



Methodological studies in the field of Agro-Environmental Indicators.
Lot 1 excretion factors

Guidelines for a common methodology

Task 5 Report

28 February 2014

Oene Oenema^{1*)}, Leon Sebek²⁾, Hans Kros¹⁾, Jan Peter Lesschen¹⁾, Marinus van Krimpen²⁾, Paul Bikker²⁾, Ad van Vuuren²⁾ & Gerard Velthof¹⁾

- 1) Wageningen University, Alterra, P.O. Box 47, NL-6700 AA Wageningen, The Netherlands
- 2) Wageningen University, Livestock Research, P.O. Box 65, 8200 AB Lelystad, The Netherlands
- *) Corresponding author oene.oenema@wur.nl

Alterra, part of Wageningen UR
Wageningen, 2014

Contents

Executive Summary	5
1 Introduction	19
2 Towards a common approach	24
2.1 Introduction	24
2.2 A common mass balance approach	26
2.3 A three-tiered approach for data collection	29
2.4 Best practices for data collection	30
3 Guidelines for animal categorization	34
3.1 Introduction	34
3.2 Some main animal categories in use in EU-27	35
3.3 Guidelines for a common categorization of animals in EU-27	50
4 Guidelines for identifying the proper Tier	53
4.1 Introduction	53
4.2 Determinants for Tier selection	54
5 General guidelines for estimating N & P excretion coefficients	58
5.1 Introduction	58
5.2 Defining animal categories and production systems	59
5.3 Estimation of feed intake	60
5.4 Estimation of N and P contents in the animal feed	61
5.5 Estimation of animal production	62
5.6 Estimation of the N and P contents in animal products	63
6 Default excretion coefficients for cattle	65
6.1 Introduction	65
6.2 Excretion coefficients of nitrogen for dairy cattle	66
6.3 Excretion coefficients of nitrogen for other cattle	70
6.4 Excretion coefficients of phosphorus for cattle	75
7 Default excretion coefficients for pigs	78
7.1 Introduction	78
7.2 Excretion coefficients for sows + piglets, weaners and fatteners	78
7.3 Excretion coefficients of phosphorus for pigs	81
8 Default excretion coefficients for poultry	83
8.1 Introduction	83
8.2 Excretion coefficients of nitrogen for layers	83
8.3 Excretion coefficients of nitrogen for broilers	85
8.4 Excretion coefficients of phosphorus for poultry	87

9	Conclusions and recommendations	89
9.1	Introduction	89
9.2	Conclusions	90
9.3	Recommendations	93
	References	98

Executive Summary

Introduction

The general objective of the study "*Nitrogen and phosphorus excretion coefficients for livestock*" (Lot 1); *Methodological studies in the field of Agro-Environmental Indicators*" (2012/S 87-142068) is "to bring clarity into the issue of excretion coefficients so that a recommendation on a single, common methodology to calculate N and P excretion coefficients can be identified. The recommendation for a uniform and standard methodology for estimating N and P excretion coefficients must be based on a thorough analysis of the strength and weaknesses of the existing methodologies and on the data availability and quality in the Member States.

The specific objectives of the study are:

- To create an overview of the different methodologies used in Europe to calculate excretion factors for N and P, and analyse their strengths and weaknesses;
- To set up a database with the excretion factors presently used in different reporting systems and describe the main factors that cause distortion within a country and across the EU;
- To provide guidelines for a coherent methodology, consistent with IPCC and CLTRP guidelines, for calculating N and P excretion factors, and taking into consideration the animal balance and taking into account different methodologies identifies under the first bullet point;
- To create default P-excretion factors that can be used by the countries who do not have yet own factors calculated;
- To identify the main components of the calculations of excretion factors and the data requirements for these components in such a detail that they allow introducing them in data collection systems.

The study consists of seven Tasks, each with specific objectives. The task reported here (*Task 5 Guidelines for a common methodology*) builds further on the analyses carried out in Tasks 1, 2, 3, 4 and 6. The main aims of Task 5 are:

- To provide guidelines for a coherent methodology for calculating N and P excretion factors; guidelines must be consistent with IPCC and CLTRP guidelines, and recent scientific results, and must take into consideration the diversity of agricultural systems in Europe, the need for underlying data and emission mitigation accounting;
- To analyse the robustness of the suggested approaches, and the strength and weakness of the suggested methodology;
- To identify the main components of the calculations of excretion factors and the data requirements for these components in such a detail that they allow introducing them in data collection systems.

This executive summary provides a brief overview of the whole project, with an emphasis on the recommendations for a coherent, common methodology.

Background

Livestock production systems exert various influences on the environment. The influences greatly depend on the livestock production system itself, the management and the environmental conditions. Much of the influence on the environment occurs via feed production, manure utilization and through emissions association with animal production.

Globally, approximately 70% of the agriculturally used land area is for the production of feed. However, only 40 to 60% of the carbon (C) and 10 to 50% of the nitrogen (N) and phosphorus (P) in feed are retained by the animals in meat, milk and egg, while the remainder is excreted in urine and faeces. As such, livestock excreta is a large source of C, N, P and other (micro) nutrients, to be used for increasing soil fertility and crop yields. Globally, livestock excretes about 100 Tg N per year (range 70-140 Tg, but only 20-40% of this amount is recovered and applied to crop land. Most of the remainder is dissipated into the environment. The amounts of P and potassium (K) in livestock manure are roughly 1.5 and 3 times the current amounts of P and K in mineral fertilizers, respectively. The total amount of N excreted by livestock in the 27 Member States of the European Union (EU-27) is in the range of 10-11 Tg and the total amount of P excreted ranges between 1.5 and 2.5 Tg per year. These amounts are in the same order of magnitude as the amounts of N and P in fertilizers in EU-27. However, the estimated N and P excretions are uncertain. Member States in the EU-27 estimate N and P excretions for the purpose of the estimation of N and P inputs to agricultural land, (gross) N and P balances, ammonia emissions, and greenhouse

gas emissions. Currently, consistency is lacking (i) at national level for excretion coefficients used for different policies, and (ii) at EU-27 level, for excretion coefficients used by Member States. These inconsistencies arise from the use of different methodologies and the use of different data (quality).

Materials and Methods

Reports from all Member States of the EU-27 and other countries with information about N and P excretion coefficients, manure production volumes, N and P contents of manure and gaseous N losses from manure storages were reviewed. For each of the reports, the methodology applied, the N and P coefficients per animal category, and the spatial scale were recorded. In addition, assessments were made of the completeness, strength and weaknesses of the methodology, the data and information used, and the quality control procedures. The following reports have been reviewed:

- General scientific literature about N and P excretion coefficients;
- OECD/Eurostat reports on Gross Nitrogen and Phosphorus Balances;
- Member States' Action Programmes under the EU Nitrates Directive;
- Member States' inventories of greenhouse gas emissions under the UNFCCC
- Member States' inventories of ammonia emissions under the UNECE-CLRTAP and EU-NEC;
- The FAO Life Cycle Analysis (LCA) of livestock production;
- The IIASA methodology applied in the model RAINS/GAINS
- The methodology applied in the GGELS project;

Results of the inventory were stored in a database with N and P excretion coefficients per animal category and Member States. Next, systematic and in-depth analyses were made of selected countries, and the strength and weaknesses of the methodologies, their data requirements, accuracy and practical feasibility were assessed. Based on the aforementioned analyses, draft guidelines for common approaches and methodologies have been developed.

Results and Discussion

General observations

Most of the pertinent policies require the reporting of gross N and P excretion (ex animal) per animal category. However, some policies (e.g. Nitrates Directive, Gross Nitrogen Balances, national policies on fertilization planning) require the reporting of N excretion

corrected for gaseous N losses during storage (ex storage). The latter is also called 'manure N and P production' , which for P is assumed to be equal to P excretion. Generally, three pertinent scales are distinguished, i.e., farm level, regional level (which can be an administrative unit, i.e., district, county, NUTS 2, or a catchment) and national scale, depending on the purpose of the accounting.

Roughly three methodologies for the estimation of N and P excretion and production are applied by Member States, i.e., (i) default coefficients, based on literature studies and expert judgement, (ii) input-output balance calculations, and (iii) measurements of the volume and N and P contents of manure produced. The most common method is the input-output balance calculation, which assumes that the amount of N and P excreted in faeces and urine is equal to the total amount of feed N and P consumed minus the N and P retained in marketed products (milk, meat, eggs, live weight gain), respectively. Hence, excretion = intake – retention. All methodologies allow in principle for making adjustments according to the length of the production cycle, to provide an annual output factor per "animal place" . The latter is necessary to allow for non-productive time needed for cleaning and re-stocking the housings.

Input-output balances require the estimation of the intake of N and P via feed, and of the N retention in animal products. The amounts of N and P consumed by the animal depends on the amount of feed digested by the animal, and the N and P contents of that feed. Total feed intake depends on the maintenance cost and production level of the animal (e.g., growth rate, milk and egg production), and the feeding value and digestibility of the feed. Data on the annual N and P retention in meat, egg, milk, or wool produced is usually derived from production statistics and scientific reports about the N and P contents in animal products.

Review of policy reports

For reporting emissions of greenhouse gases from agriculture to the UNFCCC, detailed IPCC guidelines are available, which include recommendations for the calculation of N excretion coefficients. The Guidelines contain recommendations at three levels of detail (Tier levels). The Tier 1 approach is the most simple method and includes default estimates of N excretion coefficients. The Tier 2 and 3 approaches Of IPCC are more detailed; Tier 3 include

country specific methodologies and estimates. Our inventory indicates that 4 Member States use default coefficients (Tier 1) and 21 use country specific methodologies (Tier 3), while the method was not clearly reported for 2 Member States.

For reporting emissions of ammonia from agriculture to the UNECE-CLRTAP and EU-NEC, detailed guidelines are provided by the EMEP/EEA Air Pollutant Emission Inventory Guidebook, which include recommendations for the calculation of N excretion coefficients, at two Tier levels. Our inventory indicates that 18 Member States use default N excretion coefficients and 9 use country specific methodologies. The OECD/Eurostat Nitrogen and Phosphorus Balance Handbooks provide also guidance to the calculations of N and P excretion coefficients. When N and P excretion coefficients are not compliant with the guidelines in the OECD/Eurostat Handbook, OECD/Eurostat take estimates from pertinent country reports to the UNFCCC.

Our review indicates that the N excretion coefficients per animal category may vary by up to a factor of 2 between Member States. The same holds for P excretion. Interestingly, estimated N excretion coefficients per animal category may vary up to 20% for a Member State, depending on the (policy) reports.

Country-specific estimation of N and P excretion coefficients

Country-specific input-output balances require information about N and P retention in animal products and about the intake and composition of feed per animal category. Our in-depth analyses indicate that differences between countries in N and P excretion coefficients are a result of differences in the N and P contents of animal products, the N and P contents of the animal feed, and animal performance. A fraction of these differences can be ascribed to differences in production systems (difference in (i) animal breeds and marketed animal products, (ii) feed rations and use of (veterinary) supplements (including antibiotics, hormones), (iii) production level (intensity), (iv) housing systems, and (v) size of the system and level of specialisation. Another fraction is likely related to “noise” in the data. Data origin is a main source of difference.

Towards a common approach

The data collection – processing – reporting systems for N and P excretion by livestock in EU-27 are diverse and often complex, in part because of differences between Member States in livestock production systems and in historical and cultural backgrounds. A

common methodology would allow for a common and transparent estimation of N and P excretion in EU-27, and hence for a common basis for the estimation of manure N and P production, N and P balances, and ammonia and greenhouse gas emissions.

Best practice for estimating N and P excretion coefficients is applying the 'balance method' , i.e., nutrient excretion = feed nutrient intake – nutrient retention in the animal and animal products. In all cases, a mass balance approach must be applied for the derivation of the excretion coefficients per animal category, i.e.,

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

where

$N_{\text{excretion}}$ and $P_{\text{excretion}}$ are the total N and P excretion (kg per animal per year), respectively,

N_{intake} and P_{intake} are the total N and P intake via animal feed (kg per animal per year), respectively,

$N_{\text{retention}}$ and $P_{\text{retention}}$ are the total amounts of N and P retained in milk, meat, egg, wool, etc., (kg per animal per year), respectively.

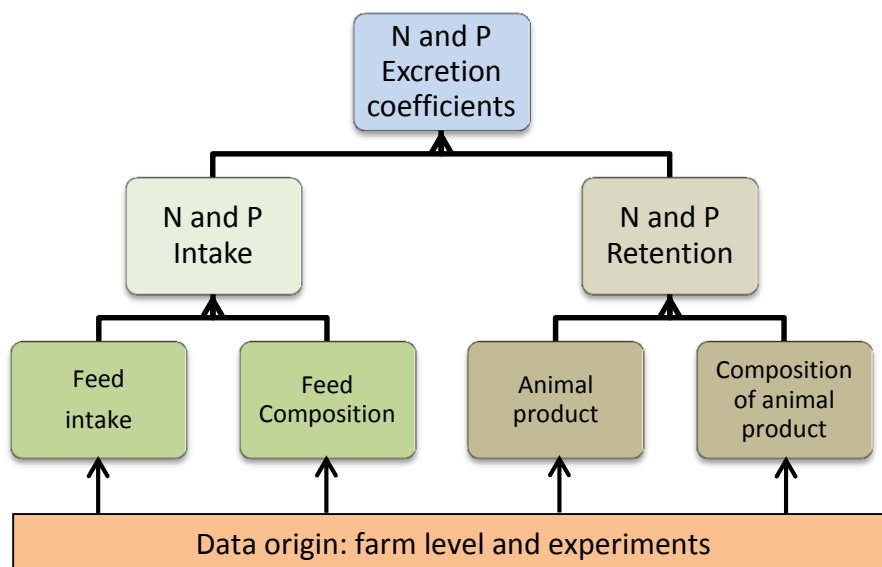


Figure 1 Data needed for the estimation of nitrogen and phosphorus excretion coefficients with the mass balance (see text).

This is a simple and robust method. The primary data for the estimation of N and P excretion coefficients have to be collected at farm level and in experiments, and proceeds in steps (see Figure 1). The animal-specific excretion coefficients must be derived on the basis of data and information of animal breeds, animal feeding, feed composition, animal productivity and the composition of the animal products (Figure 1). The following five building blocks can be distinguished:

1. Robust animal categorization with the number of animals per animal category;
2. Feed intake per animal category;
3. Feed composition (i.e., the N and P contents of the feed) per animal category;
4. Animal production per animal category;
5. Composition of the animal products (i.e., the N and P contents) per animal category

The collection of accurate data and information about feed use and composition, and animal production and composition per animal category may follow a three-tiered approach (see Figure 2). A three-tier approach describes three procedures for the collection of data that are needed for the estimation of N and P excretion coefficients. The three tiers are a function of the relative importance of the animal category, and the data collection/processing infrastructure.

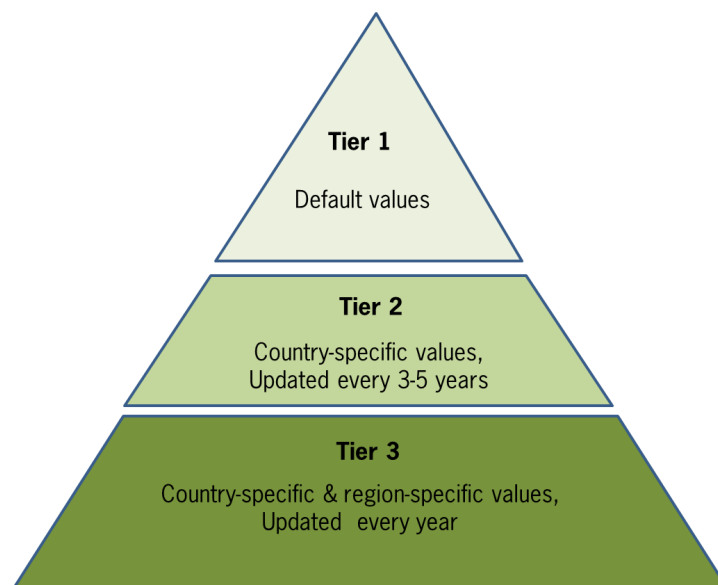


Figure 2 The three-tier approach for the collection of data that are needed for the estimation of N and P excretion coefficients per animal category.

The Tier 1 approach applies the most simple approach for data collection. In the Tier 1 approach default excretion coefficients per animal category are established. These default values should be evaluated and updated every 3 to 5 years, using the mass balance approach and accurate data to be able to apply the mass balance approach. The Tier 2 approach applies country-specific data to estimate excretion coefficients per animal category. These country-specific excretion coefficients should be evaluated and updated every 3 to 5 years, using the mass balance approach and accurate data, to be able to apply the mass balance approach. The Tier 3 approach applies country-specific or region-specific data to estimate excretion coefficients per animal category. These country-specific or region-specific excretion coefficients should be evaluated and updated every year, using the mass balance approach and accurate data to be able to apply the mass balance approach.

Conclusions

- When reporting N and P excretion coefficients in policy reports, countries in EU-27 often use different approaches, which often lead to different estimates of the N and P excretion coefficients.
- An in-depth analysis of country reports indicated that the differences in N and P excretion coefficients per animal category may result from differences in animal productivity and animal husbandry practices, but also due to differences in (1) animal categorization, (ii) methods, and (iii) data and information collection/processing/reporting procedures.
- There are relatively large differences in the categorization of animal species between 'formal inventories and databases'. This diversity in animal categorization hampers a comparison of excretion coefficients between countries. Moreover, it suggests 'inefficiencies' in (duplication of) data collection/processing/reporting. Evidently, there is a need for harmonization of animal categorization systems.
- Main animal categories in most countries are cattle, pigs and poultry. These animal categories commonly account for more than 75% of the total N and P excretion within a country. For all other animal categories (buffaloes, horses, donkeys, mink, foxes, rabbits, guinea-pigs, hamsters, deer) together, the total N and P excretion is commonly less than 25%. Hence, most efforts should be made in estimating the N and P excretion coefficients of cattle, pigs and poultry correctly.
- The variation in N and P excretion coefficients within animal categories are relatively large for dairy cattle, due to relatively large differences in cattle breeds, milk production

per cow, feed management and especially protein content of the animal feed, and housing versus grazing.

- The variation in N and P excretion coefficients of broilers and layers is relatively small for conventional systems, as the animal breeds and feed composition does not vary much between farms and between countries, due to the effects of competition and globalization. However, differences between organic and conventional systems in N and P excretion coefficients for broilers and layers may be up to a factor of 2. This holds especially when high efficient conventional broiler production systems are compared with moderate efficient organic broiler production systems.
- Differences in production systems, within an animal category, which lead to differences in N and P excretion coefficients, are mainly defined by differences in:
 - Animal breeds (small vs large breeds, low vs high productivity),
 - Marketed animal products (small vs large final weight, young vs old animals)
 - Feed rations (e.g., low vs high protein)
 - Use of (veterinary) supplements in the animal feed (including antibiotics, hormones)
 - Production level (intensity)
 - Housing systems, including grazing vs restricted grazing vs zero-grazing systems

These aspects must be considered in accounting N and P excretion of the main animal categories (e.g., cattle, pigs, poultry) when the influence of variations in production systems on N and P excretion coefficients is significant.

