Area(*T*) , $A_{burnt\_ha\_i}$ = Area burnt (*T*) , x_{renew_i} = $Frac_{Renew\_i}$, $x_{res\_above\_i}$ = R_{AGi} , $N_{res\_above\_coefficient\_kg\_dry\_i}$ = N_{AGi}, $x_{res\_above\_harvest\_i}$ = $Frac_{Remove\_i}$ in IPCC Guidelines.

[52] This term is included in the equation to account for N release and the subsequent increases in N_2O emissions (e.g., van der Weerden *et al.*, 1999; Davies *et al.*, 2001) from renewal/cultivation of grazed grass or grass/clover pasture and other forage crops.

[53] $Y_{res\_above\_tonnes\_dry\_i}$ = AG_{DMi} in IPCC Guidelines.

[54] $x_{res\_below\_i}$ = R_{BGi} , $N_{res\_below\_coefficient\_kg\_dry\_i}$ = N_{BGi}, in IPCC Guidelines.

[55] $x_{res\_below\_above\_i}$ = R_{BG-BIO} in IPCC Guidelines.

Table 21. If data are not available on N contents of belowground residues ($N_{res\_below\_coefficient\_kg\_dry\_i}$) default values can be found in Table 21.

Using the default procedure in Table 21 $N_{res\_left\_kg}$ can also be estimated with Equation 69.

Tier 2

An improvement on this approach for determining $N_{res\_left\_kg}$ (i.e., Tier 2) would be the use of country-specific data rather than the values provided in Table 21, as well as country-specific values for the fraction of above-ground residue burned.

Table 21. Table 11.2 IPCC 2006 Guidelines

TABLE 11.2
DEFAULT FACTORS FOR ESTIMATION OF N ADDED TO SOILS FROM CROP RESIDUES [a]

Crop	Dry matter fraction of harvested product (DRY)	Above-ground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = (Crop_{(T)}/1000)^{*} slope_{(T)} + intercept_{(T)}$					N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
		Slope	± 2 s.d. as % of mean	Intercept	± 2 s.d. as % of mean	R^2 adj.			
Major crop types									
Grains	0.88	1.09	± 2%	0.88	± 6%	0.65	0.006	0.22 (± 16%)	0.009
Beans & pulses[b]	0.91	1.13	± 19%	0.85	± 56%	0.28	0.008	0.19 (± 45%)	0.008
Tubers[c]	0.22	0.10	± 69%	1.06	± 70%	0.18	0.019	0.20 (± 50%)	0.014
Root crops, other[d]	0.94	1.07	± 19%	1.54	± 41%	0.63	0.016	0.20 (± 50%)	0.014
N-fixing forages	0.90	0.3	± 50% default	0	-	-	0.027	0.40 (± 50%)	0.022
Non-N-fixing forages	0.90	0.3	± 50% default	0	-	-	0.015	0.54 (± 50%)	0.012
Perennial grasses	0.90	0.3	± 50% default	0	-	-	0.015	0.80 (± 50%)[l]	0.012
Grass-clover mixtures	0.90	0.3	± 50% default	0	-	-	0.025	0.80 (± 50%)[l]	0.016[p]
Individual crops									
Maize	0.87	1.03	± 3%	0.61	± 19%	0.76	0.006	0.22 (± 26%)	0.007
Wheat	0.89	1.51	± 3%	0.52	± 17%	0.68	0.006	0.24 (± 32%)	0.009
Winter wheat	0.89	1.61	± 3%	0.40	± 25%	0.67	0.006	0.23 (± 41%)	0.009
Spring wheat	0.89	1.29	± 5%	0.75	± 26%	0.76	0.006	0.28 (± 26%)	0.009
Rice	0.89	0.95	±19%	2.46	± 41%	0.47	0.007	0.16 (± 35%)	NA
Barley	0.89	0.98	± 8%	0.59	± 41%	0.68	0.007	0.22 (± 33%)	0.014
Oats	0.89	0.91	± 5%	0.89	± 8%	0.45	0.007	0.25 (± 120%)	0.008
Millet	0.90	1.43	± 18%	0.14	± 308%	0.50	0.007	NA	NA
Sorghum	0.89	0.88	± 13%	1.33	± 27%	0.36	0.007	NA	0.006
Rye[e]	0.88	1.09	± 50% default	0.88	± 50% default	-	0.005	NA	0.011

TABLE 11.2 (CONTINUED)
DEFAULT FACTORS FOR ESTIMATION OF N ADDED TO SOILS FROM CROP RESIDUES [a]

Crop	Dry matter fraction of harvested product (DRY)	Above-ground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = (Crop_{(T)}/1000)^{*} slope_{(T)} + intercept_{(T)}$					N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
		Slope	± 2 s.d. as % of mean	Intercept	± 2 s.d. as % of mean	R^2 adj.			
Soyabean[f]	0.91	0.93	± 31%	1.35	± 49%	0.16	0.008	0.19 (± 45%)	0.008
Dry bean[g]	0.90	0.36	± 100%	0.68	± 47%	0.15	0.01	NA	0.01
Potato[h]	0.22	0.10	± 69%	1.06	± 70%	0.18	0.019	0.20 (± 50%)[m]	0.014
Peanut (w/pod)[i]	0.94	1.07	± 19%	1.54	± 41%	0.63	0.016	NA	NA
Alfalfa[j]	0.90	0.29[k]	± 31%	0	-	-	0.027	0.40 (± 50%)[n]	0.019
Non-legume hay[j]	0.90	0.18	± 50% default	0	-	-	0.015	0.54 (± 50%)[n]	0.012

[a] Source: Literature review by Stephen A. Williams, Natural Resource Ecology Laboratory, Colorado State University. (Email: stevewi@warnercnr.colostate.edu) for CASMGS (http://www.casmgs.colostate.edu/). A list of the original references is given in Annex 11A.1.

