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System documentation and first results

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Foreword

This report documents the first version the Finnish Normative Manure System (FNMS) and its first results. When using the data presented, please, be aware that

- **the results presented here contain development needs which still need to be addressed to improve the quality of the results,**
- **the system is updated and maintained regularly, and**
- **due to this, the system will be constantly developed further and at all times the users of the normative manure data are advised to check the most recent documentation and results from http://www.luke.fi/projektit/normilanta**

Animal manure is an unavoidable by-product from animal production. It has been traditionally utilised as a fertiliser in crop production. In current times of concentrated animal and thus also manure production, information on manure quantity and quality has become increasingly necessary for ensuring efficient manure management and utilisation.

The multiple aim of manure management is to ease the workload deriving from manure handling, to make efficient use of the valuable resources in manure and to control the environmental effects of manure. Different manure types are produced in animal houses depending on the housing technology. Adequate storage capacity enables manure fertiliser use in the optimal season, and manure nutrient content must be known to fertilise according to soil type and crop need. To enhance manure utilisation, installations for processing it may be designed, built and operated based on case-specific data on the quantity and quality of the manure to be processed. Also, decisionmakers depend on accurate manure data for policy instruments, whether legislative or support mechanisms. Reporting of agricultural emissions and actions to reduce them as well as research and development towards enhancing circular economy and nutrient recycling depend on high quality manure data.

As the uses for manure data have increased, its poor quality has also become evident. The Finnish manure data was previously outdated, roughly estimated and/or totally lacking. The data used in different tasks and by different stakeholders was variable, inconsistently collected and documented, and subsequently incomparable.

The pursuit to update Finnish manure data started in co-operation with Natural Resources Institute Finland Luke and Finnish Environment Institute SYKE during HYÖTYLANTA research programme (2008-2010) and Baltic Manure project (2011-2013). As a part of this pursuit, e.g. a large farm survey to determine the current status of manure management on Finnish animal farms was conducted (2013-2014). The further the task has proceeded, the more apparent the need for an "official" source of data on average Finnish manure has become.

Thus, the idea of a modelled system for calculating Finnish manure quantity and quality was introduced and the project "Finnish Normative Manure" executed in 2014-2017. The system aims to present average Finnish manure for a large set of animal groups in different species, breeds, genders and ages, and in different manure types. The system can also be used to calculate regional and farm-specific manure data, and it forms a joint basis for all manure-related work in policymaking, technology development, research and practical farming.

the Authors

Abstract

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This report contains the documentation of the first version of the Finnish Normative Manure System (FNMS). The system calculates Finnish manures as a mass balance starting from animal feeding and excretion (excretion ex animal) and considering national manure management in housing (manure ex housing) and manure storage (manure ex storage). The system calculates manures for 74 animal categories in four manure types (slurry, farmyard manure, deep litter and source-separated dung and urine). The total annual quantities of manure, dry matter, organic matter and nutrients (nitrogen, phosphorus, potassium) are reported per animal and per animal place (t/year). Also, the content of dry matter, organic matter and nutrients in manures are reported (kg/t). The system quantifies national manure amounts and their nutrient contents. It also enables calculation of regional manures. In addition, the calculation of biological methane production potential was included to enable estimation of biogas production potential from manure nationally and regionally.

The calculation system works well and the results reported can be used for various purposes in policymaking, regulation, emission inventories, research and development all aiming at enhanced manure utilisation. The system can still benefit from developing especially the quality of the background data used.

The system was created in co-operation with Luke and SYKE during 2014-2017. Financing for the system development was received from Finnish Ministry of the Environment (main project) and Ministry of Agriculture and Forestry (additional work e.g. related to excretion calculation and background data collection).

A Finnish summary of this documentation report is also available (Luostarinen et al. 2017a).

Keywords: Excretion, Manure, Model, Normative, Nutrient.

Terminology

Animal categories

BOAR	An uncastrated male pig used for breeding
BROILER	Chicken reared for meat production
BROILER BREEDER(S)	Parent stock (males and females) kept to lay eggs for broiler production
BULL	An uncastrated adult bovine animal, male
CALF	The offspring of a cow (male/female)
COCKEREL (laying hen)	Male breeder kept to enable laying eggs for hatching
DAIRY COW	Cows kept for producing milk or for rearing calves for a dairy herd
EWE	An adult female sheep
FATTENING PIG	Pigs typically reared from a live weight of 30-50 kg to slaughter.
GILT	A young female pig before she has produced her first set of offspring
GOAT	A ruminant allied to sheep and kept for milk, meat and sometimes wool (male/female)
GOATLING	A young goat until it is weaned or the meat derived from it
HEIFER	>1 year old cow (different ages) before giving birth to first calf
HIGH YIELDING	High-yielding cattle breeds for dairy (e.g. Frisian, Ayrshire) and beef (e.g. Hereford, Aberdeen Angus)
HORSE	A large horse with the height of >140 cm
LAMB	A young sheep until it is weaned or slaughtered
LAYING HEN BREEDER	Parent stock (males and females) kept to lay eggs for hatching
LOW YIELDING	Finnish indigenous cattle breeds for dairy and beef production
PIGLET	The offspring of a sow = Pigs from birth to weaning
PONY	An small horse with the height of <140 cm
PULLET	Young chicken below the age for laying eggs
RAM	An uncastrated male sheep
SHEEP	A ruminant kept mainly for meat and wool and sometimes for milk
SOW	Female pig during the rearing periods of mating, gestating and farrowing • Farrowing sow = Sow between perinatal period and weaning of the piglets • Gestating sow = Pregnant sow, including gilts • Mating sow = Sow ready for service and before gestation
SUCKLER COW	A cow that is allowed to rear its own calf before this is reared for beef production rather than for milk production
TURKEY	Large poultry species kept for the production of meat • Growing turkey = birds for slaughter • Breeder female/male = parent stock to kept to lay eggs for turkey production
WEANED PIG	Young pigs from weaning until fattening, typically reared from a live weight of around 8 kg to 30-50 kg

Manure types

DEEP LITTER	A solid manure type in which urine is absorbed into the bedding material and manure is removed only seldom (e.g. after each batch)
DUNG	A solid manure type from source-separating manure management system, a mixture of faeces, bedding material and a small amount of absorbed urine
EXCRETA	Faeces and urine directly from animal
FAECES	The solid excreta of animals
FARMYARD MANURE (FYM)	A solid manure type in which faeces and urine are mixed with large amounts of bedding (usually straw)
MANURE	Usually a mixture of faeces and urine with or without bedding material and cleaning water, depending on the type of animal housing system
SLURRY	A liquid manure type in which faeces, urine, small amount of bedding material and all cleaning waters are mixed together to form a sludge-like manure with dry matter content below 15%
SOLID MANURE	A general term for all solid/dry manure types (deep litter, farmyard manure, dung)
URINE	The liquid excreta of animals OR source-separated urine collected separately from dung

Other terminology

AMMONIA (NH_3)	Inorganic form of nitrogen
AMMONIUM NITROGEN (NH_4^+)	Inorganic, positively charged form of ammonia
BATCH	A period of growing poultry and pigs
BEDDING MATERIAL	Material placed on the floors of livestock houses with solid floors or partially slatted floors to provide some comfort to the animals and to absorb moisture and urine. Commonly straw, chopped straw, sawdust, wood shavings, sand, peat. Rubber or plastic mats may also be provided for animals to lie on.
BEST AVAILABLE TECHNOLOGY (BAT)	The most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole (IE-directive)
BIOLOGICAL METHANE PRODUCTION POTENTIAL (BMP)	The maximum amount of methane produced from an organic material during anaerobic digestion

DRY MATTER (DM)	The residue remaining following heating under standard conditions (usually around 105° C to constant weight) to drive off water. Often expressed as a percentage of the weight of original material (may also be called total solids, TS)
EX ANIMAL	Manure directly from animal
EXCRETION	The excreta remaining from animal feed after growth and products (milk, meat, eggs)
EX HOUSING	Manure after housing
EX STORAGE	Manure after storage
FINNISH NORMATIVE MANURE SYSTEM (FNMS)	A model for calculating manure quantity and quality in Finland
LITTER	See: Bedding material
ORGANIC MATTER	See: Volatile solids
TOTAL AMMONIACAL NITROGEN (TAN)	The total amount of ammonium and ammonia nitrogen contained in e.g. livestock manures.
TOTAL NITROGEN (Ntot)	Total Kjeldahl nitrogen
TOTAL PHOSPHORUS (Ptot)	Phosphorus extractable in strong acid, a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample
TOTAL POTASSIUM (Ktot)	Potassium extractable in strong acid
URIC ACID NITROGEN	Nitrogen in the uric acid of poultry excreta (uric acid = The main end product of the protein metabolism of birds)
VOLATILE SOLIDS (VS)	The weight loss after a sample of total solids is ignited in a furnace (heated to dryness at 550° C; total solids = dry matter DM)

Contents

1. Introduction

Reliable information on the quantity and quality of different manure types is a prerequisite for sustainable utilisation of manure nutrients, organic matter and/or energy content. Due to the targets on circular (bio)economy on Finnish national and EU level, especially nutrient recycling and resource-efficiency are gaining increasing attention.