- The balance method is a common and universally applicable method to estimate N and P excretion coefficients at farm level, regional level and national levels. The accuracy and quality of the calculated excretion coefficients depends on the quality of the data used (data origin). To enable review of the quality of excretion coefficients, it is necessary to document the data origin.
- There are five building blocks when applying the mass balance method:
 - Animal categorization with the number of animals per animal category;
 - Feed intake per animal category;
 - Feed composition (i.e., the N and P contents of the feed) per animal category;
 - Animal production per animal category;
 - Composition of the animal products (i.e., the N and P contents) per animal category

- Any common, universal approach (including the mass balance approach) must account for the differences between countries in (i) the importance of livestock production, and hence in the relative magnitude of N and P excretion as a source of N and P, (ii) the type of livestock production systems (animal species, animal housing, animal feeding), and (iii) in the data and information collection and processing infrastructure. This holds especially also for the EU-28, where mean livestock density may range between Member States from an average of less than 0.5 livestock units (LSU) per ha to more than 3 LSU per ha.
- A three-tier approach addresses the aforementioned differences between countries in importance and type of livestock production and data collection/processing/reporting infrastructure. It describes three approaches for the collection of data that are needed for the estimation of N and P excretion coefficients. The three tiers are a function of the relative importance of the animal category, and the total N and P excretion by livestock within a region or country. All three tiers apply the mass balance method, but differ in the efforts needed to collect the data and information for estimating the N and P excretion coefficients, and thereby also in the accuracy of the coefficients.
- Main determinants of N and P excretion and hence for the selection of the most appropriate Tier are (i) livestock density, (ii) animal productivity in combination with animal feeding, and (iii) the relative importance of livestock categories. Decision trees have been developed for selecting the most appropriate Tier per country and per livestock category
- The proposed three-tier approach for the collection of data and information for the estimation of N and P excretion coefficients is also consistent approach, because in all three Tiers a mass balance approach is applied for the derivation of the excretion coefficients per animal category, i.e.,

$$\bigcirc \quad N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$\bigcirc \quad P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

This balance approach can be applied at scales ranging from an animal, a farm, a region, country, continent and the whole world. The mass balance approach is also consistent with IPCC and CLTRP guidelines; Tier 2 of the IPCC guidelines applies a mass balance approach, while Tier 3 of both IPCC and CLTRAP apply country-specific approaches, which are based on a mass balance.

- A decision tree has been developed which allows to find the most appropriate Tier. The choice of a Tier depends on (i) the importance of animal production and hence total N

excretion within a country, the importance and size of an animal category and hence the total N excretion by this animal category, (iii) the regional variation in N excretion within a country, and (iv) the data availability within a country.

- Default N excretion coefficients have been established for the main animal categories, as function of age, production level and (main) production systems. Also, default P excretion coefficients have been derived as function of age and production level.

Recommendations

- It is recommended to use the mass balance as a common and universally applicable method to estimate N and P excretion coefficients per animal category across EU-28:

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

- It is recommended to use a 3-Tier approach for the collection of data and information needed to estimate N and P excretion coefficients, so as to address differences between countries in livestock production and data collecting/processing infrastructure, and to economize on data collection/processing efforts. The three Tiers differ in the origin, scale and frequency of data and information collection.
- It is recommended to use a Tier 3 approach for all main animal categories when livestock density in a country is > 2 livestock units per ha (>2 LSU per ha), equivalent to an excretion of about > 200 kg N and > 40 kg P per ha agricultural land per year.
- It is recommended to use a Tier 2 approach for all main animal categories when livestock density in a country is > 0.5 LSU < 2 per ha (equivalent to an excretion of about > 50 kg N <200, and > 10 kg P < 40 per ha agricultural land per year).
- It is recommended that countries invest in Tier 2 and 3 methods (and hence use country-specific, region-specific and/or year-specific excretion coefficients).
- It is recommended to use a Tier 1 approach for all animal categories within a country when total livestock density is <0.5 livestock units per ha (<0.5 LSU per ha), which is equivalent to about 50 kg N and 10 kg P per ha agricultural land per year.
- It is recommended to use region-specific N and P excretion coefficients when N and P excretion coefficients of the main animal categories differ significantly (>20%) between regions.
- It is recommended that computer programs are made available to allow the calculation of the N and P excretion per animal category at regional and national levels in a uniform

way. It is also recommended to provide training courses for the use of these programs and the calculation of the N and P excretion coefficients.

- It is recommended that all countries have well-documented and accessible methods for the estimation of N and P excretion coefficients per animal category. These reports should be updated once every 3-5 years and reviewed by external experts.
- We recommend that efforts are undertaken to harmonise the various animal categories in formal policy reporting. We recommend that the FSS categorization is taken as the main list of animal categories, also because the inventory of the number of animals takes place regularly according to the FSS list of animal categories. We recommend also that a transparent scheme and computer program is developed for translating the inventory data of FSS into the current animal categories of secondary databases (e.g., UNFCCC/IPCC, EMEP/EEA, Nitrates Directive, FAO and OECD).
- For main animal categories (e.g., cattle, pigs and poultry, contributing >10% to the total N and P excretion within a country and/or region) it is recommended to consider a secondary categorization according to 'production system' , when more than 20% of the animals are in "another" system and when the N and/or P excretion coefficients differ by more than 20% from the overall mean N and P excretion coefficients. We recommend to distinguish between:
 - Fast-growing and heavy breeds vs slow-growing breeds
 - Organic production systems vs common production systems
 - Housed ruminants vs grazing ruminants
 - Caged poultry vs free-range poultry
- It is recommended that a review is made of the diversity of production systems within a country for the main animal categories cattle, pigs and poultry once in 5 yrs, so as to trace changes in production systems, including organic versus conventional systems, housed vs grazing ruminants, caged versus free range poultry, and fast growing breeds versus slow growing breeds.
- It is recommended that the N and P excretion coefficients for main animal categories (cattle, pigs poultry) in countries with a relatively high livestock density are updated every year (Tier 3 approach), because of rapid developments in animal breeding and production systems, and changes in feeding ingredients as function of weather and market conditions.

- It is recommended that the N and P excretion coefficients for minor animal categories (sheep, goat buffaloes, horses, donkeys, mink, foxes, rabbits, guinea-pigs, hamsters, deer) are updated once in 3-5 yrs.

1 Introduction

Livestock production systems exert various influences on the environment (e.g. Steinfeld et al., 2006). The influences greatly depend on the livestock production system itself, the management and the environmental conditions. Much of the influence on the environment occurs via feed production, manure utilization and through emissions association with animal production (FAO, 2009; Herrero, et al., 2013). The expectation for the next few decades is that the livestock production sector will further expand by 30 to 50%, though not in all continents equally (Alexandratos and Bruinsma, 2012).

The Gross Nitrogen Balance (GNB) is a key indicator for assessing the effects of agriculture on the environment. For establishing accurate GNBs, accurate information is needed of all input and output items of the GNB, at national and preferably regional scales (Sutton et al., 2011, and references therein).

The amount of nitrogen (N) in manure entering agricultural land and the amount of N leaving agricultural land in harvested grass, either via grazing or mowing, are the least accurate items on the GNB, because these flows are not measured at farm or national level. In fact, these flows are extremely difficult to measure directly; they can more easily be quantified in an indirect way. Currently, there are no uniform, standard and accepted methodologies and terminologies for estimating the amounts of N and P in animal excrements. Member States tend to use methods which they have developed and improved over time, and sometimes use different methodologies for different reporting requirements, as reported by the DireDate project (Oenema et al., 2011; http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-11-005/EN/KS-RA-11-005-EN.PDF). This makes comparisons between countries and estimates at EU-27 level complicated.

Globally, approximately 70% of the agriculturally used land area is for the production of animal feed (Steinfeld et al., 2010; Herrero et al., 2013). However, only 40 to 80% of the carbon (C) and 10 to 50% of the nitrogen (N) and phosphorus (P) in feed are retained by the animals in meat, milk and egg, while the remainder is excreted in urine and faeces. As such, livestock excreta is a large source of C, N, P and other (micro) nutrients, to be used for increasing soil fertility and crop yields. Globally, livestock excretes about 100 Tg N per year (range 70-140 Tg), but only 20-40% of this amount is recovered and applied to crop land (Oenema et al., 2005). Most of the remainder is dissipated into the environment. The

amounts of P and potassium (K) in livestock manure are roughly 1.5 and 3 times the current amounts of P and K in mineral fertilizers, respectively (Sheldrik et al., 2003).

The total amount of N excreted by livestock in the 27 Member States of the European Union (EU-27) is in the range of 10-11 Tg and the total amount of P excreted ranges between 1.5 and 2.5 Tg per year (Oenema et al., 2007). These amounts are in the same order of magnitude as the amounts of N and P in fertilizers in EU-27. However, the estimated N and P excretions are uncertain. Member States in the EU-27 estimate N and P excretions for the purpose of the estimation of N and P inputs to agricultural land, (gross) N and P balances, ammonia emissions, and greenhouse gas emissions. Currently, consistency is lacking (i) at national level for excretion coefficients used for different policies, and (ii) at EU-27 level, for excretion coefficients used by Member States. These inconsistencies arise from the use of different methodologies and the use of different data (quality).

In response, the European Commission initiated by the end of 2012 the study "Nitrogen and phosphorus excretion factors for livestock", which is Lot 1 of "Methodological studies in the field of Agro-Environmental Indicators" (2012/S 87-142068). The general objective of the Lot 1 study is *'to bring clarity into the issue of excretion factors so that a recommendation on a single, common methodology to calculate N and P excretion coefficients can be identified'*. Recommendation for a uniform and standard methodology for estimating N and P excretion coefficients must be based on a thorough analysis of the strength and weaknesses of the existing methodologies and on the data availability and quality in the Member States. Therefore, the specific objectives of the study are:

- To create an overview of the different methodologies used in Europe to calculate excretion factors for N and P, and analyse their strengths and weaknesses;
- To set up a database with the excretion factors presently used in different reporting systems and describe the main factors that cause distortion within a country and across the EU;
- To provide guidelines for a coherent methodology, consistent with IPCC and CLTRP guidelines, for calculating N and P excretion factors, and taking into consideration the animal balance and taking into account different methodologies identifies under the first bullet point;
- To create default P-excretion factors that can be used by the countries who do not have yet own factors calculated;
- To identify the main components of the calculations of excretion factors and the data requirements for these components in such a detail that they allow introducing them in data collection systems.

Within this study the following seven tasks are distinguished, each with specific deliverables:

Task 1 Overview of existing excretion factors

Deliverables:

- a database covering all EU member states with the different excretion factors used;
- a report per country on the methodologies used for the different factors.

Task 2 In-depth analyses of selected country reports

Deliverable:

- a report per country on the methodologies used for the different factors, the reasons for the choice of the particular method, the strengths and weaknesses of the approaches and other similar issues, including the NUTS level involved in calculations

Task 3 Analyses of the coherence, differences and best practices

Deliverables:

- a report on the coherence and differences of the different methodologies used for reporting on excretion
- a report on the comparability of the different data flows and on the coherence of the data reported to different institutions
- a report on best practices identifies across EU.

Task 4 Regional representativeness

Deliverable:

- a report on the need for regional excretion factors and data to be collected at regional level

Task 5 Guidelines for a common methodology

Deliverables:

- draft guidelines for potential common methodologies for estimating N and P excretion factors to be discussed in the workshop in Task 7
- final guidelines based on the workshop in Task 7.

Task 6 Default P excretion factors

Deliverable:

- A report establishing default values for components in the calculation of P excretion factors.

Task 7 Expert/ statistician workshop

Deliverables:

- Support to organising the workshop
- A workshop document summarising the outcome of Tasks 1-6, with specific focus on Task 5
- The minutes of the workshop.
- The revision of the preliminary results of task 5, on the basis of the conclusions of the workshop.

The task reported here (*Task 5 Guidelines for a common methodology*) builds further on the analyses carried out in Tasks 1, 2, 3 and 4. The main aims are:

- To provide guidelines for a coherent methodology for calculating N and P excretion factors; guidelines must be consistent with IPCC and CLTRP guidelines, and recent scientific results, and must take into consideration the diversity of agricultural systems in Europe, the need for underlying data and emission mitigation accounting;
- To analyse the robustness of the suggested approaches, and the strength and weakness of the suggested methodology;
- To identify the main components of the calculations of excretion factors and the data requirements for these components in such a detail that they allow introducing them in data collection systems.

The expected outcome of the work reported here is:

- Draft guidelines for potential common methodologies for estimating N and P excretion factors to be discussed in the workshop of Task 7.
- Final guidelines based on workshop of Task 7.

In Chapter 2, general guidelines for a common three-tier methodology are presented. Chapter 3 presents an overview of animal categorization and suggestions for a more uniform animal categorization. Chapter 4 presents guidelines to facilitate the selection of the proper Tier and to identify the need for regional-specific excretion coefficients. Chapter 5 identifies the main components of the calculations of excretion factors and the data requirements for these components in such a detail that they allow introducing them in data collection systems. Chapters 6, 7 and 8 provide default N and P excretion coefficients for cattle, pigs and poultry, respectively. Finally, the main conclusions and recommendations are summarized in Chapter 9.

2 Towards a common approach

2.1 Introduction

Currently, there is not a common, universal approach that is used for estimating nitrogen (N) and phosphorus (P) excretions by livestock. When reporting N and P excretion coefficients in policy reports, countries often use different approaches, which often lead to different estimates of the N and P excretion coefficients (Velthof, 2014)¹. A further in-depth analysis indicated that the differences in N and P excretion coefficients between countries may result from differences in animal productivity and animal husbandry practices, but also due to differences in (i) animal categorization, (ii) methods, and (iii) data and information collection/processing/reporting procedures (Sebek et al., 2014)². Evidently, these studies indicated that there is a clear need for a common, harmonized approach for estimating N and P excretion coefficients.

Any common, universal approach must account for the differences between countries in (i) the importance of livestock production, and hence in the relative magnitude of N and P excretion as a source of N and P, (ii) the type of livestock production systems (animal species, animal housing, animal feeding), and (iii) in the data and information collection infrastructure. This holds especially also for the EU-28, where livestock density may range from an average of less than 0.5 livestock units (LSU) per ha to more than 3 LSU per ha. Also, some countries have relatively large populations of cattle (dairy and/or beef), while other countries have relatively more pigs or poultry or sheep or goat. Further, countries with a high livestock density commonly have developed a more detailed infrastructure for data and information collection than countries with a low livestock density.

¹ Velthof, G.L. (2014). Overview of existing excretion factors in European Countries. Report Task 1 of Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat (2012/S 87-142068), Luxembourg.

² Šebek, L.B. P. Bikker, A.M. van Vuuren, and M. van Krimpen. (2014) Nitrogen and phosphorous excretion factors of livestock. Task 2 : In-depth analyses of selected country reports. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat (2012/S 87-142068), Luxembourg.

For national greenhouse gas inventories, countries base the greenhouse gas emissions methods provided by the IPCC guidelines, which recommendations for the calculation of the N excretion of livestock (IPPC, 2006). These guidelines do consider differences between countries in the importance and types of livestock production and data availability through distinguishing a three-tier approach. The Tier 1 approach is the most simple method and includes default estimates of excretion. The Tier 2 approach is based on a mass balance approach ($N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$), and included default values for the fraction of N retained in animal products. The Tier 3 approach is a country-specific approach, used by countries that have the knowledge and data acquisition infrastructure for estimating N excretion coefficients with a refined method. As shown by Velthof (2014), all three Tiers are being used in the greenhouse gas emission inventories. The IPCC guidelines do not provide guidelines for estimating P excretion coefficients.

For national ammonia (NH₃) inventories, countries base the NH₃ emissions on methods provided by the EMEP/EEA air pollutant emission inventory guidebook (formerly referred to as the EMEP/CORINAIR emission inventory guidebook). These guidelines do also consider differences between countries in the importance and types of livestock production and data availability through distinguishing a three-tier approach. The Tier 1 approach is the most simple method and includes default NH₃ emission coefficients per animal category. The Tier 2 approach provides default values for N excretion coefficients. The Tier 3 approach is a country-specific approach, used by countries that have the knowledge and data acquisition infrastructure for estimating N excretion coefficients with refined methods.

In the methodology of the Eurostat/OECD nutrient balances and OECD Phosphorus Balance Handbook also different methods have been used for different countries to estimate N and P excretion coefficients. Two methods are suggested for the amount of N and P in animal manure (i) direct measurements, and (ii) the mass balance ($N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$). As shown by Velthof (2014), a range of methods are being used for estimating the amounts of N and P in animal manure.

Best available techniques (BAT) for pig and poultry production have been described in detail in “Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry and Pigs” (European Commission, 2013). However, this document does not provide best practices and/or guidelines for calculating N and P excretion coefficients.

Finally, the ERM/AB-DLO study (Ketelaars and van der Meer, 1999) presents a general basis for the estimation of N excretion coefficients in the framework of the EU-Nitrates Directive. This study applies the mass balance to all animal categories uniformly. However, the ERM/AB-DLO study does not consider differences between countries in the importance and types of livestock production and in data availability. It just applies one uniform method to all animal categories and to all countries.

In short, a variety of methods are being used by countries to estimate N and P excretion coefficients. No common, universal approach is available yet. The IPCC Guidelines provide the most detail guidance for estimating N excretion coefficients (but not for P), and do account for the differences between countries. However, each Tier is based on a different approach (in principle). Also, the estimated uncertainties for the Tier 1 coefficients are relatively large ($\pm 50\%$) and the default N retention coefficients may also vary significantly.

The purpose of this chapter is to present a common, universal approach that can be used by all countries for the estimating of N and P excretion coefficients. The approach accounts for differences between countries in the importance and types of livestock production systems, and in data and information collection procedures, but not in the method. In all cases, in all Tiers, a mass balance method is being applied: $N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$. Differences between the Tiers relate only to differences in data collection procedures. This chapter summarizes a common, universal approach for estimating N and P excretion coefficients.

2.2 A common mass balance approach

The following common mass balances are proposed for estimating animal-specific N and P excretion coefficients:

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

where

$N_{\text{excretion}}$ and $P_{\text{excretion}}$ are the total N and P excretion (kg per animal per year), respectively, N_{intake} and P_{intake} are the total N and P intake via animal feed (kg per animal per year), respectively,

$N_{\text{retention}}$ and $P_{\text{retention}}$ are the total amounts of N and P retained in milk, meat, egg, wool, etc., (kg per animal per year), respectively.

The mass balance method is a simple and robust method, universally applicable. The mass balance can be applied at different scale, from animal level, farm level (see box 1), regional

level, country level and global level. Figure 1 illustrates the mass balance for estimating the animal-specific N and P excretion coefficients in more detail and indicates the data that are needed for applying the mass balance.

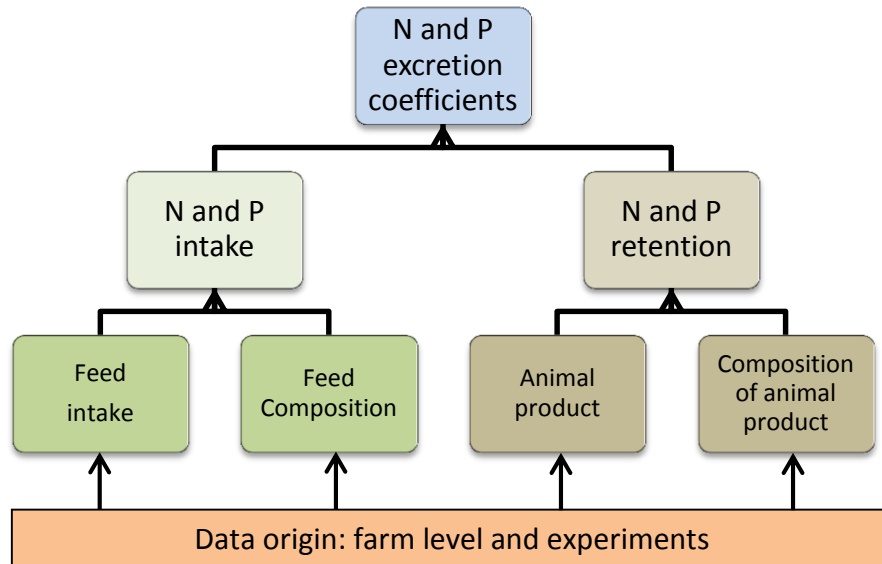


Figure 1 Data needed for the estimation of animal-specific N nitrogen and phosphorus excretion coefficients with the mass balance: $N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$ and $P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$ (see text).

The animal-specific excretion coefficients must be derived on the basis of data and information per animal category. Hence, the mass balance must be applied to each functional animal category. Different animal categories are distinguished, on the basis of animal species and further possibly on the basis of animal breeds, sex, age, weight, production system, productivity, and animal feeding. The animal categorization is further discussed in Chapter 3.

For each animal category the following four building blocks can be distinguished in the mass balance:

1. Feed intake;
2. Feed composition (i.e., the N and P contents of the feed);
3. Animal production; and
4. Composition of the animal products (i.e., the N and P contents).