[b] The average above-ground residue:grain ratio from all data used was 2.0 and included data for soya bean, dry bean, lentil, cowpea, black gram, and pea.

[c] Modelled after potatoes.

[d] Modelled after peanuts.

[e] No data for rye. Slope and intercept values are those for all grain. Default s.d.

[f] The average above-ground residue:grain ratio from all data used was 1.9.

[g] Ortega, 1988 (see Annex 11A.1). The average above-ground residue:grain ratio from this single source was 1.6. default s.d. for root:AGB.

[h] The mean value for above-ground residue:tuber ratio in the sources used was 0.27 with a standard error of 0.04.

[i] The mean value for above-ground residue: pod yield in the sources used was 1.80 with a standard error of 0.10.

[j] Single source. Default s.d. for root:AGB.

[k] This is the average above-ground biomass reported as litter or harvest losses. This does not include reported stubble, which averaged 0.165 x Reported Yields. Default s.d.

[l] Estimate of root turnover to above-ground production based on the assumption that in natural grass systems below-ground biomass is approximately equal to twice (one to three times) the above-ground biomass and that root turnover in these systems averages about 40% (30% to 50%) per year. Default s.d.

[m] This is an estimate of non-tuber roots based on the root:shoot values found for other crops. If unmarketable tuber yield is returned to the soil then data are derived from Vangessel and Renner, 1990 (see Annex 11A.1) (unmarketable yield = 0.08 * marketable yield = 0.29 * above-ground biomass) suggest that the total residues returned might then be on the order of 0.49 * above-ground biomass. Default s.d.

[n] This is an estimate of root turnover in perennial systems. Default s.d.

[p] It is assumed here that grass dominates the system by 2 to 1 over legumes.

Table 22. Combustion factors (IPCC 2006 Guidelines Table 2.6)

	Combustion factor
Wheat residues	0.90
Maize residues	0.80
Rice residues	0.80

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Activity data should include estimates of land areas for each crop type, which are then used to estimate residues that are commonly burned, the fraction of residue burned and d.m. content of residue. The mass of crop residue burned ($C_{res\_burnt\_kg}$) can be calculated from Equation 70[56].

Equation 70. $$C_{res_{burnt_{kg}}}(kg) = \sum_i \left\{ A_{burnt_{ha_i}}(ha) \times Y_{crop_{kg_i}}(kg\ fresh\ weight/ha) \times x_{res_{above_{crop_i}}} \times x_{dry_i}(kg\ d.m./kg\ fresh\ weight) \times x_{res_{above_{burn_i}}} \times C_f \right\}$$

The most important data here are the actual amount of crops produced (by type) with residues that are commonly burned. Annual crop production statistics are equivalent to the terms $A_{burnt\_ha\_i}$ (area of land on which crops are grown whose residues are burned) * $Y_{crop\_kg\_i}$ (average yield of crop *i*) in Equation 70. Crop-specific data for each country, on ratios of residue to crop, fraction of residue burned and dry matter content of the residue, can be incorporated at any time to replace the default values. A potentially valuable data source is the study by Hall et al. (1996).

It is assumed that country statistics giving the area of cropped land will always be available. In the absence of better data, the following values should be used. Default values of $x_{res\_above\_crop\_i}$ can be obtained from Table 20. For consistency with IPCC 2006 Guidelines and assuming x_{dry_i} = 0.85 (Anon, 1997), for wheat: $Y_{crop\_kg\_i}$ = 3.6, C_f = 0.9; for maize: $Y_{crop\_kg\_i}$ = 11.8, C_f = 0.8; rice: $Y_{crop\_kg\_i}$ = 4.6, C_f = 0.8. If $x_{res\_above\_burn\_i}$ is not known, the value of 1 should be used. For crops other than wheat, maize and rice, the values for wheat should be used.

Economy Wide Material Flow Accounts.

The Guidelines (2012) for the Economy Wide Material Flow Accounts (EW-MFA) provide some guidelines on the estimation of the amount of crop residues removed from the field. The amount of crop residues for a crop is estimated by multiplying data on the main production of the crop with a harvest factor (ratio between main crop and residue). The fraction of crop residues removed from the field is subsequently estimated by multiplying the total crop residues with the recovery rate. The main crops which provide crop residues are listed in Table 23. Data on the main production of these crops are available from Eurostat Crop Statistics.

Step 1: Identification of crops which provide residues for further socio-economic use.

In most cases this will include all types of cereals, sugar crops, and oil bearing crops. Only in exceptional cases other crops need to be considered.

[56] $C_{res\_burnt\_kg} = AR_{residue\_burnt}$, $A_{burnt\_ha\_i}$ = A, $Y_{crop\_kg\_i}$ = Y, $x_{res\_above\_crop\_i}$ = s , x_{dry_i} = d $x_{res\_above\_burn\_i}$ = p_b in EMEP/EEA Guidebook.