Of organic recyclable materials, manure is the most abundant biomass with the most nutrients to be recycled in Finland (Marttinen et al. 2017). While most manure is already being reused as a fertiliser in agriculture, there is a significant potential to enhance its use. New solutions are needed especially in intensive animal production and on regions with high animal density. To facilitate effective planning of such enhanced manure use on transnational, national, regional and farm levels, new tools providing updated data on manure quantity and quality are needed. In many countries, however, such data is only partly or not at all available.

More precisely, information on manure quantity and quality is needed in several different tasks related to i) practical manure management and use on farms (e.g. storage capacity, manure application rates), ii) research and development on manure management and processing into new products, iii) policymaking (e.g. Rural Development Programme (RDP), legislation) and iv) emission inventories. All the above mentioned tasks contain the joint target of effective actions towards improved nutrient recycling and reduced emissions. Further, as a member state in the European Union and due to different international conventions, Finland is e.g. obliged to report data on or derived from animal excretion and manure management to several different purposes, including agri-environmental indicators, Nitrates directive and emission inventories (greenhouse gases, ammonia, nutrient runoff). National manure data used in all these purposes need to be scientifically valid, reliable, comparable and always updated.

Manure quality can be determined with comprehensive sampling and subsequent chemical analysis. Manure quantity and quality can also be modelled calculating from excretion to manure management. Both methods are being used internationally. For instance, Denmark turned from manure sampling and analysis to a normative, modelled system in 1990s. They considered sampling and analysis too susceptible for interpretation and error. Many other countries use both modelling and sampling depending on the task at hand (Luostarinen & Kaasinen 2016).

However, the manure data in Finland or in other EU member states is not solid. European Commission has commissioned surveys on how the member states collect manure data and what its quality is like. According to the results, i) manure data is largely lacking, ii) manure data is often based on estimates instead of measured/calculated results, iii) different stakeholders offer, receive and/or use variable and incomparable manure data, and iv) there is no harmonisation of methods for manure data provision (van Beek et al. 2011). Within agri-environmental indicators, manure data is considered the weakest (van Beek et al. 2011) and there is discussion on the need to create updated joint calculation procedures for calculating nitrogen excretion (Velthof et al. 2015).

Due to similar observations in the Baltic Sea Region, the Interreg project Baltic Manure (2011-2013) recommended determination of standardised methods for manure data calculation and using them as the basis for manure fertilisation. In October 2013, the Baltic Sea states made a Ministerial Declaration to create guidelines for determination of manure nutrient content and implement them in each Helsinki Commission (HELCOM) country by 2018. As part of this work, the Baltic Sea countries reported their state-of-the-art in manure data provision to show the large differences in the methods applied (Luostarinen & Kaasinen 2016).

In light of this background and several identified deficiencies in Finnish manure data, a normative manure system was developed in cooperation between Natural Resources Institute Finland Luke and Finnish Environment Institute SYKE during 2014-2017. Since 2014, the need for manure data has increased significantly.

1.1. Manure data in Finland before the normative system

At the time of writing, information on Finnish manure quality is regulated by the Government Decree on the restriction of discharge of certain emissions from agriculture (1250/2014, a national decree to enact the Nitrates directive 91/676/EC). The Decree requires each animal farm to sample and analyse their manure minimum every five years. The farm may base their manure fertilisartion on the analysis result or they can choose to use so called “table values” (1250/2014, appendix 2), which are based on a large quantity of manure analysis results from commercial laboratories. This option between the farm-specific analysis and the table values is also included into the voluntary agri-environmental support scheme of the Rural Development Programme 2014-2020.

Manure quantity is currently based on a rough calculation of excreted manure and average additions of bedding material and water in different manure types (slurry, farmyard manure, deep litter, dung and urine). The quantities are the basis for estimating minimum storage capacity for different manures (1250/2014, appendix 1).

The Government Decree 1250/2014 is applied to all Finland as a nitrate vulnerable zone, and thus it also applies to all farms. Many of the clauses in the Decree are tied to measures in the RDP, requiring their fulfillment to receive support and subjecting the farms to surveillance.

1.2. Advantages and challenges of analysis-based manure data

The most important advantage of using farm-specific manure analysis or table values is their simplicity. They are understandable to all stakeholders. The table values are based on a large dataset of analysed manures, which adds to its reliability. Moreover, such a dataset would not be available without the legislative requirement for manure analysis minimum every five years. Farm-specific manure analysis increases the precision of manure data per farm as long as the farming practices stay relatively stable during the five years of one analysis being valid.

However, both farm-specific manure analysis and the table values are subject to errors and do not offer all the manure data needed. A shared weakness for both is that they are mostly limited to only manure after storage, as usually the manure is sampled from storage and prior to being spread (ex storage). Thus, the results are not applicable for excretedfaeces and urine (ex animal) or for manure directly after collection from animal houses (ex housing). This is a major shortcoming e.g. in policy making (excretion data often as a basis for manure-related environmental effects and their control) and for technologies in manure management and processing (manure ex animal and ex housing important).

Moreover, the table values are generalisations. They are limited to only a few animal categories and manure types (slurry/solid manure/urine of cattle and pigs, solid manure of sheep, goats, horses, broilers, laying hen, turkeys, minks and foxes). More precise division is impossible as the samples are poorly identifiable. For example, naming the sample “poultry manure” does not determine which poultry is meant. Additionally, the quality of manure from different animals and of different manure types is not taken into account even though they may vary considerably. For example, “cattle slurry” neglects the differences in e.g. breeds, age groups, feeding and manure management between farms producing beef or dairy cattle. Practices within farms may also vary significantly in relation to e.g. water usage and bedding choice and amount. Overall, the table values should be updated regularly to reflect the change in housing practices.

Farm-specific manure analysis may give a more precise result. Still, the chance for errors is significant due to several reasons, such as poor sampling of the heterogeneous material, errors in sample preparation and/or errors/variation in analysis methods. The latter has been noticed e.g. when comparing the datasets of two separate commercial laboratories in Finland.

The short-comings of the analysis-based system may lead to overfertilisation on some farms and underfertilisation on others, depending on the choice between analysis and table values and their

representativeness of the actual farm-specific manure. The effects on farm economy and the environment also vary accordingly.

1.3. A normative calculation system for manure data

The challenges related to table values, manure sampling and analysis and also partial lack of manure data may be overcome with a science-based normative manure system. It calculates both manure quantity and quality starting from feeding and excretion of the animals and proceeding to the manure management choices in housing and manure storage.

The system produces manure data from the entire manure management chain, including the quantity and quality of faeces and urine excreted (ex animal), manure from different housing solutions (ex housing) and manure to be spread on the fields after storage (ex storage). The data can be used in different actions as required. Farm-specificity can be included into the system by allowing e.g. choice of feeding (instead of average feeding recommendations), bedding material and amount, water use and storage type. The amount of separate animal categories is largely infinite and can take into account different breeds (e.g. dairy and beef cattle in high-producing and indegenous breeds), ages (e.g. heifers 1-2 years and calves 0-6 and 6-12 months) and average manures e.g. for Finnish cattle according to animal numbers. The number and specificity of animal categories can be chosen as necessary for the end use of the calculation results.

A fully functioning normative manure system provides an equal basis for development and implementation of manure use to all stakeholders from policymaking to practical farming. To be acceptable to all users, the system must be well-documented and thus transparent, and regularly updated.

1.4. Aim of this documentation report

This report documents the first version of the Finnish normative manure system built by Natural Resources Institute Luke and Finnish Environment Institute SYKE in 2014-2017. The system calculates manure quantities and qualities for numerous animal categories, starting from feeding and excretion of the animals and proceeding along the manure management chain in animal housing and manure storage.

The system is meant to provide consistent, up-to-date information on average manure quality and quantity for all stakeholders e.g. in policymaking, research, technology development and farms. The ultimate aim of the system is also to set a solid base for a Finnish up-to-date database for manure-related information, such as nutrient excretion rates and the results from the normative system. Such a database is planned to be established as a separate project.

Normative manure system is a tool needed for all manure-related agri-environmental measures, whether regulative or voluntary. As manure is the most important source of ammonia emissions, has a significant effect on the greenhouse gas emissions from agriculture and has a major role in national nutrient balances, the manure data behind these emission inventories is crucial for fulfilling the targets set for Finland. The same data is also used as the background data for regulation, including e.g. environmental permitting of animal houses, capacity requirements for manure storages and the average nutrient content of manure to be used e.g. in planning manure fertilisation. The agri-environmental scheme of rural development programme also holds actions affecting manure use and their impact assessment, subsequent revision and planned actions in new programme periods need manure data.