The annual N_{intake} and P_{intake} and the annual $N_{\text{retention}}$ and $P_{\text{retention}}$ are obtained by applying the following formulae per animal category (all in kg N and P per animal per year):

Annual N_{intake} and $P_{\text{intake}} = [\text{annual feed intake}] \times [\text{mean N and P composition of the feed}]$

Annual $N_{\text{retention}}$ and $P_{\text{retention}}$ = [annual animal production] x [mean N and P composition of the animal products]

The annual $N_{\text{excretion}}$ and $P_{\text{excretion}}$ are obtained by applying the following formula per animal category (all in kg N and P per animal per year):

Annual $N_{\text{excretion}}$ and $P_{\text{excretion}}$ = [Annual N_{intake} and P_{intake}] - [Annual $N_{\text{retention}}$ and $P_{\text{retention}}$]

The estimation of the feed intake by animals and the estimation of the N and P retention in animal products is further discussed in Chapter 5. In general, the accurate estimation of N and P in feed intake is more complex than the estimation of N and P in animal products. For animal categories that are housed during their whole live, the estimation of the N and P in feed intake follows from their total feed supply (possibly corrected for unused feed) and the mean N and P contents of the animal feed. The estimation of the feed intake by grazing animals (cattle, sheep and goat) is more complex, as feed intake during grazing cannot be weighted. In this case, the energy and protein requirements of the animals, as function of animal production, are estimated from equations established by scientists and published in peer-reviewed publications and reports. In this case, a balance is established between (i) calculated feed requirements and (ii) estimated feed supply, in terms of digestible energy (see Chapter 5).

Box 1. Application of the mass balance at farm level

The mass balance is currently used also on intensive livestock farms and dairy farms in Denmark and The Netherlands. Special computer programs have been developed to estimate farm-specific N and P excretion coefficients and total N and P excretion at farm level. These programs are applicable at farm level and allow the farmer to estimate how much animal manure is produced on the farm and how much may have to be exported from the farm in case the manure N and P production exceeds the room for manure N and P application at the farm. The maximum manure N application is set by the EU 1991 Nitrates Directive at 170 kg of N in the manure that is available for application to land. The maximum P application may be related to the mean P withdrawal with harvested forage crops (suggesting 'balanced P application'). Farms producing more manure N and P than these threshold values may have to export animal manure to other farms, and/or require a

derogation from the obligations of the EU-Nitrates Directive, so as to be able to apply more than 170 kg manure N per ha agricultural land.

2.3 A three-tiered approach for data collection

The collection of accurate data and information in practice about feed use and composition, and animal production and composition per animal category within a region or country is often complicated and time consuming. Hence, there is a need to economize on efforts, depending also on the relative importance of the animal category and the total N and P excretion by livestock within a region or country. Therefore, a three-tiered approach is proposed here for data collection (see Figure 2).

A three-tier approach describes three “approaches” (or efforts or procedures) for the collection of data that are needed for the estimation of N and P excretion coefficients. The three tiers are a function of the relative importance of the animal category, and the total N and P excretion by livestock within a region or country.

The Tier 1 approach applies the most simple approach for data collection, requiring the least efforts. In the Tier 1 approach default excretion coefficients per animal category are established, on the basis of general characteristics of the animal category, animal production system and animal feed composition. These default values should be evaluated and updated every 3 to 5 years, using the mass balance approach discussed in section 2.2.

The Tier 2 approach applies country-specific data to estimate excretion coefficients per animal category. These country-specific excretion coefficients should be evaluated and updated every 3 to 5 years, using the mass balance approach and accurate data, to be able to apply the mass balance approach.

The Tier 3 approach applies country-specific or region-specific data to estimate excretion coefficients per animal category. These country-specific or region-specific excretion coefficients should be evaluated and updated every year, using the mass balance approach and accurate data to be able to apply the mass balance approach.

The data collection approaches of the three Tiers are further discussed in section 2.4

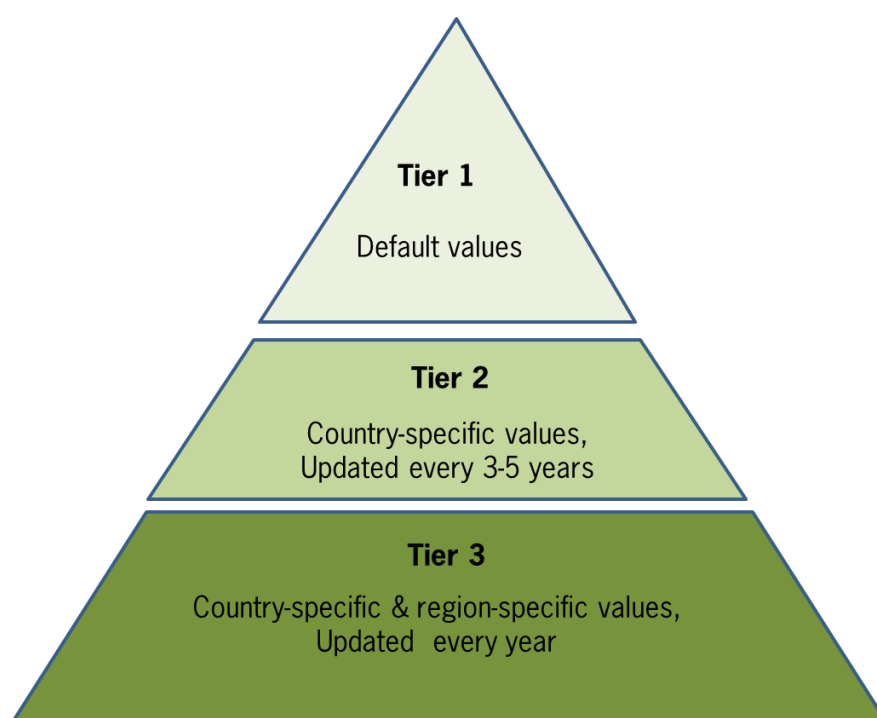


Figure 2 The three-tier approach for the collection of data that are needed for the estimation of N and P excretion coefficients.

2.4 Best practices for data collection

The three Tiers discussed in section 2.3 represent three data collection approaches for the estimation of the total annual N and P excretions per animal category per country. The accuracy of the calculated N and P excretions will vary with the Tier chosen, due to differences in the origin and quality of the data.

To calculate N and P excretion on national (or regional) level, several data origins can be distinguished (Sebek et al., 2014)³. Table 1 shows the recommended data origins for the three Tier levels discussed in section 2.3. The three Tiers differ in the origin of the data (surveys versus literature) and in the update interval of the data. Statistical reference is used

³ Šebek, L.B. P. Bikker, A.M. van Vuuren, and M. van Krimpen. (2014) Nitrogen and phosphorous excretion factors of livestock. Task 2 : In-depth analyses of selected country reports. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat (2012/S 87-142068), Luxembourg.

as an abbreviation for data that are based on a referred national (or regional) inventory (survey).

Table 1. Best practices for data origin of the building blocks of the Tier 1, 2 and 3 methodologies.

Tier level and building blocks	Data origin and update interval						
	Statistical reference		Literature		Update interval, years		
	Yes	No	Natio nal	Inter- national	1	2-5	5-10
Tier 1 Default values for EU							
<i>Animal number per animal category</i>	X					X	
<i>N & P intake</i>		X		X		X	
<i>N & P retention</i>		X		X		X	
<i>Feed intake</i>		X				X	
<i>N & P contents of the feed</i>		X				X	
<i>Animal production</i>		X				X	
<i>N & P contents of the animal products</i>		X					X
Tier 2 Country-specific values							
<i>Animal number per animal category</i>	X					X	
<i>N & P intake</i>		X	X			X	
<i>N & P retention</i>		X	X			X	
<i>Feed intake</i>	X					X	
<i>N & P contents of the feed</i>		X	X			X	
<i>Animal production</i>	X					X	
<i>N & P contents of the animal products</i>		X	X				X
Tier 3 Region & year specific values							
<i>Animal number per animal category</i>	X				X		
<i>N & P intake</i>		X	X		X		
<i>N & P retention</i>		X	X		X		
<i>Feed intake</i>	X				X		

<i>N & P contents of the feed</i>		X	X		X		
<i>Animal production</i>	X				X		
<i>N & P contents of the animal products</i>		X	X				X

The data collection approaches differ in the efforts needed to obtain the required data and information, and thereby also in the precision of the resulting N and P excretion coefficients. For regions and countries with a relatively high livestock density and hence large N and P excretion it is recommended to use Tier 3 (at regional level). Best practice for regions and countries with a relatively low livestock density and hence low N and P excretion and also low data availability is using a Tier 2 approach for the largest animal categories (in terms of numbers and N and P excretion per animal, and a Tier 1 approach for all other animal categories. Further guidance for identifying the most appropriate Tier is provided in Chapter 4. Here, a summary is provided of the three data collection approaches (Tiers).

For Tier 1, the aforementioned data are obtained from the (inter)national literature, which describe the experiments, farms, and/or regions used for the estimation of the required data in a scientifically sound and robust manner. The data collection and calculations are reported and published in peer-reviewed scientific journals or in reviewed reports that are accessible via websites and/or libraries. The reports clearly indicate the animal categories, animal production conditions, feeding systems and regions for which the N and P excretion coefficients hold. Best practice is that these N and P excretion coefficients are reviewed and up-dated once in 3-5 yrs. The result of this procedure is that the N and P excretion coefficients can be considered as “default N and P excretion coefficients” , for the indicated animal category, conditions and regions. Tier 1 N and P excretion coefficients may apply especially to so called ‘small animal categories’ , i.e., animal categories with a very low livestock density in a region and hence with a low total N and P excretion. Default N and P excretion coefficients for cattle, pigs and poultry have been derived in Chapters 6, 7 and 8, respectively.

For Tier 2, the aforementioned data are collected as a “representative” sample per country / region, in a scientifically sound and robust manner. The results of the data collection and calculations are also reported and published in peer-reviewed scientific

journals or in reviewed reports that are accessible via websites and/or libraries. The reports clearly indicate the animal categories, animal production conditions, feeding systems and the country/region for which the N and P excretion coefficients hold. Best practice is that these N and P excretion coefficients are reviewed and up-dated once in 3-5 yrs. The result of this procedure is that the N and P excretion coefficients can be considered as “national (or regional) default N and P excretion coefficients” , for the indicated animal category, conditions and country/region. Tier 2 N and P excretion coefficients typically apply to animal categories that combine a medium to high livestock density with steady feeding and production systems, i.e., systems with relatively few changes in animal productivity and feed composition and quality (see also Chapter 4).

For Tier 3, the aforementioned data are collected as a “representative” sample per country / region, in a scientifically sound and robust manner in a similar way as in Tier 2, but now each year. The results of the data collection and calculations are also reported and published in peer-reviewed scientific journals or in reviewed reports that are accessible via websites and/or libraries. The reports clearly indicate the animal categories, animal production conditions, feeding systems and country/region for which the N and P excretion coefficients hold. Best practice is that these N and P excretion coefficients are reviewed and up-dated every year. The result of this procedure is that the N and P excretion coefficients can be considered as “year-specific N and P excretion coefficients” , for the indicated animal category, conditions and country/region. Tier 3 N and P excretion coefficients typically apply to animal categories that combine a medium to high livestock density with annual fluctuations in feeding and advancing production systems, i.e., systems with relatively large changes in animal productivity and feed composition and quality (see also Chapter 4).

3 Guidelines for animal categorization

3.1 Introduction

There are millions of different species of animals in the world. A species is here defined as a group of organisms capable of interbreeding and producing fertile offspring. Commonly, these millions of different species are grouped into 6 different groups, i.e., invertebrates, fishes, amphibians, reptiles, mammals, and birds (Hickman et al., 2006).

In the course of the last 10,000 years, humans have been able to domesticate only some 14 animal species (Diamond, 2002). Mankind is keeping these 14 species of domesticated animals for a variety of reasons. In terms of societal use they produce meat, milk, eggs, wool, hides, manure and draught, they convert crop residues into food and manure, and they may serve as a savings bank and provide social status. These species fall apart in ruminants (cattle, buffaloes, sheep, goats) and monogastrics (swine, fowl, rabbits, horses, donkeys), because of differences in feeding abilities and strategies. The main domesticated farm animal species are shown in Table 2.

Table 2. List of common domesticated animal species in EU and their estimated date of domestication.

Animal species	Domesticated animal species	Domestication date
Sheep	<i>Ovis orientalis aries</i>	10000 BC
Pig	<i>Sus scrofa domestica</i>	9000 BC
Cattle	<i>Bos taurus</i>	8000 BC
Goat	<i>Capra aegagrus hircus</i>	8000 BC
Chicken	<i>Gallus gallus domesticus</i>	6000 BC
Donkey	<i>Equus africanus asinus</i>	5000 BC
Water buffalo	<i>Bubalus bubalis</i>	4000 BC
Horse	<i>Equus ferus caballus</i>	4000 BC
Reindeer	<i>Rangifer tarandus</i>	3000 BC
Fox	<i>Vulpes vulpes</i>	1800 AD
European Mink	<i>Mustela lutreola</i>	1800 AD
Hamster	<i>Mesocricetus auratus</i>	1930 AD

Domesticated farm animal species are mainly kept for producing milk, meat, egg and wool. The number of draught (or working) animals (mainly horses and cows) have drastically decreased following the introduction of tractors and other mechanization in agriculture. In contrast, the number of leisure animals have rapidly increased during the last decades; these include pet animals (or companion animals) and sport animals (mainly horses and dogs). Further, also the number of laboratory animals have increased.

Because of their different functions, animal species have been categorized in different functional units or animal categories. Animal categories may be based also on the age of the animals (age classes), or on the weight of the animals (weight classes), or on different breeds (and hence different animal performances). Sometimes, the management or housing system is an argument for distinguishing different animal categories, for example caged animals versus free-range animals, of grazing animals versus housed animals. Unlike the categorization of animal species, there is no uniform or unique way of categorization of domesticated farm animals. Different countries use different categories, also because the functions of the animal species may be different in different countries. This chapter briefly reviews the animal categorization in EU-27 and present recommendations for a common categorization.

3.2 Some main animal categories in use in EU-27

This paragraph provides a summary overview of some common animal categories used within EU-27, including, Farm Structure Survey (FSS), Farm Accountancy Data Network (FADN), Livestock regulation (EC) No 1165/2008, OECD/Eurostat database on N and P excretion, Gothenburg Protocol, EEA/CORINAIR, GAINS, CAPRI, and FAO. This summary overview is presented without much further discussion; it follows from the Tables 3 to 15 that there are large differences in the categorization of animals, which is related to the different functions of the databases. The most detailed databases are the FSS and livestock regulation databases. The Eurostat/OECD database on N and P excretion is the most complex.

The basis of the information for the animal categorization are the surveys. There are two surveys that make inventories of livestock, i.e., FSS and Livestock statistics (including slaughter statistics). The data collected in these surveys are the primary sources of activity data. All other databases are derived from these primary data sources, and hence have carried out a secondary categorization.

The FSS is carried out once in one, two to three years, depending on the countries. The list of animal categories of the FSS is shown in Table 3.

Table 3. List of animal categories with their codes as distinguished in the Farm Structure Survey (FSS).

Code.	LIVESTOCK categories
<i>3.01</i>	<i>Equidae</i>
<i>3.02</i>	<i>Bovine animals:</i>
3.02.01	Bovine animals, under one year old, male and female
3.02.02	Bovine animals, one but less than two years old, male
3.02.03	Bovine animals, one but less than two years old, female
3.02.04	Male bovine animals , two years old and over
3.02.05	Heifers , two years old and over
3.02.06	Dairy cows
3.02.99	Other cows
<i>3.03</i>	<i>Sheep and goats:</i>
3.03.01	Sheep (all ages)
3.03.01.01	Breeding females
3.03.01.99	Other sheep
3.03.02	Goats (all ages)
3.03.02.01	Breeding females
3.03.02.99	Other goats
<i>3.04</i>	<i>Pigs</i>
3.04.01	Piglets having a live weight of under 20 kilograms
3.04.02	Breeding sows weighing 50 kilograms and over
3.04.99	Other pigs
<i>3.05</i>	<i>Poultry:</i>
3.05.01	Broilers
3.05.02	Laying hens
3.05.03	Other poultry
<i>3.06</i>	<i>Rabbits, breeding females</i>
<i>3.07</i>	<i>Bees</i>
3.99	Livestock not mentioned elsewhere

Regulation (EC) No 1165/2008 concerning livestock and meat statistics provides a common and detailed legal framework for

- (a) statistics on bovine, pig, sheep and goat livestock;
- (b) slaughtering statistics on bovine animals, pigs, sheep, goats and poultry; and
- (c) production forecasts of beef, veal, pig meat, sheep meat and goat meat.

(<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R1165:EN:NOT>):

Annex II (Categories of livestock statistics) of the regulation provides a very detailed categorization for 4 livestock species (Not shown here in Tables). For bovine animals (cattle and buffaloes), a total of 22 categories have been distinguished (19 for cattle and 3 for buffaloes), for pigs 12, for sheep 4 and for goats also 4 categories. Poultry is not included in Annex II, but in Annex III (Categories of slaughtering statistics). This annex distinguishes 6 categories for bovine animals, no breakdown of categories for pigs, 2 categories for sheep, no breakdown of categories for goat, and four categories for poultry (chickens, turkeys, ducks, others).

The frequency and reference period for the Livestock statistics varies with the type of animals (Livestock regulation (EC) No 1165/2008):

1. The bovine livestock statistics shall be produced twice a year, with reference to a given day in May/June and a given day in November/December. Those Member States whose bovine-animal populations are below 1500,000 head may produce these statistics only once a year, with reference to a given day in November/December.
2. The pig livestock statistics shall be produced twice a year, with reference to a given day in May/June and a given day in November/December. Those Member States whose pig populations are below 3000,000 head may produce these statistics only once a year, with reference to a given day in November/December.
3. The sheep livestock statistics shall be produced once a year, with reference to a given day in November/December, by those Member States whose sheep populations are 500,000 head or above.
4. The goat livestock statistics shall be produced once a year, with reference to a given day in November/December, by those Member States whose goat populations are 500,000 head or above

The Farm Accountancy Data Network (FADN) distinguishes five livestock categories. The FADN survey is carried out annually on sample of all farms. The list of animal categories of the FADN is shown in Table 4. Animal categories in the FADN list are expressed in Livestock Units (LSU), which are further explained in Table 5.

Table 4. List of animal categories with their codes as distinguished in the Farm Accountancy Data Network (FADN), expressed in livestock units. For definition of livestock units, see table 5).

Code	LIVESTOCK categories
SE080	Total livestock units-LSU
SE085	Dairy cows-LSU
SE090	Other cattle-LSU
SE095	Sheep and goats-LSU
SE100	Pigs-LSU
SE105	Poultry-LSU

Table 5. Definition of livestock units (LSU). The reference unit used for the calculation of livestock units (=1 LSU) is the grazing equivalent of one adult dairy cow producing 3 000 kg of milk annually, without additional concentrated foodstuffs. Source: Eurostat ([http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Livestock_unit_\(LSU\)](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Livestock_unit_(LSU))).

Animal species	Animal categories	LSU
Bovine animals	Under 1 year old	0,400
	1 but less than 2 years old	0,700
	Male, 2 years old and over	1,000
	Heifers, 2 years old and over	0,800
	<i>Dairy cows</i>	<i>1,000</i>
	Other cows, 2 years old and over	0,800
Sheep and goats	Sheep and goats	0,100
Equidae	Equidae	0,800
Pigs	Piglets having a live weight of under 20 kg	0,027
	Breeding sows weighing 50 kg and over	0,500
	Other pigs	0,300
Poultry	Broilers	0,007
	Laying hens	0,014
	Ostriches	0,350
	Other poultry	0,030
Rabbits, breeding females	Rabbits, breeding females	0,020

Table 6. List of categories for cattle within the Eurostat/OECD database on N and P excretion.