Step 2: Estimation of total above-ground crop residues via a residue factor

The procedure to estimate the total above-ground crop residues is based on assumptions on the relation between above-ground crop residues and primary harvest of specific crops (Equation 71).. Crops are partitioned in primary harvest and above-ground crop residues. The residue factor ($x_{res\_above\_crop\_i}$) is estimated as the total above-ground crop residues divided by total primary crop harvest. This relation is typical for each cultivar, however, subject to breeding efforts and therefore variable over time. The residue factor ($x_{res\_above\_crop\_dry\_i}$) for crop *i*, allows the extrapolation of total above ground residue of crop *i* ($C_{res\_above\_dry\_i}$) from primary crop harvest of crop *i* ($C_{crop\_dry\_i}$).

Equation 71. $$C_{res_{above_{dry_i}}}\ (tonnes\ d.m.) = C_{crop_{dry_i}}\ (tonnes\ d.m.) \times x_{res_{above_{crop_{dry_i}}}}$$

The EW-MFA Guidelines recommend in absence of national information to use the residue factors which were assumed by Wirsenius (2000) for West and East Europe. In the study of Wirsenius rough estimates of residue factors in different regions were based on different data sources and own estimations, they are provided in Table 23. The EW-MFA Guidelines recommend using the default value of barley for other cereal crops.

Table 23. Assumed values for residue factors and recovery rates for the most common crop residues used in West Europe and East Europe (Wirsenius, 2000)

	Western Europe		Eastern Europe	
	Residue factor	Recovery rate	Residue factor	Recovery rate
Wheat	1.0	0.7	1.5	0.75
Barley	1.2	0.7	1.5	0.75
Sorghum	1.2	0.7	1.9	0.75
Maize	1.2	0.9	1.9	0.9
Rice	1.2	0.7	1.2	0.75
Rape seed	1.9	0.7	1.9	0.7
Soy bean	1.2	0.7	1.5	0.75
Sugar beet	0.7	0.9	0.7	0.9

Step 3:

Estimation of fraction of used residues. In most cases, only a certain fraction of the total above ground residue of crop *i* will be harvested and further used or grazed, this fraction is represented by the recovery rate. The actual used fraction of above ground residues of crop *i* ($C_{res\_above\_harvest\_dry\_i}$) can be estimated based on expert knowledge or specific studies, but it should be noted that it may vary considerably between regions, countries, and over time (Equation 72). In cases in which no information on the country specific share of used residues is available, recovery rates ($x_{res\_above\_harvest\_dry\_i}$) provided in Table 23 can be applied to the available crop residue of crop *i* to determine the actual used fraction of above ground residues of crop *i* for European countries. Wirsenius made rough estimations of recovery rates in different regions based on different data sources, own estimations and assumptions. The EW-MFA Guidelines recommend using the default value of barley for other cereal crops.

Equation 72. $C_{res_{above_{harvest_{dry_i}}}}\ (tonnes\ d.m.) = C_{res_{above_{dry_i}}}\ (tonnes\ d.m.) \times x_{res_{above_{harvest_{dry_i}}}}$

Equation 73. $x_{res_{above_{harvest_{dry_i}}}} = C_{res_{above_{harvest_{dry_i}}}}\ (tonnes\ d.m.) \div C_{res_{above_{dry_i}}}\ (tonnes\ d.m.)$

Estimation of nutrients in crop residues burned coherent with IPCC Guidelines

From IPCC Guidelines on estimation of crop residues left on the field, estimation of crop residues harvested and burned can be derived. When countries have data available on the fraction of residue burned in the field before and after harvest ($x_{res\_above\_burn\_i}$ and $x_{res\_above\_burn\_j}$), Nitrogen content of crop residues burned can be estimated with IPCC 1996 Tier 1b see Equation 74.

Equation 74. $$N_{res_{above_{burn_{kg}}}}\ (kg\ N) = \sum_i \left\{ C_{crop_{kg_i}}\ (kg) \times x_{res_{above_{crop_i}}} \times x_{above_{dry_i}} \times N_{crop_{coefficient_{kg_{dry_i}}}}\ (kg\ N\ /kg\ of\ d.m.) \times x_{res_{above_{burn_i}}} \right\} + \sum_j \left\{ C_{legumes_{kg_j}}\ (kg) \times x_{res_{above_{legumes_j}}} \times x_{above_{dry_j}} \times N_{legumes_{coefficient_{kg_{dry_j}}}}\ (kg\ N\ /\ kg\ d.m.) \times x_{res_{above_{burn_j}}} \right\}$$

Equation 75. $N_{res_{above_{burn}}}\ (tonnes\ N) = N_{res_{above_{burn_{kg}}}}\ (kg\ N) \div 1\,000$

The following data are needed:

(i) Crop production **($C_{crop\_kg\_i}$).**
These data are available from crop production statistics.

(ii) Residue to crop product mass ratio ($x_{res\_above\_legumes\_j}$ and $x_{res\_above\_crop\_i}$)

These ratios estimate the total above ground residue from data on crop production, see Equation 49 and Equation 61. Default values can be found in Table 21.

(iii) Dry matter content of the aboveground biomass ($x_{above\_dry\_i}$ and $x_{above\_dry\_j}$).

The derived amount of aboveground crop residues is multiplied with d.m. content of aboveground biomass to estimate d.m. content of aboveground crop residues. Note that assumed is that d.m. content of above-ground crop residues is equal d.m. content of above-ground biomass. If countries have specific coefficients available on above-ground residue d.m. contents these can be used. Default values can be found in Table 21.

(iv) Nitrogen content of aboveground biomass ($N_{crop\_coefficient\_kg\_dry\_i}$ and $N_{legumes\_coefficient\_kg\_dry\_j}$).

(v) N content of the derived amount of aboveground crop residues d.m. is estimated with N coefficients of aboveground biomass. If countries have specific coefficients available on above-ground residue N contents these can be used to improve the estimation. Default values can be found in Table 21.