Finland is also active in promoting nutrient recycling following the targets of circular economy. As manure is the most significant source of recyclable nutrients in biomasses, the manure data behind planning new actions towards improved nutrient recycling, is important. New tools to assist in such planning, both in authoritative and practical level, are being produced and include a national

biomass atlas and a calculator for regional nutrient recycling. Such tools require solid, updated manure data. Simultaneously, enhanced use of manure energy content and organic matter can be planned and subsequently implemented.

While the normative manure system is documented here and the first results published, development work continues. The system will benefit from e.g. updating the excretion calculation, data collection on bedding and water additions and improvement of dry matter loss and water evaporation. Many data needs of the normative manure system have previously been overlooked or the data is too old to describe current manure management practices and technologies.

Overall, the system is never “ready”, but needs regular updating and maintenance. Therefore, it is foreseen that an annual result publication with updated values is to be required, including clear documentation on the potential changes made.

2. Normative manure system: structure and calculations

2.1. Structure and main principles of the system

The normative manure system consists of five interlinked units (Figure 1):

- Animal excretion unit provides data on the quantities and qualities of faeces and urine as excreted by animals;
- Manure management unit consists of detailed data on average manure management practices for each animal category and manure type in Finland;
- Emission calculation unit calculates gaseous emissions of nitrogen (N) and carbon (C) compounds in each phase of the manure management system for each animal category and manure type;
- Normative manure calculation unit uses the afore mentioned data and calculates manure mass balances for each animal category and manure type;
- Reporting unit delivers the resulting mass balances as manure quantity and quality separately for each manure management phase (ex animal, ex housing and ex storage)
    - Per animal category,
    - Per manure type, and
    - As national or regional total quantities.

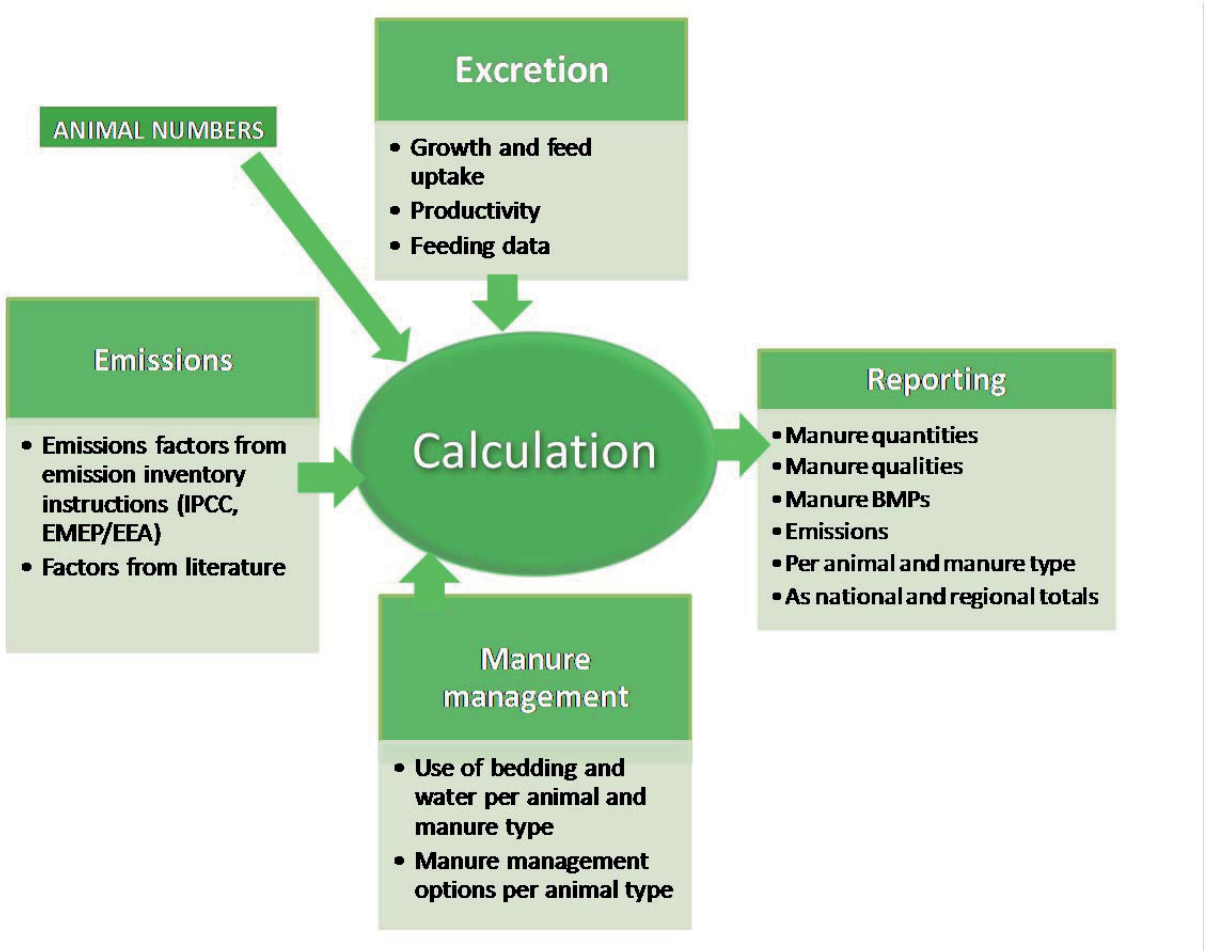

Figure 1. The structure of the Finnish normative manure system.

2.2. Calculation procedures and input data sources

The Finnish normative manure system was built in MS Office Excel. It allows choosing from different national data sets for different years and adding separate data for e.g. farm-specific calculation.

2.2.1. Animal categories and animal numbers

A total of 74 animal categories were added into the system (Tables 1-2). Most of the animal categories can already be calculated, but some were not finalised yet, mainly due to lack of some essential data. Fur animals were calculated in 2016-2017 and are reported separately (Luostarinen et al. 2017b) and sheep will be included later due to larger development needs in excretion calculation.

The animal categories were chosen with consideration of different production types (e.g. dairy and beef cattle) and breeds (e.g. high yielding and indigenous cattle), the needs of emission inventories (greenhouse gases and air pollutants) and the availability of statistical animal numbers in Finland.

In this report, results of the first system version are given for the animal categories presented in Table 1. The more detailed categorisation to be fully developed later is presented in Table 2.

Numbers of cattle, pigs, poultry and goats were acquired from Statistics Services of Natural Resources Institute Finland (Luke Statistics 2017). Numbers of horses and ponies were based on the statistics of Suomen Hippos and the Finnish Trotting and Breeding Association. The animal data used in this report represents year 2014 as the excretion calculations were made for the same year. The data is well valid for the next years as well.

Table 1. Simplified animal categories reported in the first version of the Finnish normative manure system and used in the emission inventory purposes.

CATTLE:	PIGS:	POULTRY:	OTHER ANIMALS:
Dairy cow	Sow (with piglets)[a]	Laying hen breeder (female)	Horse
Suckler cow	Boar (50- kg)	Cockerel (laying hen breeder, male)[b]	Pony
Heifer >1 yr	Fattening pig (50- kg)	Broiler	Sheep[c]
Bull >1 yr	Weaned pig (<50 kg)	Broiler breeder hen[b]	Goat
Calf <1 yr		Broiler breeder, male[b]	Fox[d]
		Pullet[b]	Mink[d]
		Turkey	Reindeer[e]
		Other poultry[b]	

[a]An average of farrowing, gestating and mating sows + piglets until weaning;
[b]Results not presented in the report;
[c]To be added after excretion calculation is updated;
[d]Published separately Luostarinen et al. 2017b;
[e]Not fully considered at the moment, included only in the emission inventory system

Table 2. Detailed animal categories included into the Finnish normative manure system.