Code	LIVESTOCK categories
PC2000	Bovine Animals 1-2 years
PC2100	Male Cattle 1-2 years
PC2200	Female Cattle 1-2 years (heifers)
PC2210	Female Cattle 1-2 years (heifers) - of which for slaughter
PC2220	Female Cattle 1-2 years (heifers) - Other
PC3000	Bovine > 2 years
PC3100	Male Cattle > 2 years
PC3200	Female Cattle > 2 years
PC3210	Heifers
PC3211	Heifers for Slaughter
PC3212	Other heifers
A112221	_OECD Other heifers - Breeding Heifers

A112223	_OECD Other heifers - Other heifers
PC3220	Cows
PC3221	Dairy Cows
PC3222	Other Cows
PC4000	Buffaloes
PC4100	Female breeding buffaloes
PC4200	Other buffaloes

The list of animals used in the Eurostat/OECD database are shown in Table 6 for cattle, in Table 7 for pigs, in Table 8 for sheep and goat and in Table 9 for poultry and Table 10 for other livestock. Interestingly, this list is more detailed than the list of the FSS presented in Table 3. In addition, there is a detailed OECD list of animal categories (cattle, pigs, poultry, fox, and mink) presented in Table 11, which are not included in the Tables 6, 7, 8, 9, 10. Further, there is also an additional list of so-called IPPC cattle (Table 12) within the Eurostat/OECD database. All these animal categories have a unique code.

Table 7. List of categories for pigs within the Eurostat/OECD database on N and P excretion.

Code	LIVESTOCK categories
PP0000	Total of the pig population
A121	_OECD Pigs < 50 kg
PP1000	Piglets < 20 kg live weight
PP2000	Pigs 20 - 50 kg live weight
PP3000	Fattening Pigs > 50 kg live weight
PP3100	Fattening pigs between 50 and < 80 kg
PP3200	Fattening pigs between 80 and < 110 kg
PP3300	Fattening pigs of at least 110 kg
PP4000	Breeding Pigs > 50 kg live weight
PP4100	Boars
PP4200	Sows
PP4210	Covered sows
PP4211	Covered sows - of which: sows covered for the first time
PP4220	Sows not covered - total
PP4221	Of which: gilts not yet covered
A129	_OECD Other Pigs

Table 8. List of categories for sheep and goat within the Eurostat/OECD database on N and P excretion

Code	LIVESTOCK categories
A13_	OECD Total Sheep and Goats
A131_	OECD Sheep and Lambs
PS0000	Sheep
PS1000	Ewes and ewe-lambs put to the ram
PS1100	Milk ewes and milk ewe-lambs put to the ram
PS1200	Other ewes and ewe-lambs put to the ram
PS2000	Other sheep
A1312_	OECD Lambs
PG0000	Goats
PG1000	Goats which have already kidded and goats mated
PG1100	Goats which have already kidded
PG1200	Goats mated for the first time
PG2000	Other goats

Table 9. List of categories for poultry within the Eurostat/OECD database on N and P excretion

Code	LIVESTOCK categories
A14_	OECD Total Poultry
A141	OECD Chickens
FSS_J14	Broilers
FSS_J15	Layers
A1419_	OECD Other Chickens
FSS_J16	Other Poultry
FSS_J16B	Ducks

FSS_J16A	Turkeys
FSS_J16CD	Other Poultry Types
FSS_J16C	Geese
FSS_J16DI	Ostriches
FSS_J16DII	Other FSS poultry

Table 10. List of categories for other livestock within the Eurostat/OECD database on N and P excretion

Code	LIVESTOCK categories
A19_	OECD Total Other Livestock
FSS_J1	Equidae
A191_	OECD Horses
A1911_	OECD Foal < 1 year
A1912_	OECD Young horses 1-3 years
A1913_	OECD Horses > 3 years
A192_	OECD Donkeys
A199_	OECD Other Livestock
FSS_J17	Other livestock - Rabbits
A1992_	OECD Other livestock - Mules
A1999_	OECD Other livestock - Other livestock

Table 11. List of categories for OECD cattle, pigs, poultry, fox, and mink within the Eurostat/OECD database on N and P excretion

Code	LIVESTOCK categories
A111911_	OECD Male Cattle for milk < 1 year
A111912_	OECD Male Cattle for meat < 1 year
A111921_	OECD female Cattle for milk < 1 year
A111922_	OECD female Cattle for meat < 1 year
A112111_	OECD Male Cattle for milk from 1 to 2 years
A112112_	OECD Male Cattle for meat from 1 to 2 years
A112211_	OECD Bulls
A112212_	OECD Male Cattle for meat > 2 years
A12121_	OECD Breeding Pigs 20 - 50 kg live weight
A12122_	OECD Fattening Pigs 20 - 50 kg live weight
A12311_	OECD Boars
A12312_	OECD Boars not yet ready to breed

A14121_	OECD Laying hens under 18 weeks
A14122_	OECD Laying hens 18 weeks and older
A14191_	OECD Broilers, breeding females under 18 weeks
A14192_	OECD Broilers, breeding females 18 weeks and older
A1995_	OECD Fox
A1996_	OECD Mink

Table 12. List of categories for IPCC cattle within the Eurostat/OECD database on N and P excretion

Code	LIVESTOCK categories
IPCC_	DC Dairy cattle
IPCC_	MDC Mature dairy cattle
IPCC_	MNDC Mature non-dairy cattle
IPCC_	NDC non-dairy cattle
IPCC_	YC Young cattle

Table 13 presents the list of animal categories that are used in the reports on ammonia emissions within the framework of the Gothenburg Protocol. This list is again quite detailed. The age and weight classes of the various animal categories differ though with the classifications provided by FSS and the Eurostat/OECD database. The list of animal categories used in the framework of the Gothenburg Protocol is more detailed than the list of animals used in the EEA/CORINAIR database, used to estimate ammonia and greenhouse gas emissions from agriculture (Table 14).

Table 15 presents the list of categories used in the models GAINS from IIASA and CAPRI from the university of Bonn (and used also by DG JRC. These models use again a different set of animal categories, or at least present the results of emissions for different sets of animals (because there may be more animal categories specified within the model, which are not shown in reports). Further, Table 16 presents the list of animals in the FAO database. This is a highly aggregated list. Finally, Table 17 presents the list of animals used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture, Forestry and Other Land Use. This list is rather similar to the list of the FAO database (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf). However, Guidelines suggest to use a more detailed sub-categorization for countries with large livestock populations (Table 18).

Table 13. List of categories used in Reports on ammonia emissions within the framework of the Gothenburg Protocol

Cattle		
	Dairy cows	
	Other cattle	
	Young cattle	
		0.5 - 1 yr male
		0.5 - 1 yr female
		< 1 yr
		< 1 yr replacement
		1 - 2 yr
		1 - 2 yr replacement
		> 1 yr male
		> 1 yr female
		> 2 yr
		> 3 yr
		Heifers
	Suckler cows	
	Calves	
		white meat
		pink meat
	Bulls	
		beef > 1 yr
	Other cattle	
Pigs		
	Fattening pigs	
		20 - 110 kg
		> 110 kg
		20-50 kg
		> 50 kg
	Sows	
		incl. piglets
		breeding
		pregnant

	Weaned pigs	
	Boars	
	Piglets	
		< 20 kg
		7 - 20 kg
		< 25 kg
		20-50 kg
	Other	
Poultry		
	Laying hens	
		breeding
		< 18 wk
		> 18 wk
	Broilers	
		fattening
		parent animals , < 18 wk
		parent animals , > 18 wk
	Turkey	
		female
		male
		slaughter
	Geese	
	Ostriches	
	Ducks	
	Pheasant	
	Other poultry then laying hens	
Horses		
		< 200 kg
		200-600 kg
		> 600 kg
		heavy
		< 3 yr
		> 3 yr

	Ponies	
	Mules and asses	
	Mules	
Sheep and goats		
	Sheep	
		Ewe
		meat
		milk
		< 1 yr
	Lambs	
	Goat	
		Does
Fur animals and rabbits		
	Rabbit	
	Mink and fitches	
	Foxes and racoon	
	Mink breeders	
Other		
	Buffalo	
	Deer	
	Reindeer	

Table 14. List of animal categories used in the EEA/CORINAIR database, used to estimate ammonia and greenhouse gas emissions from agriculture.

<http://www.eea.europa.eu/publications/emep-eea-guidebook-2013>.

Code	LIVESTOCK categories
-100902	Other cattle
-100903	Fattening pigs
-100904	Sows
-100905	Sheep & goats
-100906	Horses etc
-100907	Layers

-100908	Broilers
-100909	Turkeys
-100909	Ducks
-100909	Geese
1009100	Fur animals
-100914	Buffalos

Table 15. List of categories used in the model GAINS of IIASA (left-hand side) and CAPRI of the university of Bonn (right-hand side), and used by DG-JRC.

GAINS		CAPRI
Dairy cows		Dairy cows
Other cattle		Other cattle
Pigs		Swine
Horses		Sheep and goats
Sheep and goats		Poultry
Laying hens		
Other poultry		
Fur animals		

Table 16. List of animal categories used in the FAO database

Dairy cattle
Other cattle
Buffaloes
Sheep and goat
Horses
Camels
Pigs
Broilers
Laying hens

Table 17. List of animals used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Cattle (Dairy and Non-dairy)		
Buffalo		Camels and Llamas
Sheep		Horses
Goats		Mules and Asses
Swine		Other
Poultry		

Table 18. List of main categories and sub-categories suggested by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

REPRESENTATIVE LIVESTOCK CATEGORIES ^{1,2}	
Main categories	Subcategories
Mature Dairy Cow or Mature Dairy Buffalo	<ul style="list-style-type: none"> 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	<p>Females:</p> <ul style="list-style-type: none"> Cows used to produce offspring for meat Cows used for more than one production purpose: milk, meat, draft <p>Males:</p> <ul style="list-style-type: none"> Bulls used principally for breeding purposes Bullocks used principally for draft power
Growing Cattle or Growing Buffalo	<ul style="list-style-type: none"> Calves pre-weaning Replacement dairy heifers Growing / fattening cattle or buffalo post-weaning Feedlot-fed cattle on diets containing > 90 % concentrates
Mature Ewes	<ul style="list-style-type: none"> Breeding ewes for production of offspring and wool production Milking ewes where commercial milk production is the primary purpose
Other Mature Sheep (>1 year)	<ul style="list-style-type: none"> No further sub-categorisation recommended
Growing Lambs	<ul style="list-style-type: none"> Intact males Castrates Females
Mature Swine	<ul style="list-style-type: none"> Sows in gestation Sows which have farrowed and are nursing young Boars that are used for breeding purposes
Growing Swine	<ul style="list-style-type: none"> Nursery Finishing Gilts that will be used for breeding purposes Growing boars that will be used for breeding purposes
Chickens	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Breeding turkeys in confinement systems Turkeys grown for producing meat in confinement systems Turkeys under free-range conditions for meat production
Ducks	<ul style="list-style-type: none"> Breeding ducks Ducks grown for producing meat
Others (for example)	<ul style="list-style-type: none"> 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

3.3 Guidelines for a common categorization of animals in EU-27

For estimating N and P excretion coefficients, the animal categories must be clearly defined. This holds especially for important animal categories, i.e., categories with a large number of animals and a relatively large N and P excretion per animal. Cattle is the largest animal category in EU-27 and also in the world, in terms of N and P excretion. This holds for both dairy cattle and beef cattle. Hence, especially cattle categories have to be precisely defined. Pigs and poultry are also important categories. Sheep and goat are also important in some countries.

The categories have to be clearly described in easily accessible reports, with a definition of the categories distinguished. The basis of the information for the animal categorization are the surveys. There are two surveys that make inventories of livestock, i.e., Farm Structure Survey (FSS) and Livestock statistics (including slaughter statistics). The data collected in these surveys are the primary sources of activity data. All other databases in use in EU-28 are derived from these primary data sources, and hence have carried out a secondary categorization.

Though less detailed than the Livestock statistics and Slaughter statistics, the FSS database collects useful other data and information about animal husbandry practice, which is useful for N and P excretion estimations. Also, the Livestock statistics includes detailed information about bovine animals (cattle and buffaloes), pigs, sheep and goats, but not for poultry and other animals. Instead, data about poultry production and production of other animals are collected through the slaughtering statistics, but here no animal numbers are recorded. Therefore, it seems useful to consider the FSS database as the starting point for the animal categorization (and not the Livestock and Slaughter statistics). Using the FSS database as a basis provides a uniform framework for the animal categorization across EU-28 (Table 19). Hence, we recommend that the FSS categorization is taken as the primary (main) list of animal categories for N and P excretion coefficients, also because this inventory of the number of animals takes place in all Member States of the EU-28. In addition, we recommend that efforts are undertaken to harmonise the existing animal categories.

The animal categories in FSS are based on animal species, age (or weight) and sex, but not on the basis of the type of production system. The type of production system may have a significant effect on the N and P excretion coefficients. Therefore, a secondary animal

categorization has to be considered when more than one types of production systems co-exist within a region and/or country.

The type of production systems depends on many factors, including the geographical situation, climate, culture and market demands. Effects of these governing factors are larger in large countries than in small countries. Production systems may be defined on the basis of:

- Animal breeds (small vs large breeds, low vs high productivity),
- Marketed animal products (small vs large final weight, young vs old animals)
- Feed rations (e.g., low vs high protein)
- Use of (veterinary) supplements in the animal feed (including antibiotics, hormones)
- Production level (intensity)
- Housing systems, including grazing vs restricted grazing vs zero-grazing systems

Evidently, there is an endless variety of production systems in practice. Not all of these variety can and should be considered; only those aspects that contribute to a significant variation in N and P excretion coefficients should be considered for secondary categorization. A secondary categorization must lead to greater accuracy and also to a greater insight in the total N and P excretion within a country and/or region. Currently, there are no clear guidelines for a secondary categorization. The 2006 IPCC Guidelines do recommend a secondary categorization, but provide only qualitative, general suggestions. Here, we recommend the following steps for considering a secondary categorization to the FSS animal categorization:

- The secondary categories or subcategories comply with the type of production systems existing in a country and/or region, and are therefore easy to distinguish;
- The main category is relatively large (contributes >10% to the total N and P excretion within a country and/or region), and the subcategories are also relatively large (>20% of the total population within the animal category) and have significantly different N and/or P excretion coefficients (>20% different from the overall mean N and P excretion coefficients of the animal category).
- The subcategories are specific for certain regions and therefore lead to a more accurate estimation of the N and P excretion in these regions (see also Chapter 4 for regional differentiation).

Table 19. List of animal categories with their codes as distinguished in the Farm Structure Survey (FSS).

Code.	LIVESTOCK categories
3.01	<i>Equidae</i>
3.02	<i>Bovine animals:</i>
3.02.01	Bovine animals, under one year old, male and female
3.02.02	Bovine animals, one but less than two years old, male
3.02.03	Bovine animals, one but less than two years old, female

3.02.04	Male bovine animals , two years old and over
3.02.05	Heifers , two years old and over
3.02.06	Dairy cows
3.02.99	Other cows
<i>3.03</i>	<i>Sheep and goats:</i>
3.03.01	Sheep (all ages)
3.03.01.01	Breeding females
3.03.01.99	Other sheep
3.03.02	Goats (all ages)
3.03.02.01	Breeding females
3.03.02.99	Other goats
<i>3.04</i>	<i>Pigs</i>
3.04.01	Piglets having a live weight of under 20 kilograms
3.04.02	Breeding sows weighing 50 kilograms and over
3.04.99	Other pigs
<i>3.05</i>	<i>Poultry:</i>
3.05.01	Broilers
3.05.02	Laying hens
3.05.03	Other poultry
<i>3.06</i>	<i>Rabbits, breeding females</i>
<i>3.07</i>	<i>Bees</i>
3.99	Livestock not mentioned elsewhere

Animal productivity may indeed vary significantly between regions. This holds as well for the composition of the animal feed (diets), due to differences in feed availability. These two factors may lead to significant differences in the N and P excretion coefficients between regions, and therefore justifies a secondary categorization and/or regional differentiation. We recommend that countries make a consideration of the various types of production systems for estimating accurate N and P excretion coefficients. These consideration relate especially to:

- Fast-growing and heavy breeds vs slow-growing breeds
- Organic production systems vs common production systems
- Housed ruminants vs grazing ruminants
- Caged poultry vs free-range poultry

4 Guidelines for identifying the proper Tier

4.1 Introduction

In chapter 2 of this report, a common three-Tier approach has been proposed for collecting data and information that are needed for estimating N and P excretion coefficients. A three-tier approach describes three data collection procedures, as function of the objectives of the study/work undertaken, the relative importance of the animal category, quality criteria and data availability. In all cases, a mass balance approach is applied for the derivation of the excretion coefficients per animal category, i.e.,

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

The Tier 1 approach is the most simple approach, with default excretion coefficients per animal category. This approach may be useful for so-called “small animal categories” (i.e., small number of animals, with low N excretion per animal), irrespective of the mean livestock density in a country. The Tier 1 approach may be used also by countries with low livestock density and low data availability for the “large animal categories” .

The Tier 2 approach applies country-specific data and information collection procedures once in two to five years, that lead to country-specific default excretion coefficients per animal category. In case the regional variations in livestock density and animal breeds, animal feeding, animal housing systems and animal productivity are large, region-specific excretion coefficients per animal category should be established per animal category. This approach may be used by countries with a medium high livestock density and level of data availability.

The Tier 3 applies country-specific and/or region-specific data and information collection procedures per animal category and per year. These specific excretion coefficients are derived annually on the basis of detailed information about animal breeds, animal feeding, animal housing systems and animal productivity. This approach should be used for the so-called “large animal categories” (i.e., large number of animals, with relatively large N excretion per animal) and by countries with relatively good data availability.

This chapter provides some guidelines to facilitate the selection of the proper Tier and to identify the need for regional-specific excretion coefficients.

4.2 Determinants for Tier selection

The three Tiers proposed differ in data collection methodology and frequency, and hence in the efforts needed, and in the accuracy of the N and P excretion coefficients. Tier 3 methodology delivers the most accurate estimates of N and P excretion coefficients, but is most laborious, while Tier 1 delivers the least accurate estimates but is also least laborious. Evidently, there are trade-offs here; a proper balance has to be found between accuracy and efforts.

As indicated also in the DireDate reports (Oenema et al., 2011), N and P excretion coefficients are key variables for many Agri-Environmental Indicators (AEIs), including the Gross N and P balances, ammonia emissions, greenhouse gas emissions, risk of pollution by phosphorus, water pollution by nitrates. Hence, the relevance and required accuracy of N and P excretion coefficients should be evaluated also in the context of these AEIs. Here, each country will have its own considerations and priorities. Also, there may be large variations between regions within a country, which require consideration.

If livestock density in a country is low, total N and P excretion will be low, and the environmental pressures and risks resulting from N and P excretion will be low as well. However, this depends also on the vulnerability and sensitivity of the regional environment. In high-nature value areas and in areas with eutrophication-sensitive streams and lakes, different rating will be given to low – high Gross N and P balances, and ammonia emissions, and hence also to low – high livestock density. Here, we provide general guidelines. Evidently, these guidelines must be evaluated critical within a regional context.

The need for regional differentiation of N and P excretion coefficients will diminish as markets for animal products become more globalized. On the contrary, creation of region-specific products within an animal category will increase the need for regional differentiation of N and P excretion coefficients. Apart from regional markets of animal products, region-specific animal diets is the dominant factor for creating a need for regional differentiation of N and P excretion coefficients. Region-specific diets may develop because of region-specific environmental conditions and/or management (Kros and Oenema, 2014).