When countries have data available on the area of residues burned in the field before and after harvest ($A_{burnt\_ha\_i}$) the N content of crop residues burned ($N_{res\_above\_burn\_kg}$) can also be estimated with IPCC 2006 Tier 1 see Equation 76.

Equation 76. $$N_{res_{above_{burn_{kg}}}}\ (kg\ N) = \sum_i \left\{ A_{burnt_{ha_i}}\ (ha) \times C_f) \times (Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m\ /\ ha) \times 1\,000 \times N_{res_{above_{coefficient_{kg_{dry_i}}}}}\ (kg\ N\ /\ kg\ d.m.) \right\}$$

The following data are needed:

(i) Area of crop residues burnt

$A_{burnt\_ha\_i}$ is the annual area of crop type *i* burnt. C_f is the combustion factor, the proportion of pre-fire fuel biomass consumed, for which default values can be found in Table 22.

(ii) Crop yield statistics

Equation 66 can be used to calculate total above-ground residue d.m. ($Y_{res\_above\_tonnes\_dry\_i}$) from crop yield statistics. Data on crop yields are available from crop statistics and can be converted to d.m. yields with a correction factor see Equation 64 (x_{dry_i} for which default values can be found in Table 21. Multiplying the above-ground residue d.m. yield with area burnt and combustion factor results in the amount of above-ground residue d.m. burnt.

(iii) N contents of above-ground residues

The nitrogen content of the derived amount of aboveground crop residues dry matter burnt is estimated by multiplying the amount in dry matter with a nitrogen coefficient $N_{res\_above\_coefficient\_kg\_dry\_i}$ which represents the N content of above-ground residues (dry matter) for crop type *i*. Default values can be found in Table 21.

Estimation of nutrients in crop residues harvested coherent with IPCC Guidelines

When countries have data available on the fraction of above ground residues harvested ($x_{res\_above\_harvest}$) (used as fuel, for construction, or as fodder, see Equation 73 and Equation 60) the Nitrogen content of aboveground crop residues harvested ($N_{res\_above\_harvest\_kg}$) can be estimated with IPCC 1996 Tier 1b see Equation 77.

Equation 77. $$N_{res_{above_{harvest_{kg}}}}\ (kg\ N) = \sum_i \left\{ C_{crop_{kg_i}}\ (kg) \times x_{res_{above_{crop_i}}} \times x_{above_{dry_i}} \times N_{crop_{coefficient_{kg_{dry_i}}}}\ (kg\ N\ /kg\ of\ d.m.) \times x_{res_{above_{harvest_i}}} \right\} + \sum_j \left\{ C_{legumes_{kg_j}}\ (kg) \times x_{res_{above_{legumes_j}}} \times x_{above_{dry_j}} \times N_{legumes_{coefficient_{kg_{dry_j}}}}\ (kg\ N\ /\ kg\ d.m.) \times x_{res_{above_{harvest_j}}} \right\}$$

Equation 78. $$N_{res_{above_{harvest}}}\ (tonnes\ N) = N_{res_{above_{harvest_{kg}}}}\ (kg\ N) \div 1\,000$$

The following data are needed:

(i) Crop production ($C_{crop\_kg\_i}$)

These data are available from crop production statistics.

(ii) Residue to crop product mass ratio ($x_{res\_above\_legumes\_j}$ and $x_{res\_above\_crop\_i}$)

These ratios estimate the total above ground residue from data on crop production, see Equation 49 and Equation 61. Default values can be found in Table 21.

(iii) Dry matter content of the aboveground biomass ($x_{above\_dry\_i}$ and $x_{above\_dry\_j}$).

The derived data on aboveground crop residues are multiplied with the dry matter content of the aboveground biomass to estimate the dry matter content of aboveground crop residues. Note that assumed is that the dry matter content of above-ground crop residues is assumed to equal the dry matter content of above-ground biomass. If countries have specific coefficients available on above-ground residue dry matter contents these can be used to improve the estimation. Default values can be found in Table 21.

(iv) Nitrogen content of the aboveground biomass ($N_{crop\_coefficient\_kg\_dry\_i}$ and $N_{legumes\_coefficient\_kg\_dry\_j}$)

The nitrogen content of the derived amount of aboveground crop residues dry matter is estimated with nitrogen coefficients of aboveground biomass. If countries have specific coefficients available on above-ground residue nitrogen contents these can be used to improve the estimation. Default values can be found in Table 21

If countries do not have data available on the fraction of above ground crop residues harvested the assumed values (recovery rates) used in the EW-MFA Guidelines see Table 23 can be used. Alternatively the Nitrogen content of aboveground crop residues harvested ($N_{res\_above\_harvest\_kg}$) can be estimated with IPCC 2006 Tier 1 see Equation 79.

Equation 79. $$N_{res_{above_{harvest_{kg}}}}\ (kg\ N) = \sum_i \left\{ \left(A_{crop_{ha_i}}\ (ha) - A_{burnt_{ha_i}}\ (ha) \times C_f \right) \times Y_{res_{above_{tonnes_{dry_i}}}}\ (tonnes\ d.m / ha) \times 1\,000 \times N_{res_{above_{coefficient_{kg_{dry_i}}}}}\ (kg\ N\ / \ kg\ d.m.) \times x_{res_{above_{harvest_i}}}\ (kg\ N\ /\ kg\ Crop - N) \right\}$$

The following data are needed:

(i) Harvested Area

$A_{crop\_ha\_i}$ is the total annual area harvested of crop type *i*. If data are available on annual area of crop type *i* burnt ($A_{burnt\_ha\_i}$) and the combustion factor (C_f, see Table 22 for default values), the harvested area can be corrected for areas on which crop residues are burned. If data are not available no burning is assumed.