CATTLE:	PIGS:	POULTRY:	OTHER ANIMALS:
Dairy cow, high yielding	Farrowing sow + piglets (<10-12 kg)	Laying hen breeder (female)	Horse
Dairy cow, low yielding (indigenous)	Gestating sow	Cockerel (laying hen breeder, male)	Pony (120–140)
Suckler cow, high yielding	Mating sow	Broiler	Pony, little (<120)
Suckler cow, low yielding (indigenous)	Boar (50- kg)	Broiler breeder hen	
Heifer, beef (2- yrs)	Fattening pig (50- kg)	Broiler breeder, male	Ewe
Heifer, beef (1-2 yrs)	Weaned pig (<30 kg)	Pullet	Ram
Heifer, dairy (2- yrs)	Weaned pig (<50 kg)	Growing turkey	Lamb
Heifer, dairy (1-2 yrs)		Turkey breeder hen	
Heifer, indigenous (>2 yrs)		Turkey breeder male	Doe
Heifer, indigenous (1-2 yrs)		Other poultry	Puck
Bull, beef (>2 yrs)			Goatling
Bull, beef (1-2 yrs)			
Bull, dairy (>2 yrs)			Fox breeder, female
Bull, dairy (1-2 yrs)			Fox breeder, male
Bull, indigenous (1-2 yrs)			Fox grower
Bull, indigenous (>2 yrs)			
Calf, female, beef (< 6 months)			Mink breeder, female
Calf, female, beef (6-12 months)			Mink breeder, male
Calf, female, dairy (< 6 months)			Mink grower
Calf, female, dairy (6-12 months)			
Calf, female, indigenous (< 6 months)			Reindeer*
Calf, female, indigenous (6-12 months)			
Calf, male, beef (< 6 months)			
Calf, male, beef (6-12 months)			
Calf, male, dairy (< 6 months)			
Calf, male, dairy (6-12 months)			
Calf, male, indigenous (< 6 months)			
Calf, male, indigenous (6-12 months)			

*Not fully considered at the moment, included only in the emission inventory system

2.2.2. Normative manure calculation

The normative manure system is a mass balance using calculated data from animal excretion (2.2.3), manure management (2.2.4) and related emissions (2.2.5). The mass balance calculates manure composition for housing systems producing

- slurry,
- farmyard manure (FYM),
- deep litter, and
- source-separated dung and urine (Figures 2-5).

The results are derived in three separate steps along the manure management chain as follows:

- *Manure ex animal*: faeces and urine as excreted by the animal, i.e. prior to any losses and additions.
- *Manure ex housing*: manure as it leaves the housing unit, where it possibly has been stored for a given period of time.
- *Manure ex storage*: manure as it leaves the (outdoor) storage.

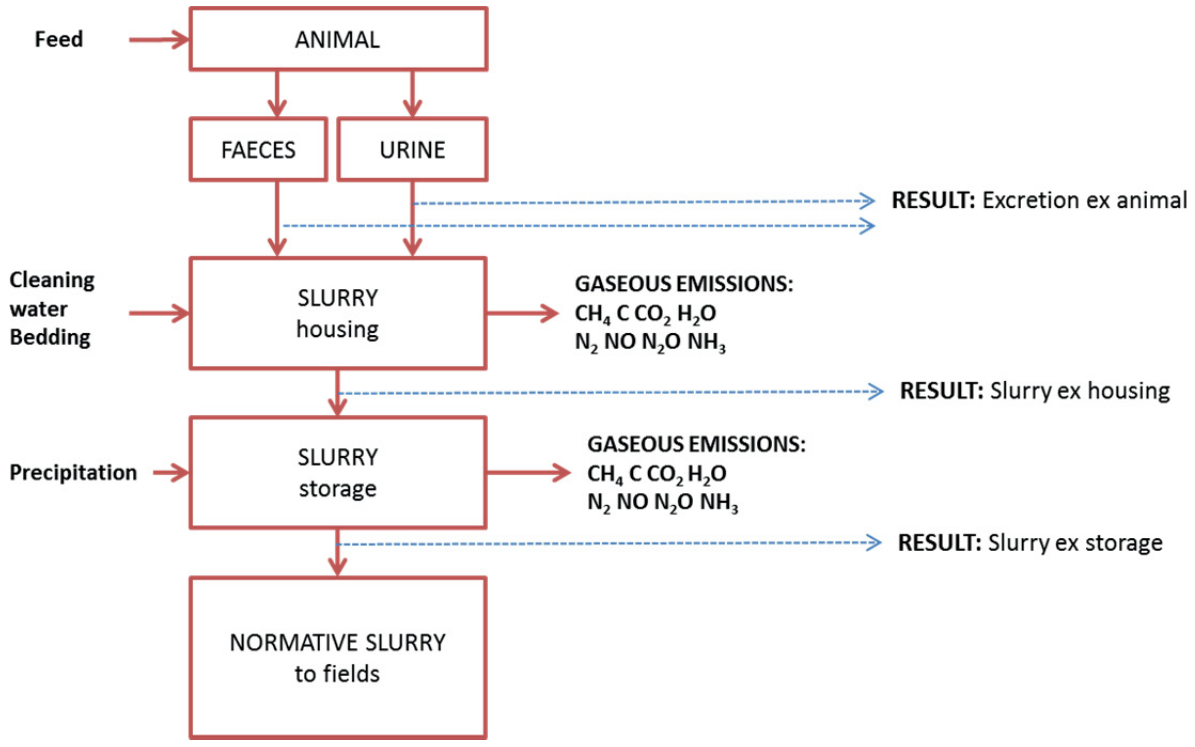

Figure 2. Mass balance of slurry systems and the results from the normative manure system.

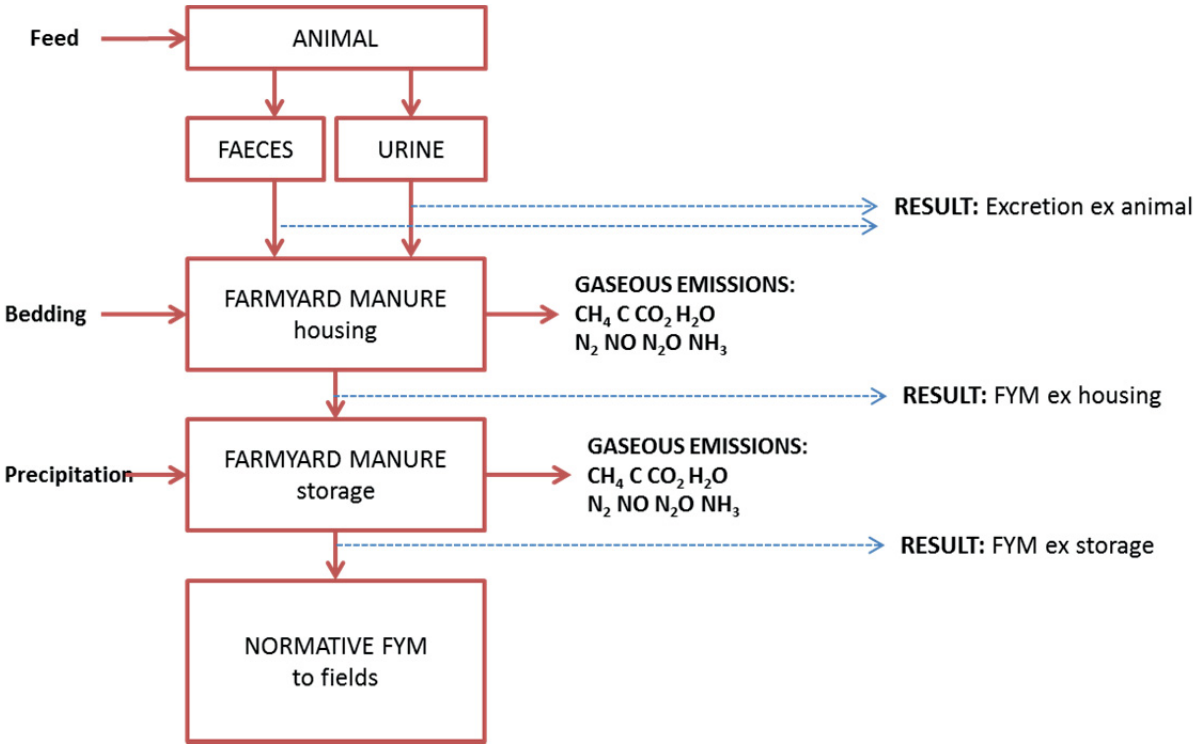

Figure 3. Mass balance of farmyard manure systems and the results from the normative manure system.