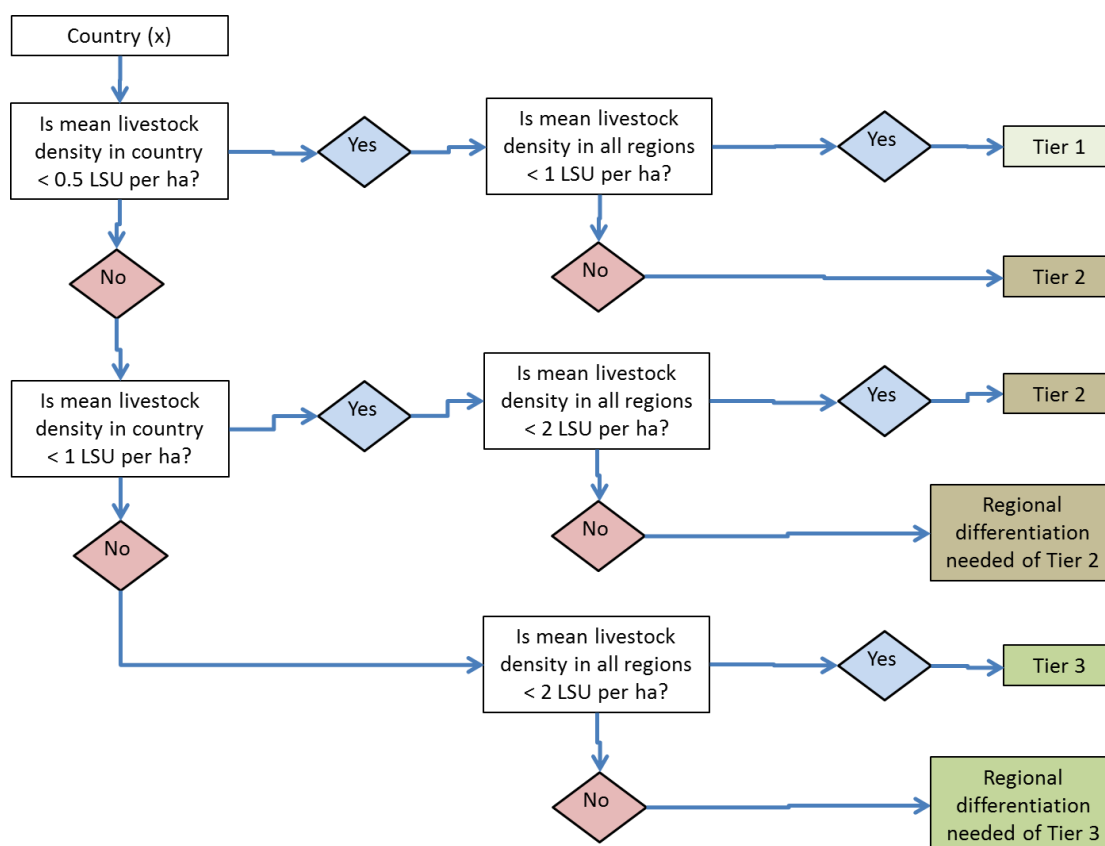


Figure 3. Decision flow diagram for selecting the proper Tier on the basis of livestock density (LSU per ha) and regional variability of livestock density within a country.

Major determinants of N and P excretion and hence for the selection of the most appropriate Tier are (i) livestock density, (ii) animal productivity in combination with animal feeding, and (iii) the relative importance of livestock categories. Information about livestock density and regional variability in livestock density is available in each country through surveys (see Chapter 3). Hence, livestock density is the primary determinant for selecting the proper Tier. Figure 3 provides a decision flow diagram for the selection of the most appropriate Tier on the basis of livestock density. Threshold values are tentatively set at 0.5, 1.0 and 2.0 livestock units per ha agricultural land (LSU per ha). Countries with large areas of high-nature value land and eutrophication-sensitive streams and lakes may decide the thresholds at a lower level.

Livestock density expressed in livestock units per ha of agricultural land does not reflect differences in animal productivity and animal feeding practices. As indicated in the Task 2 report, N and P excretion of dairy cattle may vary by a factor of at least two due to differences in milk production per cow and feed management. Hence, livestock density is only a rough indicator for N and P excretion. A more accurate estimation of the Tier would be obtained if the amount of N excretion per ha (N excretion density) is used as determinant for the selection of the most appropriate Tier. This is presented in Figure 4. If the N excretion density is estimated following Tier 3 methodology, then excretion density reflects both (i) livestock density, (ii) animal productivity, and (iii) feed management.

However, Tier 3 methodology may not be applicable to all countries, because accurate information about feed management may not be available.

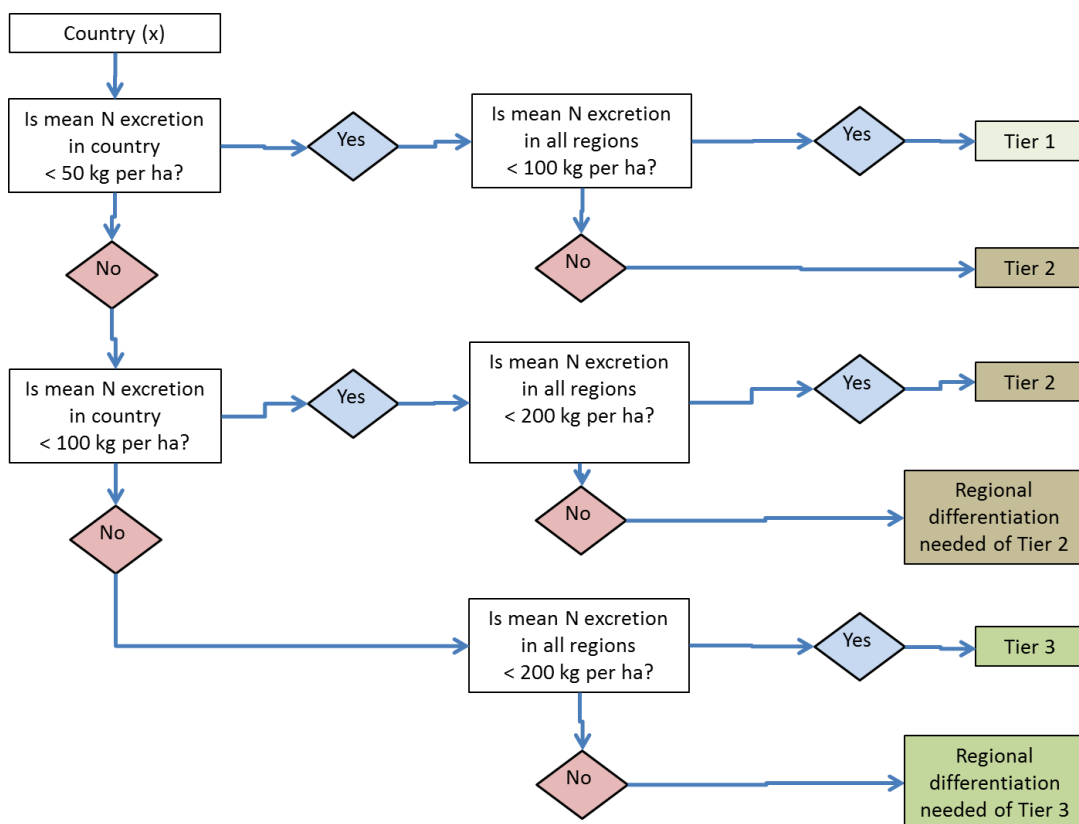


Figure 4. Decision flow diagram for selecting the proper Tier on the basis of N excretion density (kg per ha) and regional variability of N excretion density within a country.

In Figures 3 and 4, livestock density and N excretion density are based on the total number of animals of all animal categories, while using the proper coefficients for livestock density and N excretion density. However, differentiations must be made between livestock categories, when countries are recommended to use Tier 2 and especially 3 methodologies. In this case, countries are referred to the decision tree in Figure 5, which provides guidance per animal category.

A decision tree for selecting the proper Tier for animal categories is shown in Figure 5. Threshold values are tentatively set at 10, 20 and 40 kg N per ha agricultural land for selecting the proper Tier and for identifying the need for regional differentiation. Countries with large areas of high-nature value land and eutrophication-sensitive streams and lakes may decide the thresholds at a lower density. Main animal categories in most countries are cattle, pigs and poultry. These animal categories commonly account for more than 75% of the total excretion, and in many countries even more than 90%. Sheep and goats may also

have a relatively large share in total N and P excretion in some countries, and therefore should be considered as well in the analysis. For all other animal categories, (buffaloes, horses, donkeys, mink, foxes, rabbits, guinea-pigs, hamsters, deer) a Tier 1 approach will likely suffice.

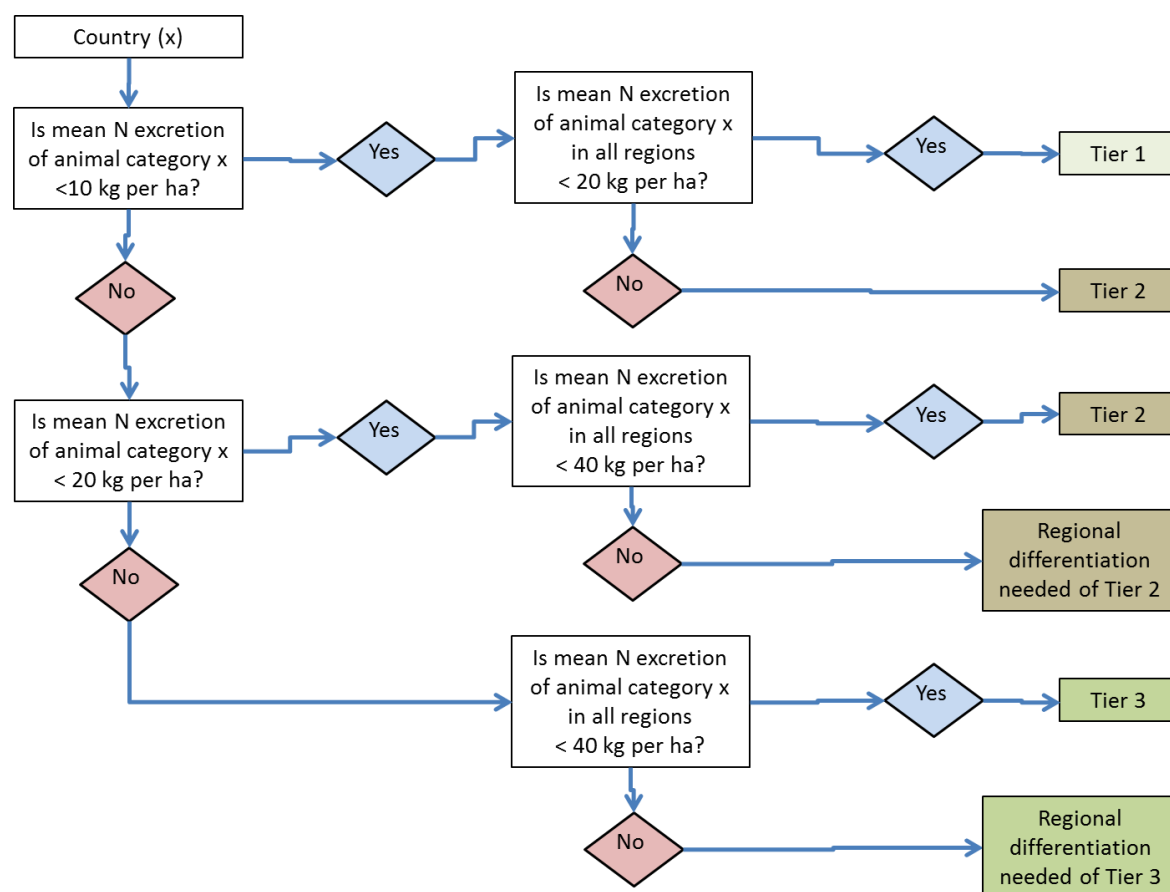


Figure 5. Decision flow diagram for selecting the proper Tier for each animal category with in a country, on the basis of N excretion density (kg per ha) and regional variability of N excretion density within a country per animal category.

5 General guidelines for estimating N & P excretion coefficients

5.1 Introduction

This chapter provides guidelines for deriving default N and P excretion coefficients. The estimation of the excretion coefficients must be based on the so-called mass balance approach, i.e.,

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

Hence, reliable information is needed on both intake and retention (or output). Intake is calculated as feed intake (as kg of dry matter, DM) x N (and P) contents of the feed. Retention is calculated as animal production (in kg milk, egg and meat (or liveweight gain) x N (and P) contents of the milk, egg and meat (or liveweight gain).

For countries that have well-documented and well-recognised country-specific methods for estimating N and P excretion coefficients on the basis of feed intake and animal production data, it is good practice to use these country-specific methods.

For countries that do not yet have well-documented methods, it is suggested to derive these methods (based on a review of existing methods). For the time being, some general guidelines are provide in this chapter and subsequent chapters, for deriving default N and P excretion coefficients.

As indicated in Chapter 2, animal-specific N and P excretion coefficients must be derived on the basis of data and information of animal categories breeds, animal feeding, feed composition, animal productivity and the composition of the animal products. The estimation of N and P excretion coefficients is based on five building blocks:

1. Animal categorization and the number of animals per animal category;
2. Feed intake per animal category;
3. Feed composition (i.e., the N and P contents of the feed) per animal category;
4. Animal production per animal category;

5. Composition of the animal products (i.e., the N and P contents) per animal category
These are further discussed below.

It is recommended that computer programs are made available to allow the calculation of the N and P excretion per animal category at regional and national levels. It is also recommended to provide training courses for the use of these programs and the calculation of the N and P excretion per animal category and all animals within a country.

5.2 Defining animal categories and production systems

In Chapter 3, it was concluded that the Farm Structure Survey (FSS) database provides the best quantitative data of the animal number per animal category and hence that the animal categorization in the FSS should be used as the primary (main) basis for the animal categorization. These categories are based on animal species, age (or weight) and sex, but not on the basis of the type of production system.

Therefore a secondary categorization was proposed in Chapter 3.3, on the basis of (differences in) production system. Production systems may differ due to differences in:

- Animal breeds (small vs large breeds, low vs high productivity),
- Marketed animal products (small vs large final weight, young vs old animals)
- Feed rations (e.g., low vs high protein)
- Use of (veterinary) supplements in the animal feed (including antibiotics, hormones)
- Production level (intensity)
- Housing systems, including grazing vs restricted grazing vs zero-grazing systems

It was recommended that the following steps have to be considered for a secondary categorization to the FSS animal categorization:

- The secondary categories or subcategories comply with the type of production systems existing in a country and/or region, and are therefore easy to distinguish;
- The main category is relatively large (contributes >10% to the total N and P excretion within a country and/or region), and the subcategories are also relatively large (>20% of the total population within the animal category) and have significantly different N and/or P excretion coefficients (>20% different from the overall mean N and P excretion coefficients of the animal category).
- The subcategories are specific for certain regions and therefore lead to a more accurate estimation of the N and P excretion in these regions.

We recommend that countries make a consideration of the various types of production systems for estimating accurate N and P excretion coefficients. These consideration relate especially to:

- Fast-growing and heavy breeds vs slow-growing breeds
- Organic production systems vs common production systems
- Housed ruminants vs grazing ruminants
- Caged poultry vs free-range poultry

5.3 Estimation of feed intake

For maintenance, (re)production, and draught, animals require water, digestible energy, protein (amino acids), mineral elements, and vitamins (Suttle, 2010). Water, digestible energy and protein are the most bulky requirements, and affect animal performance directly, because of the low buffer.

Feed intake by the animals is difficult to estimate, because of the variability in requirements between animals within an animal category. The amount of feed consumed by animals varies with animal breed, size, health and productivity of the animal. The quality of the feed available, feed constituents and method of feeding are also influencing feed intake. Finally, housing conditions (confinement versus free range) and animal welfare are known to influence feed intake. Because of changes in maintenance requirements and in animal productivity over time, feed intake changes also over time. Hence, snap-shot measurements of feed intake lead to biased results. Instead, whole-year and careful analyses of the animal production cycles have to be made to estimate feed intake per animal category accurately.

There are two approaches for estimating feed intake, i.e., (i) quantifying the intake of offered feed, and (ii) calculating the feed requirements on the basis of animal productivity and literature data. Both approaches are being applied and also compared (see Task 2 report). Quantifying feed intake can be done in feed trials, at farm level and at regional levels. Calculating feed requirements can be done at the scale of an animal, farm, region, country, etc. Both approaches should yield similar results, and may provide justification for the chosen approach and insight into the relative accuracy of the estimated feed intake.

Feed intake is usually expressed in terms of digestible energy (expressed in terms of joule per kg dry matter) and/or protein intake (expressed in gram per kg dry matter or % of dry matter). In practice, feed intake is also expressed in terms of dry matter intake. The primary drive for feed intake by animals is the need for digestible energy, which is offered mainly in the form of carbohydrates. Protein provides both digestible energy and essential amino acids; the need for protein is also a main driving force for feed intake. In addition, animals require vitamins, enzymes and some 22 mineral elements in specific quantities, depending on animal breed, size, health and productivity of the animals. Animal nutritionists make detailed analyses of the required feed per animal in terms of digestible energy, protein (amino acids), vitamins, enzymes and mineral elements, so as to improve animal productivity and animal health. Evidently, this detailed analysis is beyond the scope of the current study.

Animal performance and diet data are used to estimate feed intake, which is the amount of energy (MJ/day) an animal needs for maintenance and for activities such as growth, lactation, and pregnancy. Detailed guidance for calculating feed intake can be found in NRC (1996, 1998, 2001) and IPCC (2006). These guidebooks also provide detailed overviews of the equations and coefficients needed for estimating feed intake. These detailed approaches have been simplified in the ERM/AB-DLO study (Ketelaars and van der Meer, 1999), which is a basis for the estimation of N excretion coefficients in the framework of the EU-Nitrates Directive. In the ERM/AB-DLO study, feed intake is expressed in terms of dry

matter (kg DM per animal per year). This approach assumes that the digestible energy content of the dry matter (DM) is of good quality (and constant), and that essential amino acids, vitamins, enzymes and mineral elements are not limiting animal performance (too much). If the quality of the feed is less than good, animal productivity will be sub-optimal or intake of dry matter will be larger than in the case of good quality feed.

In the ERM/AB-DLO study, feed intake was derived from feed requirement. The basic formulae for dairy cattle is shown below:

$$DM_{\text{intake}} = q * [MW * a + LWG * b + MY * c] \quad [1]$$

where

DM_{intake} = total dry matter intake, in kg per cow per year

MW = metabolic weight = (weight)^{0.75}, in kg

LWG = liveweight gain, in kg per year

MY = milk yield per ruminant, kg per year

a = maintenance coefficient, g DM per kg MW per day

b = feed conversion coefficient for liveweight gain, kg per kg

c = feed conversion coefficient for milk production, kg per kg

q = feed quality/digestibility coefficient, dimensionless

Similar types of equations may be used also for other animal categories than dairy. Evidently, this requires calibration of the coefficients in the equation through measurements, through quantifying the quality (digestibility) and intake of the offered feed.

5.4 Estimation of N and P contents in the animal feed

The N and P contents of the feed may also vary significantly over time and between farms. This holds especially for grazing animals; the N and P contents of the offered grass greatly depends on grass species (sward composition), growing stage of the grass, N and P fertilization, weather conditions, soil type (Whitehead, 2000). Grass silage and hay usually have lower N and P contents than fresh grass, and is less variable in N and P contents. Silage maize usually has constant N and P contents, while the N and P contents of concentrated feeds may vary significantly again, depending on the composition of the feed ingredients and mineral supplementation. Hence, snap-shot sampling of feed may lead to biased results. Instead, well-designed sampling strategies are needed for whole year round sampling, to be able to estimate the N and P contents of the animal feed accurately.

It is recommended that data and information of the N and P contents of animal feeds are collected per animal category, from

- feed companies (providers of concentrated feeds),
- routine laboratories for crop and feed analyses, which analyse sample on farmers' request,
- extension services, which may implement sampling programmes, and
- research institutes, that execute feed trials.

It is recommended that the N and P contents of the animal feeds is analyzed regularly (monthly or seasonal basis, depending on Tier), so as to obtain accurate annual mean N and P contents of the feed. This holds also for the composition of farm-grown feed that is fed to the animals on the farm where the feed has been produced; samples of grazed grass and silage have to be analyzed on a seasonal basis so as to obtain accurate annual means. For Tiers 1 and 2, these analyses should be made every 3 to 5 years, for Tier 3, these analyses should be made each year. Results of these analyses should be stored in accessible data bases, and compared also with literature values.