(ii) Crop yield statistics

Equation 66 can be used to calculate total above-ground residue dry matter yield ($Y_{res\_above\_tonnes\_dry\_i}$) from crop yield statistics. Data on crop yields are available from crop statistics and can be converted to dry matter yields with a correction factor see Equation 64 (x_{dry_i}) for which default values can be found in Table 21. Multiplying the above-ground residue dry matter yield with the crop area corrected for the area burnt and the combustion factor results in the amount of above-ground residue dry matter available.

(iii) N contents of above-ground residues

The nitrogen content of the derived amount of aboveground crop residues dry matter is estimated by multiplying the amount in dry matter with a nitrogen coefficient $N_{res\_above\_coefficient\_kg\_dry\_i}$ which represents the N content of above-ground residues (dry matter) for crop type *i*. Default values can be found in Table 21.

If countries do not have data available on the fraction of above ground crop residues harvested the assumed values (recovery rates) used in the EW-MFA Guidelines see Table 23 can be used.

ANNEX 6 LIST OF EMISSIONS IN PRACTICAL IMPLEMENTATION

Table 24. Proposed worksheet for including N atmospheric emissions in GNB

Nitrogenous Emissions		**Tonnes of N**		
EU Code	Description	1985	…	2011
TNEM	Total N Emissions			
TNEM_M	Total N Emissions during Manure management			
NH3_4B1a	NH3 Cattle dairy			
NH3_4B1b	NH3 Cattle non-dairy			
NH3_4B2	NH3 Buffalo			
NH3_4B3	NH3 Sheep			
NH3_4B4	NH3 Goats			
NH3_4B6	NH3 Horses			
NH3_4B7	NH3 Mules and asses			
NH3_4B8	NH3 Swine			
NH3_4B9a	NH3 Laying hens			
NH3_4B9b	NH3 Broilers			
NH3_4B9c	NH3 Turkeys			
NH3_4B9d	NH3 Other poultry			
NH3_4B13	NH3 Other			
NO2_4B1a	NO2 Cattle dairy			
NO2_4B1b	NO2 Cattle non-dairy			
NO2_4B2	NO2 Buffalo			
NO2_4B3	NO2 Sheep			
NO2_4B4	NO2 Goats			
NO2_4B6	NO2 Horses			
NO2_4B7	NO2 Mules and asses			
NO2_4B8	NO2 Swine			
NO2_4B9a	NO2 Laying hens			
NO2_4B9b	NO2 Broilers			
NO2_4B9c	NO2 Turkeys			
NO2_4B9d	NO2 Other poultry			
NO2_4B13	NO2 Other			
N2O_4s2B11	Direct N2O Manure management: Anaerobic Lagoons			
N2O_4s2B12	Direct N2O Manure management: Liquid systems			
N2O_4s2B13	Direct N2O Manure management: Solid storage and Dry Lot			

N2O_4s2B14	Direct N2O Manure management: Other AWMS			
TNEM_S	Total N Emissions from Soils			
NH3_4D1a	NH3 Synthetic N-fertilizers			
NH3_4D2a	NH3 Farm-level agricultural operations including storage, handling and transport of agricultural products			
NH3_4D2b	NH3 Off-farm storage, handling and transport of bulk agricultural products			
NH3_4D2c	NH3 N-excretion on pasture range and paddock unspecified			
NH3_4F	NH3 Field burning of agricultural wastes			
NH3_4G	NH3 Agriculture other			
NO2_4D1a	NO2 Synthetic N-fertilizers			
NO2_4D2a	NO2 Farm-level agricultural operations including storage, handling and transport of agricultural products			
NO2_4D2b	NO2 Off-farm storage, handling and transport of bulk agricultural products			
NO2_4D2c	NO2 N-excretion on pasture range and paddock unspecified			
NO2_4F	NO2 Field burning of agricultural wastes			
NO2_4G	NO2 Agriculture other			
N2O_4D1_1	Direct Soil Emissions - Synthetic Fertilizers			
N2O_4D1_2	Direct Soil Emissions - Animal Manure Applied to Soils			
N2O_4D1_3	Direct Soil Emissions - N-fixing Crops			
N2O_4D1_4	Direct Soil Emissions - Crop Residue			
N2O_4D1_5	Direct Soil Emissions - Cultivation of Histosols			
N2O_4D1_6	Direct Soil Emissions - Other direct emissions			
N2O_4D2	Pasture range and paddock - N excretion on pasture range and paddock			
N2O_4F	Field burning of agricultural residues			

* Data on NH_3 and NO_x emissions can be downloaded from national inventories (NFR reports) to CLTRAP (http://www.ceip.at/status-of-reporting/)

* Data on N_2O can be downloaded from national inventories (CFR reports) to UNFCCC (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php)