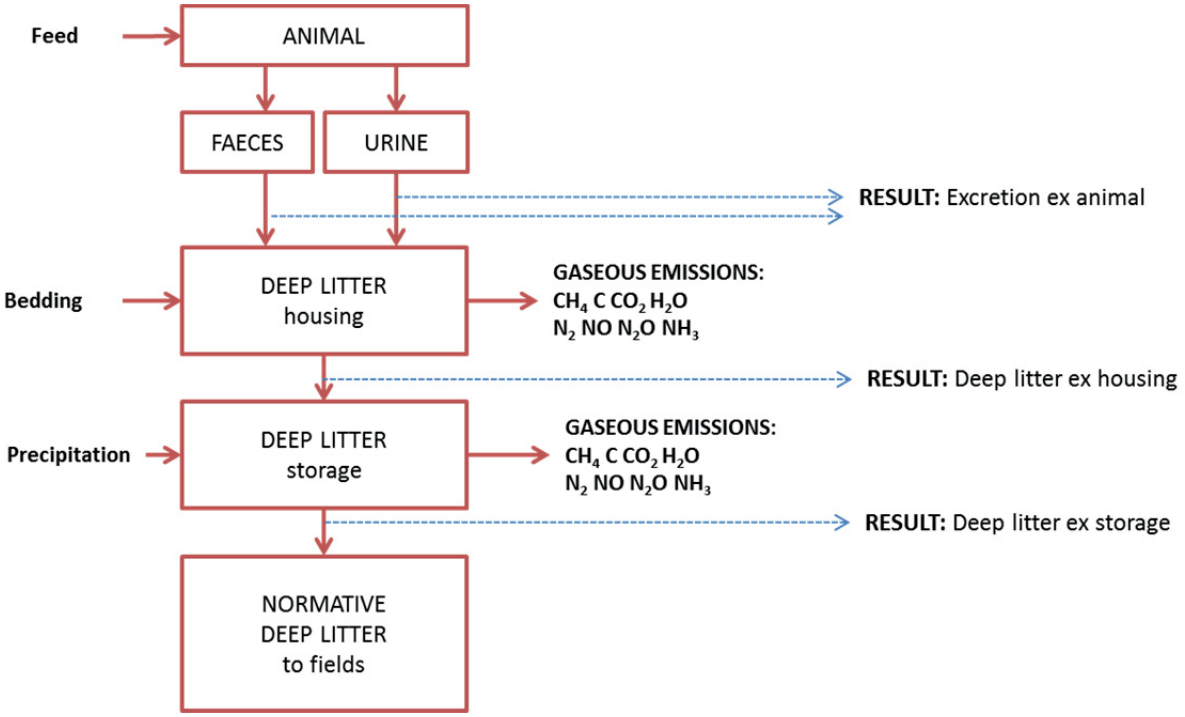

Figure 4. Mass balance of deep litter systems and the results from the normative manure system.

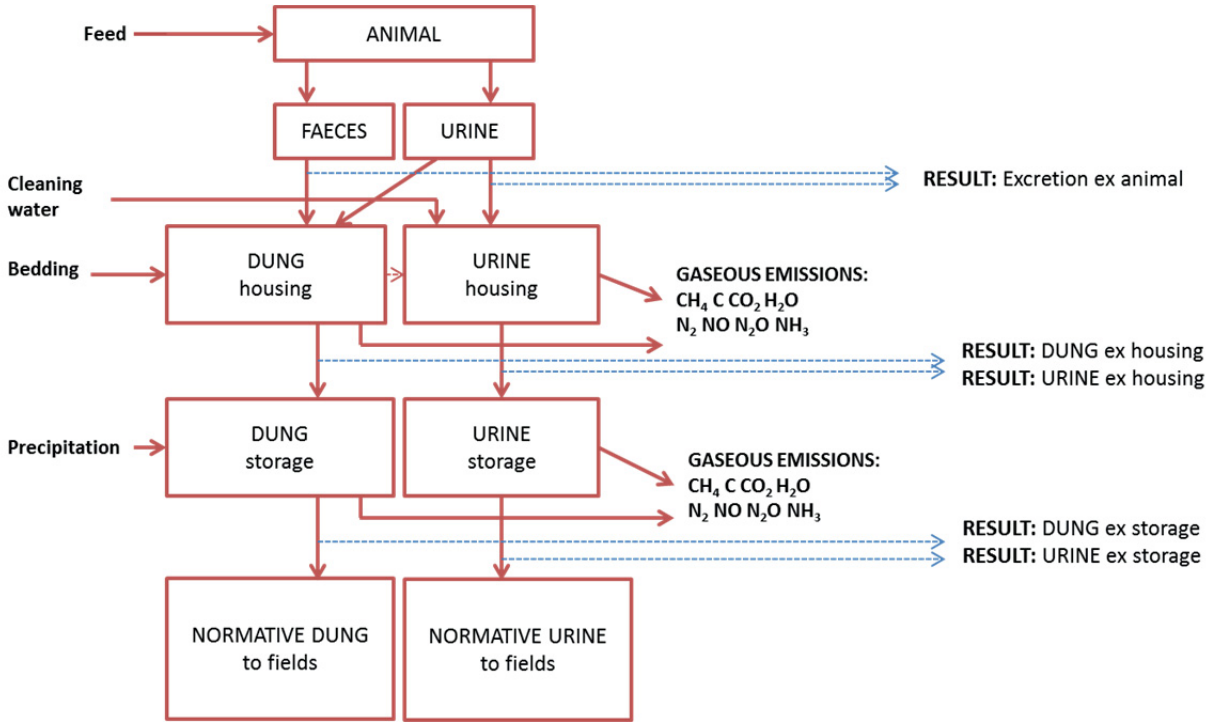

Figure 5. Mass balance of source-separated dung and urine system and the results from the normative manure system.

The inputs into the manure mass balances include the following:

- animal feed (2.2.3),
- excretion of faeces and urine (2.2.3),
- amount and properties of the bedding materials added (2.2.4),
- volume of cleaning waters added (mostly slurry systems, 2.2.4), and
- average precipitation of 600 mm (when stored without cover or with floating covers).

The outputs into the manure mass balances include the following:

- gaseous emissions to the atmosphere (2.2.5),
- dry matter loss, and
- water evaporation.

Loss of dry matter was estimated at 10% during housing in deep litter systems, excluding poultry housing (dry conditions preventing dry matter degradation; Poulsen & Kristensen 1997), and 10% during all storage, excluding storage of urine. The rate of rain water evaporation during manure storage was considered as the mean annual evaporation rate in Finland (300 mm) for uncovered outdoor storages. In case of a floating cover over slurry, evaporation was assumed as 1/3 of the mean evaporation rate in Finland. For solid manures (deep litter, FYM, dung), additional water evaporation from manure during housing and storage was estimated by adjusting the dry matter content of the calculated manures to analysed dry matter contents from respective manure types (Poulsen & Kristensen 1997).

Further, nitrogen is partially mineralised during slurry storage period. It was assumed that 10% of the organic nitrogen entering outdoor slurry storage is transformed into total ammoniacal nitrogen (TAN; EMEP/EEA 2016, Velthof et al. 2012). For solid manures (deep litter, FYM, dung), some total ammoniacal nitrogen is immobilised to organic nitrogen during manure storage period. Here, 40% of manure TAN entering storage was assumed to be transformed into organic nitrogen during storing (Haenell et al. 2016).

The data provision for the mass balances is explained in more detail in the following sections.

2.2.3. Excretion data

The basis of animal-specific excretion rates is in the mass balance calculations carried out by Natural Resources Institute Finland (Luke). Excretion rates were obtained by subtracting the share of dry and organic matter and nutrients bound in animal growth, products and reproduction from the intake through feeding:

$$Input_{FEED} - Uptake_{GROWTH} - Uptake_{PRODUCT} - Uptake_{REPRODUCTION} = Output_{EXCRETION}$$

The most important input data for the excretion calculations were the annual recommended feeding of animals (Luke Feed Tables 2016), the characteristics of different fodder compounds (Luke Feed Tables 2016), the statistics of milk (Luke Statistics 2014a, b; conversion from litres to kilograms by multiplying with litres with 1.032), slaughter weights of cattle (Evira 2014), slaughter weights of other animals (Luke Statistics 2014c) and egg production (egg production from Luke Statistics 2014d divided by the number of laying hen).

Excretion was calculated for the animal categories presented in Table 1, excluding sheep, fur animals and reindeer. The excretion results for the main animal categories represent thus weighted means for the different breeds, ages and genders within each main category (e.g. escretion of heifers > 1 year represents the weighted mean of 1-2 and >2 year old heifers for dairy, beef and reproduction in different breeds). The same calculation methods can thus also be applied for the more detailed animal categories (Table 2).

Excretion calculation of sheep and fur animals required significant development which is why they will be added into the normative manure system as separate projects. The excretion of fur animals has been developed during spring 2017 (Luostarinen et al. 2017b) and the excretion calculation of sheep will be developed during 2017. At this point, reindeer excretion is considered only partly to meet the basic requirements of emission inventories.

The excretion data unit produces the following information for each animal category, to be used in the manure calculation unit (kg/animal(place)/year):

- Quantities of faeces and urine;
- Quantities of nutrients (N, P, K) in urine and faeces separately;
- Quantities of dry and organic matter in faeces and urine separately.

At the time of writing, the national excretion calculation procedures and methods are being revised in Natural Resources Institute Finland (Luke) and thus animal-specific excretion is not documented here in more detail. Once the excretion calculation systems are revised, they will be documented separately. For more information on the principles of excretion calculation, previous descriptions can be found e.g. in Grönroos et al. (2009).