5.5 Estimation of animal production

Information about animal production (milk, meat, veal, beef, pork, poultry, mutton, egg) is commonly available at farm and national and regional levels on annual basis, based on farm accountancy data, livestock (slaughter) statistics, and trade statistics (food processing industry). These data and information are rather accurate, mainly because of the high economic values of the animal products.

The mean ratio of animal production and number of animals within an animal category (milk yield per cow, pork yield per pig, egg yield per layer, poultry yield per broiler, mutton yield per sheep, etc.) provides inside in animal productivity (animal performance), and hence in the value of the coefficients for maintenance and feed use per kg liveweight. Table 20 provides mean ratios for the 27 countries of the European Union during the last 5 years. Evidently, there are large differences between countries, which in part also reflect differences in the structure of animal production and in the trade of live animals.

In short, data and information about animal production is available on animal basis for all main animal products, and these data and information should be used as a basis for the estimation of N and P retention in animal products. Also, the ratio of animal production and animal number provides insight in the animal productivity and efficiency within a country.

Table 20. Mean ratios of animal production and animal number for dairy cattle, beef cattle, pigs, and poultry for the 27 countries of the European Union during the years 2008, 2009 and 2009.

Countries	Animal production, in kg animal product per number of animals				
	pork	milk	eggs	beef	poultry meat
Austria	170	6076	16	101	11
Belgium	171	5753	22	95	19
Bulgaria	91	3527	13	31	11
Cyprus	125	6430	6	67	21
Czech Republic	162	7016	15	52	11
Denmark	130	8550	22	74	14

Estonia	96	6796	18	50	13
Finland	148	8046	18	81	51
France	154	6128	19	72	15
Germany	198	6940	19	84	10
Greece	110	3710	8	99	6
Hungary	130	6783	12	38	12
Ireland	141	4822	11	75	9
Italy	177	5817	12	155	14
Latvia	99	4825	20	46	12
Lithuania	76	4660	12	51	13
Luxembourg	123	7050	16	75	1
Malta	112	5921	16	75	64
Netherlands	107	7315	18	88	12
Poland	125	4716	12	61	13
Portugal	162	6379	20	67	7
Romania	72	3321	7	49	9
Slovakia	119	5677	12	32	12
Slovenia	103	5674	15	70	41
Spain	131	7388	16	98	13
Sweden	171	8356	18	86	58
United Kingdom	163	7123	14	83	12
EU 27	146	6096	14	82	12
EU-15	155	6589	16	88	13

5.6 Estimation of the N and P contents in animal products

Data and information about the N and P contents of animal products are not gathered on a routine basis, mainly because there is no commercial interest in the N and P contents of animal products. Hence, information about the N and P contents of animal products (apart from milk) originates from scientific research. The variation in N and P contents of animal products, within an animal category, is relatively small ($\pm 20\%$), and rather well-understood.

The Task 2 report (Sebek et al., 2014) provides detailed overviews of the N and P contents of animal products, as recorded in the 10 countries involved in that study. Differences between countries in N and P contents of animal products may be related to differences in animal breeds, carcass weight (and fat percentage), and feeding practices.

It is recommended that the N and P contents of milk are analyzed regularly (daily, weekly monthly, depending on the importance of the dairy sector, and Tier), so as to obtain accurate annual means of the N and P contents of milk. The protein content of the milk may vary greatly (roughly between 30 to 45 g protein per litre, equivalent to 4.7 to 7.1 g nitrogen per litre) between dairy cows, between herds and also between seasons, mainly due to the

influences of genetic differences and feed composition differences (between farms, seasons). The same holds to some extent for the phosphorus content of milk; it may range between 0.8 to 1.1 g P per litre. In case analyses of phosphorus in milk are not available, the can be estimated from regression equations such as those presented by Klop et al. (2013).

It is recommended that the N and P contents of animals and of veal, beef, pork, poultry, wool, etc. are analyzed on a sample made every 5 to 10 years. The N and P contents of these animal products do not vary much, especially when the genotype and the weight of the animals (percentage of fat) are similar. Also, these analyses are costly, when done accurately. Hence, there is a need to economize on the analyses of the N and P contents of animals and animal products.

6 Default excretion coefficients for cattle

6.1 Introduction

In the EU-27, cattle contribute roughly 50 to 60% of the total amounts of N and P excreted in animal manure. At global level, cattle are also the largest producer of manure N and P, though with large differences between countries and also between continents.

The estimations of total N and P excretions by cattle are uncertain. Likely, the relative uncertainty of the N and P excretions by cattle is larger than the relative uncertainty of the N and P excretions by many other animal categories. The reasons for the relatively large uncertainties is the fact that feed intake and feed composition of cattle is not well known. Most cows graze on pastures for a significant part of the year, and it is difficult to estimate the feed intake and the composition of the feed intake of grazing animals. Other reason are the relatively large differences between breeds, and the relatively large regional differences in animal productivity and animal feeding.

This chapter provides default values for N and P excretion coefficients for cattle, as function of body weight, milk yield and protein content of the animal feed. The analysis of N excretion coefficients (Paragraphs 6.2 and 6.3) is more detailed than the analyses of the P excretion coefficients (paragraph 6.4). For the N excretion coefficients, we follow the simple approach of ERM/AB-DLO (Ketelaars and van der Meer, 1999). For the P excretion coefficients, we base the results on the analyses of Task 6 (Van Krimpen et al., 2014)⁴.

⁴ Van Krimpen, M.M., L. Sebek, P. Bikker, and A.M. van Vuuren (2014) Default phosphorus excretion factors of farm animals. Task 6. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat. Luxembourg.

6.2 Excretion coefficients of nitrogen for dairy cattle

The nitrogen (N) excretion by dairy cows follows the following formulae (see also chapter 5.2):

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retained}} \quad [1]$$

$$N_{\text{intake}} = q * [MW * a + LWG * b + MY * c] * \text{N content in feed} \quad [2]$$

$$N_{\text{retained}} = (MY * \text{N content milk}) + (LWG * \text{N content in LW}) \quad [3]$$

where

$N_{\text{excretion}}$ is the total N excretion (kg per cow per year),

N_{intake} is the total N intake (kg per cow per year),

N_{retained} is the total amount of N retained in milk and meat (kg per cow per year),

MW is the metabolic weight (kg) calculated as $(\text{weight})^{0.75}$,

LWG is the liveweight gain (kg per year),

LW is liveweight (kg),

MY is the milk yield per ruminant (kg per year).

a, b, c and q are empirical constants.

Coefficient a is the maintenance coefficient; it may range from 45 to 60 g per kg MW per day;

Coefficient b is the feed use per kg liveweight gain; it may range from 4 to more than 10 kg per kg ;

Coefficient c is the feed use per kg milk; it corrects for milk protein and milk fat, as follows:

$$c = 0.35 + 0.0013 * [MP + 2 * MF], \quad [4]$$

where

MP is the milk protein content (g per kg milk), and

MF is milk fat (g per kg milk).

Coefficient q is a parameter for the quality (digestibility) of the feed (range 1 to 1.3). For concentrate feed and high-quality herbage, q is 1; for poor quality roughages, q may be 1.3.

The product " $a * MW$ " in equation [2] represents the feed need for maintenance (MW is metabolic weight is $\text{weight}^{0.75}$), while the product " $b * MY$ " represents the feed need for milk production. Note that the total feed need expressed per liter of milk produced will decrease as the milk production per cow increase. This is a general observation, and underpinned by theoretical and practical evidence. Although the feed need for maintenance

also slightly increases with an increase in milk production (because the cow has 'to work harder when producing more milk'), no account has been made for this need in equation [2] because of relatively small effect and also because of the uncertainties involved.

Table 21 provides some estimates for the various coefficients, on the basis of experimental studies and modeling studies. Both, rough average values and lower and higher estimates have been provided, to show the ranges.

Table 21. Coefficients for estimating the N excretion of dairy cows as function of energy requirement for maintenance and production, protein content of the diet and the amount of N retained by the dairy cows in milk and liveweight gain.

Coefficients	Average	Lower estimate	Higher estimate
Weight dairy cow, kg	550	400	650
Metabolic weight, kg	114	89	129
Maintenance coefficient 'a' , g/day	52	45	60
Milk yield, kg/yr	5.500	3.000	10.000
Production coefficient 'b' , kg/kg	0.5	0.44	0.6
Protein content of diet, %	16	13	20
Protein content of milk, %	3.4	3	4
N content of protein in diet, %	6.25	6.25	6.25
N content of protein in milk, %	6.39	6.39	6.39
N retained in liveweight gain, kg	1.5	0.5	3

Using Equations [1], [2], [3], and [4] and the coefficients presented in Table 21, relationships between milk yield per dairy cow and N excretion per cow per year can be calculated as function of body weight of the cow, maintenance coefficients, protein content of the feed, and feed use per kg milk. Figure 6 shows results for a milk production of 3000 to 9000 kg per cow per year, a weight of dairy cows of 450 (for Jerseys) and 650 kg (for Holstein Frisians), a maintenance coefficient of 45 to 60 g feed dry matter per kg MBW per day, a production coefficient of 0.45 to 0.60 kg dry matter per kg milk, a protein content of the animal feed of 14 to 18%, and a protein content in the milk of 3.5 % and an amount of N retained in liveweight gain (young born calf) of 1.5 kg.

The intercept ranges from 37 kg N per cow per year for a low-weight cow, with a low maintenance coefficient of 45 g per day per kg metabolic weight (representative for year-

round housing), and a low protein content in the diet (14%), to a high value of 75 kg N per cow per year for high-weight cow, with a high maintenance coefficient of 60 g per day per kg metabolic weight (grazing, much walking) and a relatively high protein content in the diet (18%).

The regression coefficient ranges from 0.0054 kg N per kg milk for a low-weight cow and a low production coefficient of 0.45 kg per kg milk (representative for high-quality feed) and a low protein content in the diet (14%), to a high value of 0.0107 kg N per kg milk for high-weight cow and a high production coefficient of 0.60 kg per kg milk (representative for low quality feed) and a relatively high protein content in the diet (18%).

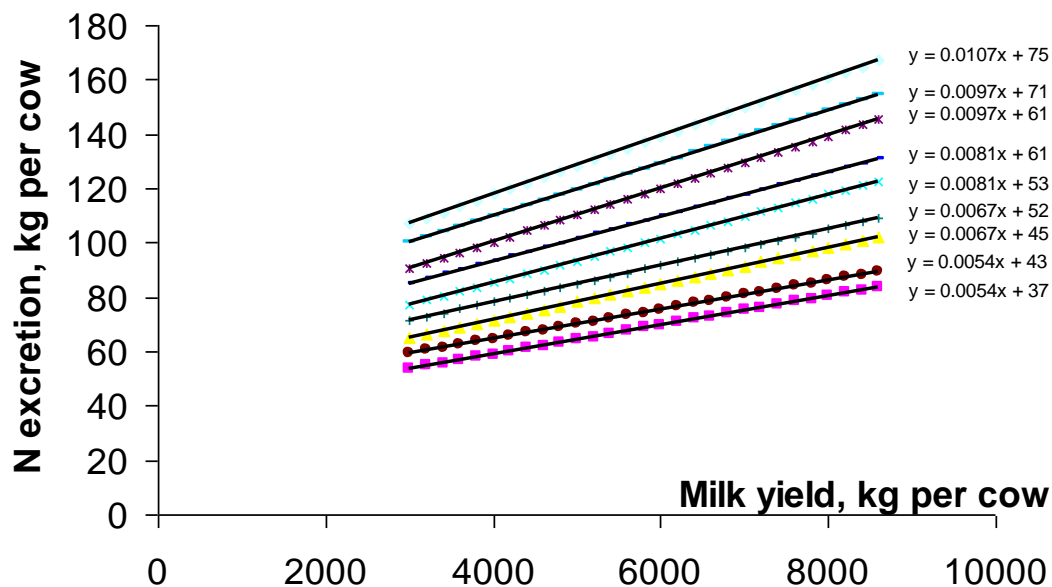


Figure 6. Nitrogen excretion by dairy cows as function of milk yield per cow, maintenance and production coefficients, and N retention. Result of sensitivity analyses using Equations [1], [2], [3], and [4] and coefficients from Table 18 (see text).

Evidently, there is a wide range of possibilities but some combinations are more plausible than others. For example, a low-weight dairy cow with a high milk production seems attractive from the point of view of low N excretion, but is not realistic. The combination of low maintenance and production coefficients, a high milk yield per cow and a low protein content in the diet is also attractive from the point of view of low N excretion, but low maintenance and production coefficients can only be realized with high quality feed, a productive herd and good management, and with not too-low protein contents in the diets.

On the other hand feed requirements are primarily determined by energy rather than protein requirements. A surplus of protein as compared to energy is 'a waste', because surplus protein cannot be utilized.

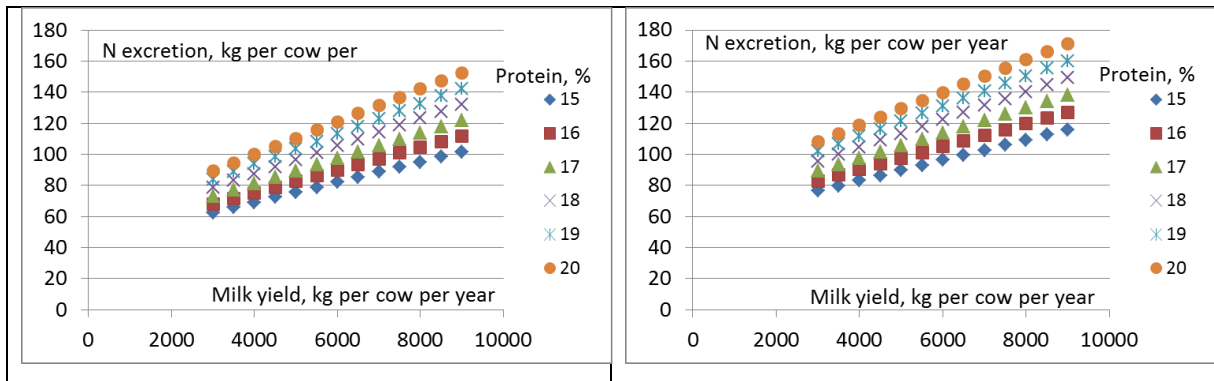


Figure 7. Total N excretion (kg N per cow per year) as function of milk yield per cow and protein content of the feed. Left-hand side figure for small dairy cows (450 kg), right-hand side for a large dairy cow (650 kg). In both cases, with 35 g protein per kg milk, and a maintenance coefficient of 52 g dry matter per day.

Figure 7 presents the most likely ranges of N excretion as function of milk production and protein content of the feed, for a small cow with a weight of 450 kg and a large dairy cow with a body weight of 650 kg. Evidently, milk yield per cow and protein content of the animal feed have large effects on the N excretion per cow per year. Annual N excretion increases 6.5 kg per 1000 kg milk at an protein content of 15%, and 10.5 kg per 1000 kg milk at a protein content in the animal feed of 20%. For 1 per cent increase in protein content of the animal feed, N excretion increases 6 kg for a cow producing 3000 kg and 10 kg for a cow producing 7500 kg milk. The difference in N excretion between the small and the large cow is 14 kg per cow per year at a protein content of 15% (2.4% N) and 19 kg at a protein content of 20% (3.2% N).

The effects of milk protein and milk fat on N excretion are relatively small. This is related in part to the counter effects of increasing protein content: it increases feed requirements and hence increases N intake, but it also increases N retention of feed N in milk. An increase in milk fat content only increases feed requirements, and hence N excretion. Milk fat and milk protein strongly co-vary. The net effect of an increase of an increase in milk protein from 35 to 40, and milk fat from 40 to 45 g per kg milk is a decrease in N excretion of 1 to 2 kg per cow per year.

Increasing the maintenance coefficient from 52 to 57 g DM per kg metabolic weight per day increases N excretion by about 5 kg per cow per year. This effect may be expected when dairy cows change from nearly full-time grazing (apart from the hours in the milking

parlour) to zero-grazing; N excretion per cow will decrease by about 5 kg per cow, or when the cows are grazing only half of the year, by 2.5 kg per cow per year.

Table 22 summarizes the relationships between milk yield per cow, feed protein content and N excretion. This table may be used as default N excretion coefficients in EU-27 (Tier 1). In case the mean protein coefficient of the feed is not known, it is recommended to take the average of Table 22, i.e. 17%. In the case of country specific N excretion coefficients, the protein content of the animal feed, the body weight of the dairy cows, and the maintenance coefficients (grazing versus non-grazing) should be adjusted to the national or regional conditions.

Table 22. Mean annual N excretion of dairy cows as function of milk yield per cow and protein content of the animal feed. The body weight of the cow was set at 550 kg, the maintenance coefficient at 55 g DM per kg metabolic weight, milk fat at 40 g and milk protein at 35 g per kg milk, and N retention in offspring at 1.5 kg.

Feed protein %	Milk yield, kg per cow per year												
	300	350	400	450	500	550	600	650	700	750	800	850	900
	0	0	0	0	0	0	0	0	0	0	0	0	0
15	73	76	79	83	86	89	92	96	99	102	105	109	112
16	79	82	86	90	93	97	101	104	108	112	115	119	123
17	85	89	93	97	101	105	109	113	117	121	125	129	133
18	91	95	100	104	109	113	118	122	127	131	135	140	144
19	97	102	107	111	116	121	126	131	136	141	145	150	155
20	103	108	113	119	124	129	134	140	145	150	156	161	166

Note that the difference between organic and conventional dairy production systems in N (and P) excretion coefficients is captured in the consideration of (i) the milk production level of the cow, (ii) the protein content of the animal feed, (iii) the weight of the animal. When these variables are addressed, differences between organic and conventional dairy production systems in N (and P) excretion coefficients are negligible small.

6.3 Excretion coefficients of nitrogen for other cattle

The category 'other cattle' in Europe includes replacement cattle and fattening cattle. It is a broad variety of cattle and includes:

- replacement cattle for dairy and beef, 0-1 year;
- replacement cattle for dairy and beef, 1-2 year;
- fattening calves <0.5 year;
- fattening cattle 0.5-2 year

- other cattle, >2 yers
- suckler cows > 2 years

The indicated age classes are arbitrary (see also chapter 3). It is recommended to make functional age classes, in the sense that the classes relate to common animal husbandry practices. This holds especially for fattening calves and cattle.

The number of other cattle has increased in EU-15 following the implementation of milk quota in the 1980s, and the subsequent decrease in dairy cattle, because some farmers switched to fattening cattle and suckling cows. Currently the number of other cattle is larger than the number of dairy cattle, but N excretion per animal is much smaller.

The nitrogen (N) excretion by other cows follows the following simplified formulae (see also chapter 6.2):

$$N_{\text{excretion}} = N_{\text{diet}} - N_{\text{retained}} \quad [1]$$

$$N_{\text{intake}} = q * [MW * a + LWG * b] * \text{N content in feed} \quad [5]$$

$$N_{\text{retained}} = (LWG * \text{N content in LW}) \quad [6]$$

where

$N_{\text{excretion}}$ is the total N excretion (kg per animal per year),

N_{intake} is the total N intake (kg per animal per year),

N_{retained} is the total amount of N retained in meat (kg per animal per year),

MW is the metabolic weight (kg) calculated as $(\text{weight})^{0.75}$,

LWG is the liveweight gain (kg per year),

LW is liveweight (kg),

a, b and q are empirical constants.

Coefficient a is the maintenance coefficient; it may range from 45 to 60 g per kg MW per day;

Coefficient b is the feed use per kg liveweight gain; it may range from 4 to more than 10 kg per kg;

Coefficient q is a parameter for the quality of the feed (range 1 to 1.3). For concentrate feed and high-quality herbage, q is 1; for poor quality roughages, q may be 1.3.

Calves receive milk during the first 6 to 8 weeks of their lives, either from their mother in the case of suckling cows or milk replacer. The protein content of the milk replacers is on average about 22%, but with a range of 21 to 26 % (3.4 to 4.2% N). Total intake of milk is about 350 kg, equivalent to 2 kg N over a period of about 50 days. Calves are introduced to a dry feed between 7 and 14 days after birth, and this is fed *ad lib* until weaning. Amounts consumed are very small for the first few weeks, but increase as the rumen begins to develop and the calf can digest the feed. The coarse calf mix normally contains 16-18%

crude protein (2.6 to 2.9% N). Calves should be consuming at least 1 kg/day of the dry feed before milk feeding is stopped.