ANNEX 7 LIST OF EXPRESSIONS USED IN EQUATIONS

Expression	Definition	Unit
Areas		
$A_{burnt\_ha\_i}$	Area of crop type *i* which is burnt	ha
A_{crop_i}	Area of crop type *i* (Crop Statistics)	1 000 ha
$A_{crop\_ha\_i}$	Area harvested of crop type *i*	ha
A_{grass}	Area of grassland (Crop Statistics)	1 000 ha
$A_{legumes\_i}$	Area of leguminous crop type *i* (Crop Statistics)	1 000 ha
A_{total}	Total land area (L0008 in Crop Statistics)	1 000 ha
A_{UAA}	Utilized Agricultural Area (Crop Statistics)	1 000 ha
Amount of biomass		
C_{crop_i}	Total crop production biomass of crop type *i* including on-holding losses and wastage, quantities consumed directly on the farm and marketed quantities, indicated in units of basic product weight	Tonnes biomass
$C_{crop\_dry\_i}$	See C_{crop_i}	Tonnes biomass in d.m.
$C_{crop\_kg\_i}$	See C_{crop_i}	Kg biomass
$C_{crop\_kg\_dry\_i}$	See C_{crop_i}	Kg biomass in d.m.
C_{grass_grazed}	Grass biomass uptake by grazing	Tonnes biomass at 15% m.c.
C_{grass_gross}	Gross biomass production of grassland. Grazing potential.	Tonnes biomass at 15% m.c.
$C_{grass\_harvested}$	Grass biomass harvest from grassland	Tonnes biomass at 15% m.c.
$C_{legumes\_kg\_i}$	Total crop production biomass of leguminous crop type *i*	Kg biomass
C_{res}	Total crop residues biomass in the reference area	Tonnes biomass
$C_{res\_above\_dry\_i}$	Total aboveground crop residue biomass for crop type *i*	Tonnes biomass in d.m.
$C_{res\_above\_kg\_i}$	See $C_{res\_above\_dry\_i}$	Kg biomass
$C_{res\_above\_harvest\_dry\_i}$	Total aboveground crop residue biomass for crop type *i* which are harvested as by-product with the fodder (crop) (e.g. straw) and can be used as feed for animals, bedding material or other purposes	Tonnes biomass in d.m.
$C_{res\_above\_legumes\_i}$	Total aboveground crop residue biomass for leguminous crop type *i*	Tonnes biomass
$C_{res\_above\_legumes\_kg\_i}$	See $C_{res\_above\_legumes\_i}$	Kg biomass

$C_{res\_ash\_i}$	Total crop residues biomass of crop type *i* which are burnt on the field and are returned to the soil with the ashes	Tonnes biomass
$C_{res\_burnt\_i}$	Total crop residues biomass of crop type *i* which are burned on the field	Tonnes biomass
$C_{res\_burnt\_kg\_i}$	See $C_{res\_burnt\_i}$	Kg biomass
$C_{res\_harvest\_i}$	Total crop residues biomass of crop type *i* which are harvested as by-product with the fodder (crop) (e.g. straw) and can be used as feed for animals, bedding material or other purposes	Tonnes biomass
$C_{res\_left\_i}$	Total crop residues biomass of crop type *i* which remain after the harvest of the (fodder) crop (e.g. stalks and stubble) above or below the ground	Tonnes biomass
$C_{res\_left\_above\_i}$	Total crop residues biomass of crop type *i* which remain after the harvest of the (fodder) crop (e.g. stalks and stubble) above the ground	Tonnes biomass
$C_{res\_left\_below\_i}$	Total crop residues biomass of crop type *i* which remain after the harvest of the (fodder) crop (e.g. stalks and stubble) below the ground	Tonnes biomass
$C_{res\_remove\_i}$	Total crop residues biomass of crop type *i* which are harvested as by-product and are removed completely from agriculture	Tonnes biomass
$C_{res\_return\_i}$	Total crop residues biomass of crop type *i* which are harvested as by-product and return to the field at a later stage (e.g. in litter)	Tonnes biomass
$C_{res\_volatilised\_i}$	Total crop residues biomass of crop type *i* which is lost due to volatilisation of nitrogen with the burning of crop residues	Tonnes biomass
$C_{roughage\_demand}$	Demand for roughage biomass	Tonnes biomass at 15% m.c.
$C_{roughage\_foddercrops}$	Total roughage fodder crop production biomass	Tonnes biomass at 15% m.c.
C_{seed_i}	Total seeds biomass input for crop type *i* in the reference area	Tonnes biomass
Yield		
$Y_{crop\_kg\_i}$	Total harvested annual biomass yield for crop type *i*	Kg biomass field-dry or fresh weight per ha
$Y_{crop\_kg\_dry\_i}$	See $Y_{crop\_kg\_i}$	Kg biomass in d.m. per ha
$Y_{grass\_gross\_kg}$	Grass biomass yield. Gross production per ha.	Kg biomass at 15% m.c. per ha
$Y_{res\_above\_tonnes\_dry\_i}$	Total above-ground residues biomass yield	Tonnes biomass in d.m. per ha
Other activity data		