2.2.4. Manure management data

Detailed information on animal-specific manure management practices is used when calculating manure ex housing and ex storage. This data represents the national average manure management on Finnish animal farms including the following information for each animal category:

- Shares of manure management systems, i.e. manure types (% of animals),
- Shares of cattle housing systems (% of animals),
- Shares of manure excreted during housing, grazing and on dry lot (% of manure excreted per animal per year),
- Information on bedding material and cleaning water additions in different housing and manure management systems,
- Information on manure management practices in housing and manure storage.

The results represented here are based on the national manure management data from 2015 (Appendix a). The data is mostly derived from the 2013 farm survey data (main results reported in Grönroos 2014) and for horses from a separate survey conducted in 2014 (Luostarinen et al. 2017c). As that data represents the situation on Finnish animal farms in 2012 (horse stables 2013), some expert estimates on the progress over the additional years have been made.

In the calculation system, most of the manure management data is located in the emission calculation unit (2.2.5). The calculation starts by multiplying annual animal numbers and animal-specific excretion values, and proceeds to calculating annually excreted faeces and urine per each animal category. From then on, the additions to and the losses from manure as bedding material, cleaning waters and gaseous losses are calculated according to the shares of average manure management practices in Finland.

The manure management systems, i.e. manure types are calculated for slurry, deep litter, farmyard manure (FYM) and source-separated dung and urine. For each animal category, an option for four different housing systems was built to allow consideration of differences in the calculation of emissions (2.2.5) and overall manure mass balances. Currently, this feature is applied only in cattle manure mass balances, including tied stall and warm, semiwarm and cold loose housing systems (Appendix b). This feature also enables calculation of gaseous emissions separately for different housing types, allowing accounting for e.g. the impact of temperature on the emissions (EMEP/EEA 2016).

The normative manure results can be calculated in two ways: 1) assuming all manure to be excreted inhouse or 2) by excluding the share of manure excreted during grazing and on dry lot. Both calculation methods have their purposes. When e.g. calculating total manure produced in Finland, data without consideration of grazing and dry lots provides the theoretical manure quantities as mass and/or reported properties. However, when manure quantities and qualities collected in practice are needed, the manure left on pastures and dry lots needs to be excluded.

Further, the results can be calculated with or without consideration of the production pauses in batch production of pigs and poultry. When using animal statistics to quantify e.g. manure produced in all Finland, the results with full animal places is needed as the animal statistics represent the occupied animal places at a given time. However, when using the total number of animal places (regardless of them being used at a given time or not), the results with consideration of production pauses are needed.

BEDDING MATERIALS

The data on average quality of the different bedding materials used in the calculation system are presented in table 3 (Kapuinen 1992). Information on density of different bedding materials is needed in the calculation when converting bedding volumes into masses.

Table 3. Quality of bedding materials (Kapuinen 1992).

Bedding materials	Density	DM	Ntot	Nsol	Ptot	Psol	Ktot	VS
	kg/m^3	%	%	%	%	%	%	% of DM
Peat	200	43	0.34	0.03	0.01	0.01	0.01	90
Saw dust*	285	50	0.16	0.02	0.02	0.01	0.05	90
Straw baled	90	95	0.45	0.10	0.05	0.03	1.40	90
Straw loose	40	95	0.45	0.10	0.05	0.03	1.40	90
Straw pelleted	640	95	0.45	0.10	0.05	0.03	1.40	90
Straw shredded	75	95	0.45	0.10	0.05	0.03	1.40	90
Wood shavings	81	80	0.25	0.03	0.03	0.01	0.08	90

* Density and DM values of saw dust are based on the report of Alakangas (2000). N and P contents of saw dust from Kapuinen (1992) are converted to meet the modified DM value.

The average quantity of bedding per animal category used in the calculation is presented in detail in Appendix c and the main justification and data sources are documented below. All bedding quantities presented are summed to receive a total bedding quantity of each animal category and manure type. The ratios between different bedding materials are expert estimates.

There is a severe lack of data on bedding and water use in Finnish animal houses. Neither the quality nor the quantity of bedding material used is well-known. The 2013 farm survey to animal farms attempted to collect data on bedding and water, but failed, as either the farms did not measure the use or they misunderstood the question. The resulting dataset is reliable only for horse stables, which replied to a separate survey in 2014. Thus, most data on bedding and water use in different animal farms and housing systems is now based on old data with data gaps and expert estimates.

Cattle

In slurry systems, the bedding quantity used for dairy cattle is derived from the studies of Ala-Suutari (2012, 2013) and Kapuinen & Karhunen (1990). The total bedding quantity is 0.172 m^3/dairy cattle/year in tied stalls, 1.6 m^3/dairy cattle/year in loose warm housing and 2.13 m^3/dairy cattle/year in loose semi-warm housing. No data was available for loose cold housing; thus the value for loose semi-warm housing is used.

These total quantities of bedding material per dairy cattle are attributed to all dairy cattle housing with slurry systems, including both dairy cows and young cattle. Thus, the quantities were divided to the different cattle categories as follows:

- Dairy cow: 57% of total bedding quantity,
- Heifer >1 yrs: 50% of dairy cow bedding quantity,
- Calf <1 yr: 25% of dairy cow bedding quantity.

The same division and the same total quantities were also attributed to suckler cows and young beef cattle in slurry systems. For bulls, 50% of the dairy cow bedding quantity was assumed.

Further, the total bedding quantity for cattle slurry systems in all housing was divided over shredded straw, peat and wood shavings as 1/3 of each.

With deep litter and farmyard manure, the bedding was attributed to baled straw and its quantity was derived from the daily masses reported by Holmström (2005). The masses were converted to cubic meters using the average density of baled straw (90 kg/m^3) and then multiplied to annual use. The same quantity was used for all housing types.

With separately collected dung and urine, the total quantity for peat was derived from Iivonen (2008) and Peltola et al. (1986) and for shredded straw from Ala-Suutari (2012, 2013). The quantity of baled straw and wood shavings was calculated aiming at a similar liquid adsorption capacity as with peat. With dairy cows and heifers, the total quantity of bedding was divided over shredded straw, peat and wood shavings in the ratio of 60:20:20. For suckler cows, the total quantity of bedding was divided over baled straw, peat and wood shavings in the ratio of 75:15:10 and for bulls in the ratio of 54:36:10. The same quantities and ratios were used in all housing types.

Pigs

In slurry systems, the bedding quantity for farrowing sows with piglets was 0.275 m^3/animal place/year and for fattening pigs 0.06 m^3/animal place/year (Kapuinen & Karhunen 1990). These amounts were assumed to be divided over shredded straw, peat and wood shavings as 1/3 of each. The same materials and quantity was assumed for gestating and mating sows. Gestating and mating sows were assumed to follow the bedding quantity and type of farrowing sows and gilts, while the bedding use of boars and weaned pigs those of fattening pigs.

In deep litter systems, bedding was baled straw and calculated by multiplying the average deep litter depth of 0.5 meters with minimum deep litter area per animal category (MMM 2010). All

bedding for sows was assumed to be the same, though deep litter is a rare choice for farrowing sows with piglets. The bedding quantity of all sows (0.8 m^3/animal place/year) and also of weaned pigs (0.35 m^3/animal place/year) was divided over baled straw, peat and wood shavings in the ratio of 80:10:10. Boars were assumed to equal fattening pigs, 0.6 m^3/animal place/year divided over baled straw, peat and wood shavings in the ratio of 60:20:20.

With farmyard manure, the bedding quantity was derived from Holmström (2005). With sows, the total bedding quantity of 1 m^3/animal place/year was divided over baled straw and peat in the ratio of 75:25. With weaned pigs, the same ratio was used for the total bedding quantity of 0.5 m^3/animal place/year. With fattening pigs and boars, the total bedding quantity was also 0.5 m^3/animal place/year, but it was divided over baled straw, peat and wood shavings in the ratio of 50:25:25.

No bedding data for separately collected dung and urine systems for pigs was found. Therefore, the same bedding use was used for dung as for FYM.

Poultry

The bedding quantity for deep litter of laying hen was taken from EC (2003), while those for deep litter of broilers and turkeys were calculated with the following assumptions:

- Broilers: bedding layer (peat) depth 2 cm, 18 birds/m^2, 6 batches per year (Hellstedt & Luostarinen 2014, Hamina 2013),
- Turkeys: bedding layer (peat) depth 4 cm, 3 birds/m^2, 2.5 batches per year (Hellstedt & Luostarinen 2014, Hamina 2013).

Horses and ponies

The bedding quantities for farmyard manure and deep litter are summed to the total quantity of 28.6 m^3/horse/year and 14.3 m^3/pony/year. The value for horses was derived using the following ratios of bedding use on horse stables (Luostarinen et al. 2017c):

- 44% peat,
- 19% saw dust
- 19% wood shavings,
- 18% loose straw.