The dry matter intake and N intake of growing cattle varies with breed, feed quality and management and housing and grazing system. It is principally determined by the energy requirements for maintenance and growth and the digestibility of the diet, but modified by a number of other animal and feed factors (NRC, 2000). The protein content of the diet can vary from 12 to 20% (N content between 19 and 32 g/kg), depending on the fractions of silage maize, grass, straw, grass silage, and concentrates in the diet. In practice, there are large differences between livestock systems that depend mainly on grass – either fresh (as grazed) or conserved (silage) and systems that use large amounts of maize silage or cereals. The grass-based systems commonly have higher protein content in the diet and lower growth rates per day than the silage maize and cereals based systems.

Table 23 provides N excretion coefficients of growing cattle of 0-1 year old, as function of growth rate and protein content of the animal feed. Clearly, N excretion increases with growth rate and protein content of the diet. The average protein content is about 15 to 16 % (bold values in Table 20). Hence, total N excretion of growing cattle of 0-1 year is in the range of 24 kg (at low growth rates) to 40 kg per animal per year at high growth rates. However, low and high values of 20 and 52 kg per animal per year are also possible.

Table 23. Mean annual N excretion of growing cattle (0-1 year old), as function of growth rate (kg per day) and protein content of the animal feed. The birth weight of the calf was set at 50 kg, the maintenance coefficient at 30 g DM per kg metabolic weight, and the feed conversion rate at 3.5 kg per kg.

Feed protein, %	Growth rate, kg/day				
	0.6	0.7	0.8	0.9	1.0
13	20	23	25	28	30
14	22	25	28	31	33
15	24	27	30	33	36
16	26	30	33	36	39
17	28	32	35	39	43
18	30	34	38	42	46
19	32	36	41	45	49
20	34	39	43	47	52

Table 24 provides N excretion coefficients of growing cattle of 1-2 year old, as function of growth rate and protein content of the animal feed. Again, N excretion increases with

growth rate and protein content of the diet. The average protein content is about 15 to 16 % (bold values in Table 21). Hence, total N excretion of growing cattle of 1-2 year is in the range of 50 kg (at low growth rates) to 70 kg per animal per year at high growth rates. However, extreme values of 40 and 90 kg per animal per year are in theory also possible.

Table 24. Mean annual N excretion of growing cattle (1-2 year old), as function of growth rate (kg per day) and protein content of the animal feed. The starting weight of the 1 year old cattle was set at 300 kg, the maintenance coefficient at 40 g DM per kg metabolic weight, and the feed conversion rate at 4.5 kg per kg.

Feed protein, %	Growth rate, kg/day				
	0.6	0.7	0.8	0.9	1
13	42	46	49	52	56
14	46	50	53	57	61
15	50	54	58	62	66
16	53	58	62	66	71
17	57	62	66	71	76
18	61	66	71	76	81
19	64	70	75	80	86
20	68	74	79	85	91

Table 25 provides N excretion coefficients of other cattle of > 2 year old, as function of growth rate and protein content of the animal feed. This category includes also breeding bulls. Again, N excretion increases with growth rate and protein content of the diet. The average protein content of this category is likely 14 to 15 % (bold values in Table 22). Hence, total N excretion of other cattle of > year is in the range of 43 kg (at low growth rates) to 77 kg per animal per year at high growth rates. However, extreme values of 37 and 104 kg per animal per year are in theory also possible.

Table 25. Mean annual N excretion of other cattle (>2 year old), as function of growth rate (kg per day) and protein content of the animal feed. The starting weight of the 2 year old cattle was set at 500 kg, the maintenance coefficient at 50 g DM per kg metabolic weight, and the feed conversion rate at 5.5 kg per liveweight gain

Feed protein, %	Growth rate, kg/day						
	0	0.1	0.2	0.3	0.4	0.5	0.6
12	37	41	45	49	53	56	60
13	40	44	49	53	57	61	66
14	43	48	53	57	62	67	71
15	46	51	56	62	67	72	77
16	49	55	60	66	71	77	82
17	52	58	64	70	76	82	88

18	56	62	68	74	81	87	93
19	59	65	72	79	85	92	99
20	62	69	76	83	90	97	104

The values presented in Tables 23, 24 and 25 are in the same range as the values proposed by the ERM/AB-DLO study (Table 26). In that study, a distinction was made between small and large breeds. In this case, small breeds refers to relatively low growth rates per day, and large breeds to high growth rates.

Table 26. Nitrogen excretion coefficients (kg N/animal/year) for growing cattle of small and large breeds with different age intervals; averages for male and female animals (ERM, 1999).

Growing cattle	Small breed			Large breed		
	Age (years)			Age (years)		
	0-1	1-2	2-3	0-1	1-2	2-3
% N in diet						
Low (12.5%)*	20	34	35	26	45	47
Medium (16.8%)	26	47	48	35	63	64
High (21.2%)	33	61	61	44	81	81

* 14.4% for animals of 0-1 year old.

The final category discussed here are suckler cows and calves. Suckler cows differ from dairy cows in that the calf typically remains with the mother for up to six or seven months before being weaned. Dry matter intake can vary considerably both during the course of a production cycle and between breeds and between systems of production, including feed composition. There is considerable evidence to show that the intake of protein is higher in the case of fresh grass than grass silage and silage maize, even at the same level of digestibility.

Table 27 provides N excretion coefficients of suckler cows, as function of growth rate, milk yield per cow per year, and protein content of the animal feed. Milk yield is an indication of the length of the period the calf is with the mother; the longer the period the higher the milk yield. The N excretion increases with growth rate and protein content of the diet. The average protein content of this category is likely 14 to 15 % (bold values in Table 27). Hence, total N excretion of suckler cattle is in the range of 60 kg (at low growth rates and rapid weaning) to 87 kg per animal per year at relatively high growth rates and late weaning. However, extreme values of 52 to over 100 kg per cow per year are in theory also possible. Increasing the growth rate from 0.1 to 0.3 kg per cow per day increases the N excretion rate by 5 kg per cow per year at low protein feeding (12%) to 10 kg at high protein content in the animal feed (18%).

Table 27. Mean annual N excretion of suckler cows, as function of growth rate (kg per day), milk yield (kg per year) and protein content of the animal feed (%). The starting weight of 74

the suckler cow was set at 500 kg, the maintenance coefficient at 55 g DM per kg metabolic weight, and the feed conversion rate at 5.5 kg per kg liveweight gain.

Feed protein, %	Growth rate 0.1 kg per day					Growth rate 0.3 kg per day				
	Milk yield, kg/cow					Milk yield, kg/cow				
	1000	1500	2000	2500	3000	1000	1500	2000	2500	3000
12	52	54	56	58	60	57	59	61	63	65
13	56	59	61	64	66	63	65	68	70	73
14	61	64	67	70	73	68	71	74	77	80
15	66	70	73	76	79	74	77	81	84	87
16	76	80	84	88	93	80	83	87	91	94
17	80	84	88	93	97	85	89	93	97	101
18	81	86	90	95	99	91	95	100	104	109

The values presented in Table 27 are in the same range as the values proposed by the ERM/AB-DLO study. In that study, N excretion coefficients ranged from 58 to 67 kg per cow for small breeds (body weight 425 kg and milk yield of 1000 kg per cow) to 80 to 99 kg per cow per year for large breeds (body weight 650 kg and 2000 kg milk per cow). For both breeds, they assumed a low liveweight gain of less than 0.1 kg per cow per day, but a relatively high protein content in the animal feed (18-20%).

6.4 Excretion coefficients of phosphorus for cattle

The Task 6 report of the current study (Van Krimpen et al., 2014) provides a detailed account of phosphorus (P) excretion coefficients used in Europe. The variation in P excretion coefficients between countries differs between animal categories. Based on a theoretical analyses of the P metabolism in the animals, and on a comparison of P excretion values between countries a list of “default values” is presented in Table 28. These default P excretion factors for different animal categories are based on the available values from the literature. Most values originated from West European countries, because values from other countries were lacking.

Table 28. Default P excretion coefficients (kg/animal/year) of different cattle categories.

Category	Description	Default values
Lactating cow of large breed	Dairy cow of FH or similar breed and producing 8,000 – 10,000 kg of milk per year	19.7
Lactating cow of	Dairy cow of Jersey breed or similar breed and	16.1

Jersey breed	producing on average 6,000 – 8,000 kg of milk per year	
Suckler cow	Lactating cow including 0.9 calf/year	12.4
Young stock <1 year	Young female animal reared to replace less-productive dairy cows, age between 0 and 12 months	3.4
Young stock > 1year	Young female animal reared to replace less-productive dairy cows, age between 12 and 24 months	7.8
Fattening cattle large breed	Non-lactating cattle fattened from 6 months until slaughter at 440 kg	4.5

7 Default excretion coefficients for pigs

7.1 Introduction

In the EU-27, pigs contribute roughly 20 to 30% of the total amounts of N and P excreted in animal manure. At global level, pigs are also significant producers of manure N and P, though with large differences between countries and also between continents.

The estimations of total N and P excretions by pigs vary significantly between countries, mainly due to differences in animal breeds, the number of weaned piglets per sow, the composition of the pig feed, and in slaughter weight.

This chapter provides default values for N and P excretion coefficients of pigs. The analysis of N excretion coefficients (Paragraph 7.2) is more detailed than the analyses of the P excretion coefficients (paragraph 7.3). For the N excretion coefficients, we follow the simple approach of ERM/AB-DLO (Ketelaar and van der Meer, 1999). For the P excretion coefficients, we base the results on the analyses of Task 6 (Van Krimpen et al., 2014).

7.2 Excretion coefficients for sows + piglets, weaners and fatteners

Usually, sows enter 'into production' at about 140 kg liveweight and are slaughtered at about 250 kg. Litter size may range from less than 8 to more than 14 piglets per sow. Frequency of delivery is once in 5 to 6 months. Hence, the number of piglets born per sow per year may range from less than 20 to more than 30 per year. The number of weaned piglets is less, due to mortality. Piglets remain with their mothers for 3-4 weeks until they have a weight of 7 kg (liveweight). Weaned piglets are removed to separate housing. A week or so after weaning, sows are served. After about 115 days piglets are born.

Table 29 provides N excretion coefficients for sows and piglets until weaning. Annual N excretion ranges from 20 to 23 kg per sow per year. Birth rate of piglets was set at a mean of 1 kg, but may range from 0.6 to 2 kg in practice. However, this variation does not have much effect on N excretion. The N content of the feed of dry and lactating sows has a large effect. In Table 29, a relatively small variation in N content was considered.

Table 30 provides estimates of N excretion coefficient for weaners from 7.5 to 25 kg and from 7.5 to 30 kg, as function of protein content in the feed. For weaners from 7.5 to 25 kg,

feed conversion rate was set at 1.7 and 1.6 kg per kg for protein contents of relatively low (16% equivalent to 26 g N) and high (20%, equivalent to 32% N) protein contents in the feed, respectively. For weaners from 7.5 to 30 kg, feed conversion rate was set at 1.9 and 1.8 kg per kg for protein contents of relatively low (16%) and high (20%) protein contents in the feed, respectively. Annual N excretion ranges from 2.8 to 3.8 kg per weaner place per year for weaners from 7.5 to 25 kg, and from 3.6 to 4.8 kg per weaner place per year for weaners from 7.5 to 30 kg, assuming an occupation of 80% of the year. Percentage N utilization ranged from 43 to 57%, depending on the protein content of the feed and feed conversion ratio.

Table 29. Production data of sows and piglets until weaning. Mean data derived for relatively good average farms. Lower and higher estimates derived from Task 2 information.

Parameter	Mean	Low	high
Piglets weaned (per sow per year)	23	20	28
Birth weight piglets, kg	1	1	1
Weaning weight piglets (kg)	7.5	7.5	7.5
Weight at transfer from piglet to fattening pig, kg	25	25	25
Annual weight gain of sows	50	50	50
Feed intake sow (kg)			
· Dry sow	700	700	700
· Lactating sow	453	420	508
· Total sow	1153	1120	1208
N content of sow feed (g/kg)			
· Dry sow	20	19	22
· Lactating sow	27	26	29
N intake sow (kg/sow/year)	26	24	30
Nitrogen retention sows + young piglets, kg			
Liveweight gain piglets, from birth to weaning (kg)	150	130	182
N content of liveweight gain - sow (g/kg)	26	26	26
N content of liveweight gain - piglet (g/kg)	30	30	30
N retention sow (kg/year)	1.3	1.3	1.3
N retention piglets (kg/year)	4.5	3.9	5.5
Total N retention (kg/year)	5.8	5.2	6.8
Nitrogen excretion (kg/sow/year)	20	19	23

Table 30. Production data of weaners from 7.5 to 25 and from 7.5 to 30 kg, as function of protein content in the feed.

Parameter	Weaners, 7.5-25 kg		Weaners, 7.5-30 kg	
	Low protein	High protein	Low protein	High protein
Start weight (kg)	7.5	7.5	7.5	7.5
End weight (kg)	25	25	30	30
Liveweight gain (kg)	17.5	17.5	22.5	22.5
FCR (kg feed/kg gain)	1.7	1.6	1.9	1.8
Feed consumed (kg)	30	28	43	40.5

Growth rate (g/day)	500	500	500	500
Growing days per cycle	35	35	45	45
N content of diet (g/kg)	26	32	26	32
N intake (kg/pig)	0.8	0.9	1.1	1.3
N content of liveweight (g/kg)	25	25	25	25
N retained (kg)	0.44	0.44	0.56	0.56
Total N excreted (kg/pig)	0.34	0.46	0.55	0.73
N utilisation (%)	57	49	51	43
Occupancy, %	80	80	80	80
No. of production cycles/year	8.3	8.3	6.5	6.5
N excreted (kg/pig place/year)	2.8	3.8	3.6	4.8

Table 31 provides estimates of N excretion coefficients for fatteners. A total of nine categories of fatteners were distinguished: Modern pigs with an end weight of 100 kg, medium-weight pigs with an end weight of 110 kg and heavy pigs with an end weight of 160 kg. Within these categories, a distinction was made between high, medium and low animal productivity (performance), as a results of differences in pig breeds, feed quality, management, housing conditions. The modern pigs kept on high productive farms have the lowest N excretion coefficients, and the heavy-weight pigs kept in low productive conditions have the highest N excretion coefficients. Occupancy was kept constant in all situations.

The N excretion coefficients ranged from 10.5 to 14.3 kg per pig place per year for modern pigs, from 11.2 to 14.9 for medium-weight fatteners, and from 15.1 to 18.9 kg per pig place per year for heavy fatteners. According to the ERM/AB-DLO (Ketelaar and Van der Meer, 1999) study, N excretion coefficients of fatteners from 25 to 100 kg range from 12 to 15 kg per pig place per year, depending on N conversion coefficient.

Table 31. Production data of fatteners from 25 to 100, from 25 to 110 and from 25 to 160 kg per pig, as function of animal productivity and protein content in the feed (i.e., low, medium and high animal productivity).

	Modern pigs			Medium-weight pigs			Heavy fatteners		
Parameter	High	Medium	Low	High	Medium	Low	High	Medium	Low
Start weight (kg)	25	25	25	25	25	25	25	25	25
End weight (kg)	100	100	100	110	110	110	160	160	160
Liveweight gain (kg)	75	75	75	85	85	85	135	135	135
FCR (kg feed/kg gain)	2.6	2.8	3	2.7	2.9	3.1	3.3	3.5	3.7
Feed consumed (kg)	195	210	225	230	247	264	446	473	500
Growth rate (g/day)	800	750	700	800	750	700	800	750	700

Growing days per cycle	94	100	107	106	113	121	169	180	193
N content of diet (g/kg)	25	27	29	25	27	29	25	27	29
Nitrogen intake (kg/pig)	4.9	5.7	6.5	5.7	6.7	7.6	11.1	12.8	14.5
N content of liveweight (g/kg)	25	25	25	25	25	25	25	25	25
N retained (kg)	1.9	1.9	1.9	2.1	2.1	2.1	3.4	3.4	3.4
Total N excreted (kg/pig)	3.0	3.8	4.7	3.6	4.5	5.5	7.8	9.4	11.1
N utilisation (%)	38	33	29	37	32	28	30	26	23
Occupancy, %	90	90	90	90	90	90	90	90	90
No. of production cycles/year	3.5	3.3	3.1	3.1	2.9	2.7	1.9	1.8	1.7
N excreted (kg/pig place/year)	10.5	12.5	14.3	11.2	13.1	14.9	15.1	17.1	18.9

The category other pigs is diverse, but relatively small in size. It includes rearing sows and boars and breeding boars. The animals are relatively heavy and have a relatively slow growth. The N excretion coefficient is set at 15 kg per animal place per year (range 12-18).

7.3 Excretion coefficients of phosphorus for pigs

The Task 6 report of the current study (Van Krimpen et al., 2014) provides a detailed account of phosphorus (P) excretion coefficients used in Europe. The variation in P-excretion coefficients between countries is relatively low. Based on a theoretical analyses of the P metabolism in the animals, and on a comparison of P excretion values between countries a list of “default values” is presented in Table 32. These default P excretion factors for different animal categories are based on the available values from the literature. Most values originated from West European countries, because values from other countries were lacking.

Table 32. Default P excretion coefficients (kg/animal/year) of different pig categories

Category	Default value
Average present sow incl. piglets to weaning	5.5
Average present sow incl. piglets up to the grower period	7.1
Weaned piglets	0.76
Growing–finishing pig	2.0

8 Default excretion coefficients for poultry

8.1 Introduction

Poultry includes laying hens, broilers, turkeys, ducks, and geese. The largest category are layers and broilers. In the EU-27, poultry contributes roughly 10 to 20% of the total amounts of N and P excreted in manure. The amounts of P excreted in manure are relatively large, due to the relatively high P content of the animal feed. At global level, poultry, are also significant producers of manure N and P, though with large differences between countries and also between continents. Poultry is also the category of animals that is growing fastest of all animals, in part because of their efficiency, but also because of the organization of the poultry sector; more than 80% of the animal breeds are delivered by just three big multinationals.

This chapter provides default values for N and P excretion coefficients of poultry. A distinction is made between layers and broilers. The analysis of N excretion coefficients (Paragraphs 8.2 and 8.3) is more detailed than the analyses of the P excretion coefficients (paragraph 8.4). For the N excretion coefficients, we follow the simple approach of ERM/AB-DLO (Ketelaar and van der Meer, 1999). For the P excretion coefficients, we base the results on the analyses of Task 6 (Van Krimpen et al., 2014).

8.2 Excretion coefficients of nitrogen for layers

In most commercial practices, hens commence laying at about 17 weeks of age, and continue to do so until end of lay, typically at 72 weeks of age. During the first 28 weeks, a slightly higher protein diet (17-18%) is fed, compared to a diet (16%-17) in weeks 46-72. Commonly, four different housing/management systems can be distinguished, namely cages, free housing in barns, free range and organic. These systems differ in housing system, breed type, feed type, and medicine (antibiotics) use, and as a consequence they differ in animal productivity and N excretion coefficients.

Table 33 provides estimates of N excretion coefficients for laying hens in the four aforementioned management systems. The last column shows the results of the ERM/AB-DLO study. The highest productivity and lowest N excretion coefficients are obtained with the cages system. However, this system is under discussion for animal welfare reasons, and will be

abandoned. The free housing and free range systems have lower productivity and higher N excretion coefficients, because of higher maintenance costs for the birds. Feed use per egg is highest in the organic systems, mainly because of the ban on the use of antibiotics.

The N excretion coefficients range from 0.7 kg per bird place per year to 0.83 kg per bird place per year for free housing in barns, up to 1.06 kg per bird place per year for organic layers.

Table 33. Production data of laying hens for four housing/production systems, namely cages, free housing in barns, free-range and organic. In addition, the mean data of the ERM/AB-DLO study are presented in the last column.