AAP_i	Total annual average livestock population of livestock type *i*	1 000 heads
AAP_{graz_i}	Total annual average livestock population of grazing livestock type *i*	1 000 heads
F_{org_i}	Total amount of organic fertilizer *i* applied to agricultural soils	1 000 tonnes
$M_{treated\_i}$	Total amount of manure treated with treatment *i* expressed in tonnes of original product before treatment	1 000 tonnes of original product
$NAPA_i$	Number of animals produced annually of livestock *i*	1 000 heads
$n_{growing\_cycle\_i}$	Average number of growing cycles per year for livestock type *i*	Number
n_{places_i}	Average number of animal places for livestock type *i* in the animal housing that is usually occupied (average capacity)	Number
RR_i	Roughage requirements of livestock type *i*	Tonnes (at 15% m.c.) per head per year
SR_i	Sowing rates of crop type *i*	kg seed per ha
t_{alive_i}	Average number of days in a year that animals of livestock type *i* are alive	Days
$t_{cleanse\_i}$	Average duration of the period per growing cycle when the animal place for livestock type *i* is empty e.g. for cleaning	Days
t_{empty_i}	Average duration during the year when the animal place for livestock type *i* is empty	Days
Factors and fractions		
C_f	Combustion factor (proportion of fuel present at the time of the fire that is actually burned)	Factor
NUE	Nitrogen use efficiency	Fraction
PUE	Phosphorus use efficiency	Fraction
$x_{above\_dry\_i}$	Dry matter fraction in the aboveground biomass of each crop type *i*	Fraction
x_{dry_i},	Dry matter fraction of harvested product of crop type *i*	Fraction
$x_{grass\_conserv}$	Fraction of total gross grassland production that is not available for consumption due to losses during the conservation of hay or silage	Fraction
$x_{grass\_feeding}$	Fraction of total gross grassland production that is not available for consumption due to losses during the feeding of fresh grass, hay and silage to animals	Fraction

$x_{grass\_harvest\_loss}$	Fraction of total gross grassland production that is not available for consumption due to losses during harvesting	Fraction
x_{grass_tramp}	Fraction of total gross grassland production that is not available for consumption due to trampling by grazing animals	Fraction
$x_{harvest}$	Fraction of total aboveground crop biomass that is removed from the field as product	Fraction
x_{ns_i}	Fraction of animals of livestock type *i* that die and are not sold	Fraction
x_{renew_i}	Fraction of total area of crop type *i* that is renewed annually.	Fraction
$x_{res\_above\_i}$	Ratio of above-ground residues d.m. to total harvested d.m. yield for crop type *i*	Ratio
$x_{res\_above\_burn\_i}$	Fraction of total aboveground crop biomass of crop type *i* that is burned on the field	Fraction
$x_{res\_above\_construct\_i}$	Fraction of total aboveground crop biomass of crop type *i* that is used for construction	Fraction
$\mathbf{x}_{res\_above\_crop\_i}$	Ratio of aboveground residue biomass. to crop product biomass for crop type *i*	Ratio
$\mathbf{x}_{res\_above\_crop\_dry\_i}$	Ratio of aboveground residue d.m. to crop product mass in d.m. for crop type *i*	Ratio
$x_{res\_above\_fodder\_i}$	Fraction of total aboveground crop biomass of crop type *i* that is used as fodder	Fraction
$x_{res\_above\_fuel\_i}$	Fraction of total aboveground crop biomass of crop type *i* that is used as fuel	Fraction
$x_{res\_above\_harvest\_i}$	Fraction of above ground crop residues which are harvested for fuel, bedding, construction etc.	Fraction
$\mathbf{x}_{res\_above\_legumes\_i}$	Ratio of aboveground residue biomass to crop product biomass for leguminous crop type *i*	Ratio
$x_{res\_below\_i}$	Ratio of below-ground residues d.m. to total harvested d.m. yield for crop type *i*	Ratio
$x_{res\_below\_above\_i}$	Ratio of belowground residues to above-ground biomass	Ratio
Nutrient coefficients		
$N_{crop\_coefficient\_i}$	Coefficient which represents the N content of harvested crop production for crop type *i*	kg N per tonne biomass
$N_{crop\_coefficient\_kg\_dry\_i}$	See $N_{crop\_coefficient\_i}$	kg N per kg biomass in d.m.
$N_{deposition\_coefficient}$	Coefficient which represents average N deposition per ha of UAA	kg N per ha
$N_{excretion\_coefficient\_i}$	Coefficient which represents average N excretion per head of livestock type *i* (per	kg N per head

	year)	
$N_{fix\_legumes\_coefficient\_i}$	Coefficient which represents N fixed by leguminous crop type *i* per ha covered by the crop	kg N per ha
$N_{fix\_free\_coefficient}$	Coefficient which represents N fixed by free living organisms per ha of UAA	kg N per ha
$N_{legumes\_coefficient\_i}$	Coefficient which represents N content of crop production for leguminous type *i*	kg N per tonne biomass
$N_{legumes\_coefficient\_kg\_dry\_i}$	See $N_{legumes\_coefficient\_i}$	kg N per kg biomass in d.m.
$N_{orgfert\_coefficient\_i}$	Coefficient which represents N content per tonne of organic fertilizer type *i*	kg N per tonne
$N_{res\_burnt\_coefficient\_i}$	Coefficient which represents N content of crop residues of crop type *i* which are burned on the field	kg N per tonne biomass
$N_{res\_remove\_coefficient\_i}$	Coefficient which represents N content of crop residues of crop type *i* which are removed from agriculture	kg N per tonne biomass
$N_{res\_above\_coefficient\_kg\_dry\_i}$	Coefficient which represents N content of above-ground residues for crop type *i*.	kg N per kg biomass in d.m.
$N_{res\_below\_coefficient\_kg\_dry\_i}$	Coefficient which represents N content of below-ground residues for crop type *i*.	kg N per kg biomass in d.m.
$N_{seed\_coefficient\_i}$	Coefficient which represents N content per tonne of organic seed input of crop type *i*	kg N per tonne biomass
$N_{treatment\_coefficient\_\_i}$	Coefficient which expresses N lost or added to manure treated due to treatment *i* in comparison with amount of N present in the original product before treatment	kg N per tonne
$P_{crop\_coefficient\_i}$	Coefficient which represents the P content of harvested crop production for crop type *i*	kg P per tonne biomass
$P_{excretion\_coefficient\_i}$	Coefficient which represents average P excretion per head of livestock type *i* (per year)	kg P per head
$P_{orgfert\_coefficient\_i}$	Coefficient which represents P content per tonne of organic fertilizer type *i*	kg P per tonne
$P_{res\_remove\_coefficient\_i}$	Coefficient which represents P content of crop residues of crop type *i* which are removed from agriculture	kg P per tonne biomass
$P_{seed\_coefficient\_i}$	Coefficient which represents P content per tonne of organic seed input of crop type *i*	kg P per tonne biomass
$P_{treatment\_coefficient\_\_i}$	Coefficient which expresses P lost or added to manure treated due to treatment *i* in comparison with amount of P present in the original product before treatment	kg P per tonne