The bedding quantities used in stables vary significantly, but an average bedding quantity of 300 kg/ton of manure ex animal (horse) was used. This quantity was divided into smaller shares according to the bedding ratios above and converted to cubic meters using the densities in table a. Finally, the shares were each multiplied with the total excreted manure of 9.8 ton/horse/year. The bedding quantity for ponies was assumed to be 50% of this.

CLEANING WATER

The quantities of cleaning waters added to slurry on dairy farms are the following:

- 2200 litres/animal/year in tied stalls (Kapuinen & Karhunen 1990),
- 1900 litres/animal/year in loose warm housing (Kapuinen & Karhunen 1990),
- 2530 litres/animal/year in loose semi-warm housing (Farm Test Cattle 2009).

The latter was also used for loose cold housing with slurry. There is no separation between cleaning water addition of different cattle categories but all is attributed to dairy cows. This is assumed to be rather accurate as the water is mostly used in cleaning the milking equipment. The cleaning water addition into slurry for bulls is 1800 litres/animal/year (Kapuinen & Karhunen 1990).

The addition of cleaning water into pig slurry was 850 litre/animal place/year for all sow categories summed together and 68 litre/animal place/year for fattening pigs (Kapuinen & Karhunen 1990). Slurry of weaned pigs and boars were assumed to receive the same cleaning water addition as that of fattening pigs.

2.2.5. Emission data

Nitrogen compounds

The Finnish calculation system for agricultural gaseous nitrogen emissions (Grönroos et al. 2017) is linked to the normative manure system to provide information on nitrogen losses along the manure management chain. For nitrogen compounds, the emission estimates produced are used in national emission inventories made for reporting emissions to the Secretariat of the UNECE[1] Convention on Long-Range Transboundary Air Pollution (CLRTAP), UNFCCC[2] Secretariat and the European Commission.

In general, the emission calculation of ammonia (NH_3), nitric oxide (NO) and dinitrogen (N_2) follow the principles of Tier 2 method described in the emission inventory guidebook (EMEP/EEA 2016). It approaches the Tier 3 method in using a greater number of animal categories than listed under Tier 2 and in inclusion of emission abatement measures for ammonia. Calculation of nitrous oxide (N_2O) follows the reporting guidelines of United Nations Framework Convention on Climate Change (UNFCCC; IPCC 2006).

Calculation of gaseous nitrogen emissions from manure management is based on the nitrogen flow approach, as described in Grönroos et al. (2017) and in the previous documentations of the Finnish ammonia and nitrous oxide emission calculation (Grönroos et al. 1998, 2009), and in the emission inventory guidebooks. In the method used, the pathways of nitrogen are followed starting from nitrogen excretion of animals and ending at the application of manure to the fields (Figure 6). In each manure management stage, the gaseous losses of nitrogen compounds (NH_3-N, N_2O-N, NO-N, N_2) are calculated. Calculation is made per each animal category (Table 1 and 2) and for each manure management system.

Nitrogen flow approach is applied to total ammoniacal nitrogen (TAN) of manure in each stage of the manure management. Because animal feeding choice and nitrogen transformation during the manure management chain affect the TAN content of manure, and because manure TAN is the basis for ammonia and other forms of gaseous N emissions, more precise emission estimates are attained than if emission calculation was based on manure total nitrogen. However, in direct N_2O calculation also information on total nitrogen is needed.

For mammals, it is assumed that all nitrogen in urine is TAN and all nitrogen in faeces is organically bound (e.g. Haenell et al. 2016). For poultry, uric acid nitrogen (UAN) excreted is considered completely TAN (Haenell et al. 2016). However, as the normative manure system calculates only total nitrogen excretion for poultry, the proportion of UAN is assumed to be 70% of the total nitrogen, following the default value presented in EMEP/EEA (2016).

Nitrogen from bedding materials is also included in the N flow approach. Moreover, the transformation processes of manure nitrogen during manure storing (immobilisation of solid manure TAN to organic form and mineralisation of slurry organic nitrogen to TAN) is included as described in chapter 2.2.2.

The national legislation requires that manure channels and storages must be waterproof. Thus, it is expected that direct manure leakages to soil and waters from animal houses and manure storages do not occur.

For more detailed information on gaseous nitrogen emission calculation system, see Grönroos et al. (2017).

[1] United Nations Economic Commission for Europe
[2] United Nations Framework Convention on Climate Change

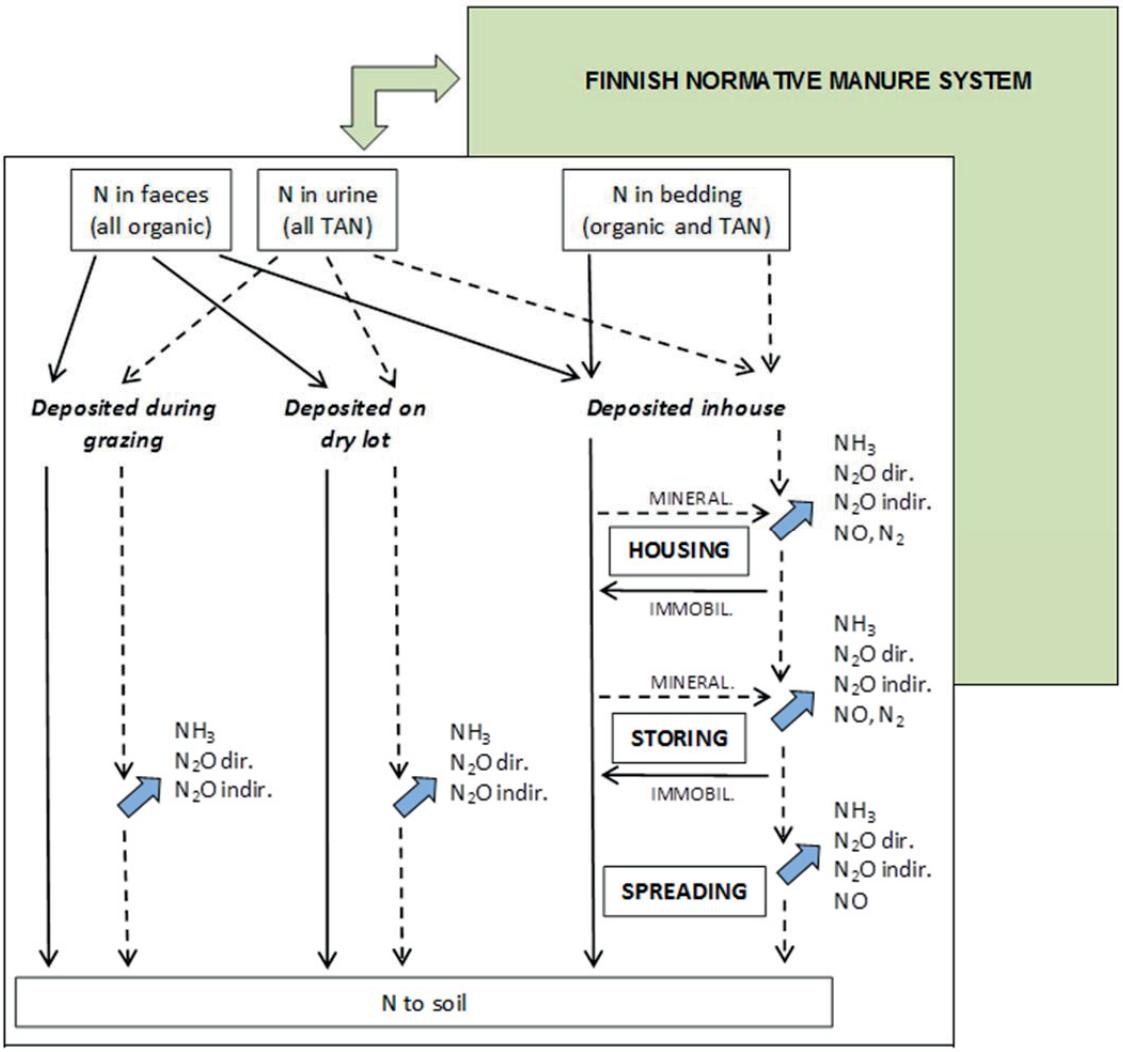

Figure 6. Schematic diagram of the nitrogen flows in manure management system (incl. manure spreading and grazing) and the related gaseous nitrogen emission calculation system used for calculating the NH_3, N_2O, NO and N_2 emissions from manure management in Finland. Nitrogen transformation processes (immobilisation and mineralisation) and the link between emission calculation system and the Finnish normative manure system are highlighted. Broad blue arrows: emissions of N-compounds to the atmosphere. Emissions are calculated separately for each animal category and manure management system. For clarity, all manure management systems are not shown in figure.