Parameter	Cage	Barn	Free Range	Organic	ERM/AB-DLO
Body weight at 17 weeks, kg	1.35	1.35	1.35	1.35	1.3
Body weight at 72 weeks, kg	1.95	2.00	2.00	2.00	1.9
Number of eggs	310	300	300	250	
Mean egg weight, g	63.5	64	64	64	
Egg yield, kg per bird	19.7	19.2	19.2	16.0	18
Feed intake, kg per bird	44	48	52	54	45
N content eggs, g per kg	18.5	18.5	18.5	18.5	
N content liveweight, g/kg	28.5	28.5	28.5	28.5	
N content of feed, g per kg	26.4	27.5	28	28	28
Feed conversion ratio, kg per kg	2.24	2.50	2.71	3.38	2.5
Total feed N consumed, kg per bird	1.16	1.32	1.46	1.51	1.26
Amount of N retained, kg per bird	0.38	0.37	0.37	0.31	
N excretion, kg per bird	0.78	0.95	1.08	1.20	
Production cycle, days	392	400	400	400	405
Empty period, days	14	14	14	14	14
N excretion, kg per bird place per year	0.70	0.83	0.95	1.06	0.79

8.3 Excretion coefficients of nitrogen for broilers

The broiler market is strongly globalized. As a consequence, there are not many breeds and differences between systems are relatively small. Within the EU-27, there is concern about animal welfare and that is the reasons that restrictions are being implemented on for example the

available surface area per broiler (which affect the feed conversion ratio and production costs. Also, there are differences in the final weight of the slaughtered animals.

Table 34 present some production data for broiler farms. Two systems are considered, namely conventional systems and organic farming systems. For both systems, production performances of mean farms, high-efficient farms and low-efficient farms have been presented, to show the possible ranges in practice. It was assumed that the slaughter weight of the broilers is 2.1 kg on conventional farms and 2.6 on organic farms.

The number of production cycles depends on (i) slaughter weight, (ii) growth rate per day, and (iii) days needed for cleaning the housing system between production cycles. In all cases it was assumed that cleaning the house requires just 1 day. In practice though, it may take also 5 days; in the latter case the N excretion per bird place per year go down by 5% when the number of cycles is 4 to 5 times per year, to up to 9% when the number of cycles is 7 to 8 times per year.

For conventional production systems, the N excretion ranges from 0.4 to 0.5 kg per bird place per year, and for organic farms from 0.7 to 0.8 kg per bird place per year (Table 34).

Table 34. Production data of fatteners from 25 to 100, from 25 to 110 and from 25 to 160 kg per pig, as function of animal productivity and protein content in the feed (i.e., low, medium and high animal productivity).

	Efficiency conventional farms			Efficiency organic farms		
Parameter	mean	high	low	mean	high	low
Body weight at the start, kg	0.042	0.042	0.042	0.042	0.042	0.042
Growth per day, g/day	49	53	45	37	42	32
Body weight at slaughter, kg	2.1	2.1	2.1	2.6	2.6	2.6
Feed conversion ratio, kg per kg	1.75	1.65	1.90	2.60	2.30	2.90
Growth period, days	42.0	38.8	45.7	69.1	60.9	79.9
N content liveweight, g/kg	28	28	28	28	28	28
N content of feed, g per kg	32	30	32	34	32	34
Total feed consumed, kg	3.60	3.40	3.91	6.65	5.88	7.42
Total feed N consumed, kg	0.12	0.10	0.13	0.23	0.19	0.25
Amount of N retained, kg	0.06	0.06	0.06	0.07	0.07	0.07
N excretion, kg per bird	0.06	0.04	0.07	0.15	0.12	0.18
Days for house cleaning, per cycle	1.00	1.00	1.00	1.00	1.00	1.00
Production cycles, number per year	8.5	9.2	7.8	5.2	5.9	4.5
Total feed intake, kg per year	30.6	31.1	30.5	34.6	34.7	33.5
Total N intake, kg per year	0.98	0.93	0.98	1.18	1.11	1.14

Total N retained, kg per year	0.49	0.53	0.45	0.37	0.42	0.32
Total N excreted, kg per year	0.49	0.41	0.53	0.80	0.69	0.81

8.4 Excretion coefficients of phosphorus for poultry

The Task 6 report of the current study (Van Krimpen et al., 2014) provides a detailed account of phosphorus (P) excretion coefficients used in Europe. The variation in P-excretion coefficients between countries is relatively low. Based on a theoretical analyses of the P metabolism in the animals, and on a comparison of P excretion values between countries a list of “default values” is presented in Table 35. These default P excretion factors for different animal categories are based on the available values from the literature. Most values originated from West European countries, because values from other countries were lacking.

Table 35. Default P excretion coefficients (kg/animal/year) of broilers and laying hens

Category	Default values
Broiler chickens, 40 days	0.098
Laying hens, free-range	0.183
Laying hens, cages	0.166

9 Conclusions and recommendations

9.1 Introduction

The main objectives of the task 5 reported here were:

- To provide guidelines for a coherent methodology for calculating N and P excretion factors; guidelines must be consistent with IPCC and CLTRP guidelines, and recent scientific results, and must take into consideration the diversity of agricultural systems in Europe, the need for underlying data and emission mitigation accounting;
- To analyse the robustness of the suggested approaches, and the strength and weakness of the suggested methodology;
- To identify the main components of the calculations of excretion factors and the data requirements for these components in such a detail that they allow introducing them in data collection systems.

The expected outcome of the task reported here is:

- Draft guidelines for potential common methodologies for estimating N and P excretion factors to be discussed in the workshop of Task 7.

This chapter summarizes the main conclusions and presents the main recommendations and guidelines for a coherent methodology for estimating N and P excretion coefficients for the main animal categories.

9.2 Conclusions

- When reporting N and P excretion coefficients in policy reports, countries in EU-27 often use different approaches, which often lead to different estimates of the N and P excretion coefficients (Velthof, 2014)⁵.
- An in-depth analysis of country reports indicated that the differences in N and P excretion coefficients per animal category may result from differences in animal productivity and animal husbandry practices, but also due to differences in (1) animal categorization, (ii) methods, and (iii) data and information collection/processing/reporting procedures (Sebek et al., 2014)⁶.
- There are relatively large differences in the categorization of animal species between 'formal inventories and databases'. This diversity in animal categorization hampers a comparison of excretion coefficients between countries. Moreover, it suggests 'inefficiencies' in (duplication of) data collection/processing/reporting. Evidently, there is a need for harmonization of animal categorization systems.
- Main animal categories in most countries are cattle, pigs and poultry. These animal categories commonly account for more than 75% of the total N and P excretion within a country. For all other animal categories (buffaloes, horses, donkeys, mink, foxes, rabbits, guinea-pigs, hamsters, deer) together, the total N and P excretion is commonly less than 25%. Hence, most efforts should be made in estimating the N and P excretion coefficients of cattle, pigs and poultry correctly.

⁵ Velthof, G.L. (2014). Overview of existing excretion factors in European Countries. Report Task 1 of Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat (2012/S 87-142068), Luxembourg.

⁶ Šebek, L.B. P. Bikker, A.M. van Vuuren, and M. van Krimpen. (2014) Nitrogen and phosphorous excretion factors of livestock. Task 2 : In-depth analyses of selected country reports. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat (2012/S 87-142068), Luxembourg.

- The variation in N and P excretion coefficients within animal categories are relatively large for dairy cattle, due to relatively large differences in cattle breeds, milk production per cow, feed management and especially protein content of the animal feed, and housing versus grazing.
- The variation in N and P excretion coefficients of broilers and layers is relatively small for conventional systems, as the animal breeds and feed composition does not vary much between farms and between countries, due to the effects of competition and globalization. However, differences between organic and conventional systems in N and P excretion coefficients for broilers and layers may be up to a factor of 2. This holds especially when high efficient conventional broiler production systems are compared with moderate efficient organic broiler production systems.
- Differences in production systems, within an animal category, which lead to differences in N and P excretion coefficients, are mainly defined by differences in:
 - Animal breeds (small vs large breeds, low vs high productivity),
 - Marketed animal products (small vs large final weight, young vs old animals)
 - Feed rations (e.g., low vs high protein)
 - Use of (veterinary) supplements in the animal feed (including antibiotics, hormones)
 - Production level (intensity)
 - Housing systems, including grazing vs restricted grazing vs zero-grazing systems

These aspects must be considered in accounting N and P excretion of the main animal categories (e.g., cattle, pigs, poultry) when the influence of variations in production systems on N and P excretion coefficients is significant.
- The balance method is a common and universally applicable method to estimate N and P excretion coefficients at farm level, regional level and national levels. The accuracy and quality of the calculated excretion coefficients depends on the quality of the data used (data origin). To enable review of the quality of excretion coefficients, it is necessary to document the data origin.
- There are five building blocks when applying the mass balance method:

- Animal categorization with the number of animals per animal category;
 - Feed intake per animal category;
 - Feed composition (i.e., the N and P contents of the feed) per animal category;
 - Animal production per animal category;
 - Composition of the animal products (i.e., the N and P contents) per animal category
- Any common, universal approach (including the mass balance approach) must account for the differences between countries in (i) the importance of livestock production, and hence in the relative magnitude of N and P excretion as a source of N and P, (ii) the type of livestock production systems (animal species, animal housing, animal feeding), and (iii) in the data and information collection and processing infrastructure. This holds especially also for the EU-28, where mean livestock density may range between Member States from an average of less than 0.5 livestock units (LSU) per ha to more than 3 LSU per ha.
- A three-tier approach addresses the aforementioned differences between countries in importance and type of livestock production and data collection/processing/reporting infrastructure. It describes three approaches for the collection of data that are needed for the estimation of N and P excretion coefficients. The three tiers are a function of the relative importance of the animal category, and the total N and P excretion by livestock within a region or country. All three tiers apply the mass balance method, but differ in the efforts needed to collect the data and information for estimating the N and P excretion coefficients, and thereby also in the accuracy of the coefficients.
- Main determinants of N and P excretion and hence for the selection of the most appropriate Tier are (i) livestock density, (ii) animal productivity in combination with animal feeding, and (iii) the relative importance of livestock categories. Decision trees have been developed for selecting the most appropriate Tier per country and per livestock category
- The proposed three-tier approach for the collection of data and information for the estimation of N and P excretion coefficients is also consistent approach, because in all

three Tiers a mass balance approach is applied for the derivation of the excretion coefficients per animal category, i.e.,

- $N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$

- $P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$

This balance approach can be applied at scales ranging from an animal, a farm, a region, country, continent and the whole world. The mass balance approach is also consistent with IPCC and CLTRP guidelines; Tier 2 of the IPCC guidelines applies a mass balance approach, while Tier 3 of both IPCC and CLTRAP apply country-specific approaches, which are based on a mass balance.

- A decision tree has been developed which allows to find the most appropriate Tier. The choice of a Tier depends on (i) the importance of animal production and hence total N excretion within a country, the importance and size of an animal category and hence the total N excretion by this animal category, (iii) the regional variation in N excretion within a country, and (iv) the data availability within a country.
- Default N excretion coefficients have been established for the main animal categories, as function of age, production level and (main) production systems. Also, default P excretion coefficients have been derived as function of age and production level.

9.3 Recommendations

- It is recommended to use the mass balance as a common and universally applicable method to estimate N and P excretion coefficients per animal category across EU-28:

$$N_{\text{excretion}} = N_{\text{intake}} - N_{\text{retention}}$$

$$P_{\text{excretion}} = P_{\text{intake}} - P_{\text{retention}}$$

- It is recommended to use a 3-Tier approach for the collection of data and information needed to estimate N and P excretion coefficients, so as to address differences between countries in livestock production and data collecting/processing infrastructure, and to

economize on data collection/processing efforts. The three Tiers differ in the origin, scale and frequency of data and information collection.

- It is recommended to use a Tier 3 approach for all main animal categories when livestock density in a country is > 2 livestock units per ha (>2 LSU per ha), equivalent to an excretion of about > 200 kg N and > 40 kg P per ha agricultural land per year.
- It is recommended to use a Tier 2 approach for all main animal categories when livestock density in a country is > 0.5 LSU < 2 per ha (equivalent to an excretion of about > 50 kg N < 200 , and > 10 kg P < 40 per ha agricultural land per year).
- It is recommended that countries invest in Tier 2 and 3 methods (and hence use country-specific, region-specific and/or year-specific excretion coefficients).
- It is recommended to use a Tier 1 approach for all animal categories within a country when total livestock density is < 0.5 livestock units per ha (< 0.5 LSU per ha), which is equivalent to about 50 kg N and 10 kg P per ha agricultural land per year.
- It is recommended to use region-specific N and P excretion coefficients when N and P excretion coefficients of the main animal categories differ significantly ($> 20\%$) between regions.
- It is recommended that computer programs are made available to allow the calculation of the N and P excretion per animal category at regional and national levels in a uniform way. It is also recommended to provide training courses for the use of these programs and the calculation of the N and P excretion coefficients.
- It is recommended that all countries have well-documented and accessible methods for the estimation of N and P excretion coefficients per animal category. These reports should be updated once every 3-5 years and reviewed by external experts.
- We recommend that efforts are undertaken to harmonise the various animal categories in formal policy reporting. We recommend that the FSS categorization is taken as the

main list of animal categories, also because the inventory of the number of animals takes place regularly according to the FSS list of animal categories. We recommend also that a transparent scheme and computer program is developed for translating the inventory data of FSS into the current animal categories of secondary databases (e.g., UNFCCC/IPCC, EMEP/EEA, Nitrates Directive, FAO and OECD).

- For main animal categories (e.g., cattle, pigs and poultry, contributing >10% to the total N and P excretion within a country and/or region) it is recommended to consider a secondary categorization according to 'production system' , when more than 20% of the animals are in "another" system and when the N and/or P excretion coefficients differ by more than 20% from the overall mean N and P excretion coefficients. We recommend that the following aspects are considered for distinguishing different production systems:
 - Fast-growing and heavy breeds vs slow-growing breeds
 - Organic production systems vs common production systems
 - Housed ruminants vs grazing ruminants
 - Caged poultry vs free-range poultry
- It is recommended that a review is made of the diversity of production systems within a country for the main animal categories cattle, pigs and poultry once in 5 yrs, so as to trace changes in production systems, including organic versus conventional systems, housed vs grazing ruminants, caged versus free range poultry, and fast growing breeds versus slow growing breeds.
- It is recommended that the N and P excretion coefficients for main animal categories (cattle, pigs poultry) in countries with a relatively high livestock density are updated every year (Tier 3 approach), because of rapid developments in animal breeding and production systems, and changes in feeding ingredients as function of weather and market conditions.
- It is recommended that the N and P excretion coefficients for minor animal categories (sheep, goat buffaloes, horses, donkeys, mink, foxes, rabbits, guinea-pigs, hamsters, deer) are updated once in 3-5 yrs.

References

- Alexandratos N, and Bruinsma J (2012) World Agriculture towards 2030/2050. The 2012 revision. ESA Working paper No. 12-03, Rome, FAO.
- Diamond, J. 2002. Evolution, consequences and future of plant and animal domestication. *Nature* 418, 700-707 | doi:10.1038/nature01019
- European Commission (2013). Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry and Pigs. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). JOINT RESEARCH CENTRE. Institute for Prospective Technological Studies Sustainable Production and Consumption. Unit European IPPC Bureau.
- Herrero M., Havlík P., Valin H., Notenbaert A., Rufino M. C., Thornton P. K., Blümmel M., Weiss F., Grace, Obersteiner M., Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems, *Proc Natl Acad Sci USA*, 2013.
- Hickman C, Roberts L, Keen S, Larson A, l'Anson H, Eisenhour D. 2006. Integrated Principles of Zoology. 14th ed. Boston MA: McGraw-Hill; 910 p.
- IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture, Forestry and Other Land Use
(http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf)
- FAO, 2009. Livestock in the Balance. The State of Food and Agriculture. The State of Food and Agriculture 2009 <http://www.fao.org/docrep/012/i0680e/i0680e.pdf>.
- Ketelaars J.J.M.H. and H.G. van der Meer (1999) Establishment of criteria for the assessment of the nitrogen content of animal manures. Final report of the second phase ERM project number 5765, AB DLO, Wageningen.
- Klop, G.; Ellis, J.L.; Bannink, A.; Kebreab, E.; France, J.; Dijkstra, J. 2013. Meta-analysis of factors that affect the utilization efficiency of phosphorus in lactating dairy cows. *Journal of Dairy Science* 96: 3936 – 3949.
- Kros, H. and O. Oenema, Task 4: Regional representativeness of nitrogen and phosphorus excretion factors. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat.
- Lesschen, J.P., van den Berg, M., Westhoek, H., Witzke P., and Oenema, O., 2011. Greenhouse gas emission profiles of European livestock sectors. *Animal Feed Science and Technology*, 166-167, 16-28.

- Menzi, H., O. Oenema, C. Burton, O. Shipin, P. Gerber, T. Robinson, and G. Franceschini. 2010. Impacts of Intensive Livestock Production and Manure Management on the Environment. Pages 139-163 in: Steinfeld H. et al. (eds.) *Livestock in a Changing Landscape: Drivers, Consequences and Responses*. Chapter 9 Island Press.
- NRC (2001). *Nutrient Requirements of Dairy Cattle*, 7th Ed., National Research Council (NRC) Nat. Acad. Press, Washington, DC.
- NRC (1998). *Nutrient requirements of swine*. 10th Ed. National Research Council (NRC) Nat. Acad. Press, Washington, DC.
- Oenema, O., and Tamminga S., 2005. Nitrogen in global animal production and management options for improving nitrogen use efficiency. *Science in China Series C: Life Sciences*, 48, 871-887.
- Oenema, O., Oudendag, D., Velthof, G.L., 2007. Nutrient losses from manure management in the European Union. *Livest. Sci.* 112, 261–272
- Oenema, O. 2011. Direct and indirect data needs linked to the farms for agri-environmental indicators. Final Report DireDate. Eurostat, Luxembourg. 88 pp.
- Šebek, L.B. P. Bikker, A.M. van Vuuren, and M. van Krimpen. (2014) Nitrogen and phosphorous excretion factors of livestock. Task 2 : In-depth analyses of selected country reports. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat
- Sheldrick, W. F., J. K. Syers, and J. Lingard. 2003. Contribution of livestock excreta to nutrient balances. *Nutrient Cycling in Agroecosystems* 66:119–31.
- Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C (2006) *Livestock' s long shadow: environmental issues and options*. Rome: Food and Agriculture Organization.
- Steinfeld H, Mooney H, Schneider F, Neville LE (Eds.) (2010) *Livestock in a changing landscape: Drivers, Consequences and Responses*. Washington, DC: Island Press.
- Suttle, 2010
- Sutton, M.A., Howard, C.M., Erisman, J.W., Billen, G., Bleeker, A., Grennfelt, P., van Grinsven, H., Grizetti, B., (Eds.) 2011. *The European Nitrogen Assessment. Sources, Effects and Policy Perspectives*. Cambridge University Press, UK.
- Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S (2002) Agricultural sustainability and intensive production practices. *Nature* **418**, 671-677.
- Van Krimpen, M.M., L. Sebek, P. Bikker, and A.M. van Vuuren (2014) Default phosphorus excretion factors of farm animals. Task 6. Methodological studies in the field of Agro-Environmental Indicators. Lot 1 excretion factors. Eurostat
- Velthof, G.L., Lesschen, J.P., Webb, J. Pietrzak, S., Miatkowski, Z., Pinto, M., Kros, J. and Oenema, O., 2014. The impact of the Nitrates Directive on nitrogen emissions from

agriculture in the EU-27 during 2000-2008. *Science of Total Environment* 468-469: 1225-1233.

Westhoek, H., Rood, T., van de Berg, M., Janse, J., Nijdam, D., Reudink, M., and Stehfest, E., 2011. The protein puzzle: the consumption and production of meat, dairy and fish in the European Union. The Hague: PBL Netherlands Environmental Assessment Agency.

Whitehead, D.C. 2000. Nutrient Elements in Grassland: Soil-plant-animal Relationships. CABI.