Results in Nutrients		
aGNS	Atmospheric Gross Nitrogen Surplus	Tonnes of Nitrogen
GNS	Gross Nitrogen Surplus	Tonnes of Nitrogen (or kg Nitrogen per ha)
hGNS	Hydrospheric Gross Nitrogen Surplus	Tonnes of Nitrogen (or kg Nitrogen per ha)
$N_{animalfeed}$	Total N consumed by livestock	Tonnes of N
$N_{animalfeed\_farm}$	Total N consumed by livestock with animal feed produced at farms (grass, maize etc.).	Tonnes of N
$N_{animalfeed\_import}$	Total N consumed by livestock with animal feed products from industry (concentrates etc.)	Tonnes of N
$N_{animalretention}$	Total N retained in animal or animal products	Tonnes of N
$\Delta N_{content\_treated}$	Total change in N content of treated manure due to manure treatment	Tonnes of N
N_{crop}	Total N removal with harvested crop production	Tonnes of N
$N_{deposition}$	Total N deposition on the reference area	Tonnes of N
$N_{deposition\_oxidized}$	Total oxidised N deposition.	Tonnes of N
$N_{deposition\_reduced}$	Total reduced N deposition	Tonnes of N
$N_{excretion}$	Total N excreted	Tonnes of N
N_{fix_free}	Total N fixation by free living organisms	Tonnes of N
$N_{fix\_legumes}$	Total N fixation by leguminous crops	Tonnes of N
$N_{fix\_legumes\_kg}$	Total N fixation by leguminous crops	Kg of N
N_{grass_gross}	Total N in gross grassland production	Tonnes of N
N_{grass_net}	Total N in net grassland production	Tonnes of N
$N_{manure\_treated\_i}$	Total N in the manure treated with treatment *i*	Tonnes of N
$N_{manure\_untreated\_i}$	Total N in the original manure before it was treated with treatment *i*	Tonnes of N
$N_{orgfert}$	Total N in organic fertilizers (excluding manure) applied to the reference area	Tonnes of N
N_{res_ash}	Total N in ashes of burned crop residues of crop type *i* which are returned to the soil	Tonnes of N
N_{res_burnt}	Total N in crop residues burned on the field	Tonnes of N
$N_{res\_harvest}$	Total N in harvested crop residues crop type *i*	Tonnes of N
$N_{res\_harvest\_kg}$	See $N_{res\_harvest}$	Kg of N
N_{res_left}	Total N in crop residues left on the field for crop type *i*	Tonnes of N
$N_{res\_left\_kg}$	See N_{res_left}	kg of N

$N_{res\_left\_above\_kg}$	Total N in above ground crop residues of crop type *i* left on the field	kg of N
N_{res_remove}	Total N in crop residues harvested and removed from agriculture	Tonnes of N
N_{res_return}	Total N in crop residues of crop type *i* which are harvested as by-product and return to the field at a later stage (e.g. in litter)	Tonnes of N
$N_{res\_volatilised}$	Total N which is lost due to volatilisation with the burning on the field of crop residues of crop type *i*	Tonnes of N
N_{seed}	Total N input of seeds to the reference area	Tonnes of N
$P_{animalfeed}$	Total P consumed by livestock	Tonnes of P
$P_{animalfeed\_farm}$	Total P consumed by livestock with animal feed produced at farms (grass, maize etc.).	Tonnes of P
$P_{animalfeed\_import}$	Total P consumed by livestock with animal feed products from industry (concentrates etc.)	Tonnes of P
$P_{animalretention}$	Total P retained in animal or animal products	Tonnes of P
$\Delta P_{content\_treated}$	Total change in P content of treated manure due to manure treatment	Tonnes of P
P_{crop}	Total P removal with harvested crop production	Tonnes of P
$P_{excretion}$	Total P excreted	Tonnes of P
P_{grass_gross}	Total P in gross grassland production	Tonnes of P
P_{grass_net}	Total P in net grassland production	Tonnes of P
$P_{manure\_treated\_i}$	Total P in the manure treated with treatment *i*	Tonnes of P
$P_{manure\_untreated\_i}$	Total P in the original manure before it was treated with treatment *i*	Tonnes of P
$P_{orgfert}$	Total P in organic fertilizers (excluding manure) applied to the reference area	Tonnes of P
P_{res_burnt}	Total P in crop residues burned on the field	Tonnes of P
$P_{res\_harvest}$	Total P in harvested crop residues of crop type *i*	Tonnes of P
P_{res_left}	Total P in crop residues left on the field for crop type *i*	Tonnes of P
P_{res_remove}	Total P in crop residues harvested and removed from agriculture	Tonnes of P
P_{res_return}	Total P in crop residues of crop type *i* which are harvested as by-product and return to the field at a later stage (e.g. in litter)	Tonnes of P
P_{seed}	Total P input of seeds to the reference area	Tonnes of P