Carbon compounds

Calculation of carbon losses as carbon dioxide and methane during manure management are included in the normative manure system. Methane emissions are calculated according to the IPCC guidelines for national greenhouse gas inventories (IPCC 2006) with the following equation:

$$CH_4\ [kg] = VS\ [kg] \times B_0 \times 0.67\ [kg\ CH_4\ per\ m^3\ CH_4] \times MCF$$

Where:

VS : The amount of volatile solids as excreted by the animals (kg)

B_0 : The maximum CH_4 producing capacity for a given manure (m^3 CH_4 kg^{-1} VS excreted)

MCF : Methane conversion factor (%).

VS excretion rates are obtained from excretion unit. B_o values and MCF values are the same as used in the national GHG emission inventories (IPCC 2006).

For example, in pig slurry systems, slurry is stored inhouse for a period, in Finland typically ca two weeks, and subsequently transferred to an outdoor storage. The methane emission estimate is, however, calculated for "manure management", without allocation between indoor and outdoor storing. Especially in cases where precise estimate on manure properties ex housing is needed (e.g. planning manure processing), it is appropriate to estimate emissions of methane and carbon dioxide also during inhouse storing. For this, partitioning coefficients are used to divide methane emissions from manure management between housing and outdoor storing. Here, the coefficients were only used for pig slurry and for deep litter systems in all animal categories (Table 4). For other animal and manure categories, methane from manure management was allocated to manure outdoor storing entirely because in these cases manure is removed from the house to the outdoor storage relatively soon after excretion.

Table 4. Methane (manure management) partitioning coefficients.

Animal and manure category	Inhouse	Outdoor
Pig slurry	5%	95%
All animal categories, deep litter	90%	10%

The amount of carbon dioxide released during manure management in anaerobic conditions (slurries) was estimated based on the methane emissions as follows (Hamelin 2013):

- for cattle slurry and urine: 2.13 kg CO_2 is released per 1 kg CH_4
- for pig slurry and urine: 1.83 kg CO_2 is released per 1 kg CH_4

The amount of carbon dioxide released during manure management in aerobic conditions (FYM, deep litter, dung) was estimated based on the NH_3 emissions as follows (Hamelin 2013):

- for cattle manure (without bedding) 50.58 kg CO_2 is released per 1 kg NH_3
- for pig manure (without bedding) 38.14 kg CO_2 is released per 1 kg NH_3
- for poultry manure (without bedding) 62.46 kg CO_2 is released per 1 kg NH_3
- for horse manure (without bedding) 68.34 kg CO_2 is released per 1 kg NH_3
- For bedding material 165.51 kg CO_2 is released per 1 kg NH_3

Manures managed in aerobic conditions are a mixture of manure and bedding material (straw, peat etc.). The ratio of CO_2 : NH_3 was therefore calculated as a function of the proportion of manure and bedding material based on the respective data obtained from the excretion and manure management data units for each animal, manure and housing type combination.

2.2.6. Reporting

The reporting unit of the Finnish normative manure system produces concise tables and graphs on manure quantity and quality in chosen animal categories, providing the ultimate result of the system. The results can be obtained as:

- Specific reports per animal or animal place with data on all relevant manure types (Appendix d-h), and
- Summaries for national animal statistics on a given year or as a specific (e.g. regional, farm-specific) case (chapter 4).

The result tables and graphs include data for manure ex animal, ex housing and ex storage in the following categories:

- Manure quantity per manure type
- Quantity of dry matter, organic matter and nutrients per manure type

- Quality of manure per manure type (kg/ton of manure), as follows:
    - Total nitrogen (Ntot)
    - Soluble nitrogen (Nsol)
    - Total phosphorus (Ptot)
    - Total potassium (Ktot)
    - Dry matter (DM)
    - Organic matter (volatile solids, VS)

The calculation system can be used to provide national, regional, farm-specific and/or animal-specific data. For example, national averages can be calculated for broader animal categories, such as cattle, pigs or poultry. The ratios of each specific animal category in cattle/pigs/poultry are then considered based on annual animal statistics. To provide regional data, regional specificities in animal production may be used as the background data. Farm-specific results can be derived by choosing the feeding and manure management options used on a farm. The manure left on pastures and dry lots can be excluded or the manures can be calculated as if all excretion coincides in housing.

2.2.7. System maintenance

The annual updating and maintenance of the normative manure system is an important task ensuring up-to-date manure data for all potential users. Simultaneously, the time series necessary for e.g. emission inventories is produced. The normative manure system is also integrated into two internet-based applications serving manure data on biomass quantities and spatial distribution in Finland (Biomassa-atlas) and on possibilities for regional nutrient recycling via processing of biomasses and using the end-products e.g. as fertilisers.

Without regular updating and maintenance, the manure data from the normative manure system soon becomes outdated. The tasks and their execution in practice will be determined later in separate negotiations between the research organisations and the relevant ministries. Preliminarily the main responsibilities between the two research organisations are the following:

- Luke: excretion calculation, animal numbers;
- SYKE: emission calculation, normative manure calculation;
- Together: background data addition/improvement, larger data updates, such as manure management data from potential future farm surveys, updating the documentation.

3. Normative manure system: results and discussion

The animal-specific results of the Finnish normative manure system are presented in detail in Appendix d-h.

The normative manure system calculates total manure quantity and quality as tons per animal (place) per year. It also offers concentrations (kg/ton of manure) of total and soluble nitrogen, total phosphorus, total potassium, dry matter and organic matter per animal category and manure type. The animal-specific results are reported in two ways: assuming all manure is produced inhouse or excluding manure left on pasture and dry lots. In both cases, full time occupation of animal place is supposed, i.e. without production pauses between batches.

The results reported are national averages for all farms in Finland per animal category. Farm-specifically the manure quantity and quality may differ from the results presented due to e.g. different feeding and manure management choices. At this stage of system development, however, no correction factors or other tools for farm-specific calculation have been made.

Some results are discussed in more detail in the following with comparisons to the Finnish table values (Nitrates decree 1250/2014). The results for goats (Appendix h) is not discussed here as the table values are given for sheep and goats together and only goats were now calculated.

3.1. Cattle

The first results for cattle manures are reported for dairy cows, suckler cows, over one-year-old bulls and heifers, and up to one-year-old calves. The results are given as all manure excreted inhouse and as manure excluding the portion left on pasture and dry lots (Appendix d). Different breeds, genders and ages can also be calculated separately (see: Table 2), but here the results for the weighted means of the different cattle categories, average milk yields and average slaughter weights are reported.

Average Finnish cattle manure as slurry and solid manure were converted from the normative mass-based results (kg/t) to kg/m^3 to enable comparison to the Finnish table values (Table 5). The required conversion was made assuming that the density of slurry is 1000 kg/m^3 and that of solid manures 772 kg/m^3 (Viljavuuspalvelu 2016). Moreover, the calculated solid manure is given as FYM (the most common solid manure) and deep litter. The table values do not distinguish between different solid manure types.

Table 5. Comparison of calculated manure properties and table values (1250/2014) for average Finnish cattle slurry and solid manure ex storage. The calculated solid manure is given as FYM and deep litter (converted from kg/t to kg/m^3 using the density of 772 kg/m^3). Manure left on pasture and dry lots is excluded from the calculated values.

EX STORAGE (kg/m^3 of manure)	Ntot	Nsol	Ptot	Ktot
CATTLE SLURRY				
Calculated	4.36	2.49	0.88	4.74
Table value	2.90	1.70	0.50	-
CATTLE SOLID MANURE				
Calculated (FYM)	3.28	0.50	0.60	5.77
Calculated (Deep litter)	4.78	0.66	0.80	8.42
Table value	4.00	1.10	1.00	-

The calculated cattle slurry results in a higher nutrient content than in the table values. The calculated cattle FYM and deep litter represent on average rather similar total nitrogen content as in the table values, but lower soluble nitrogen and total phosphorus. This may be due to several factors.

The data on bedding use and cleaning waters in slurry systems is rather weak and old in the normative manure system. Dilution due to cleaning water addition may be underestimated resulting in more concentrated slurry. On the other hand, cattle slurry sampling is subject to error and the samples become easily too diluted, which may be reflected in the table values.

For solid manures, the insufficient data on bedding materials may cause error in the calculation. However, sampling of solid manure is also difficult as many subsamples should be taken and mixed together. Also, dry matter loss and water evaporation from solid manures is not really known, but affect the results. Further, the conversion from manure mass to volume depends on the density used. The density is now taken from one commercial laboratory and it is not certain that it represents cattle manures well. This makes a signifigance difference with solid manures.

The calculated result of both slurry and solid manures is restricted to the feeding recommendations and the average manure management solutions. It does not include all the farm-scale variation underlying the table values. Especially cattle feeding varies significantly between farms due to the use of farm-specific feed and high share of roughage. Also, the calculation could be done with more detailed cattle categories than done here.

In this sense, the calculated result is considered a reliable average of all dairy cow manure in Finland. The same also applies to other cattle categories calculated (Appendix d). It should, however, be noted that the development work on the background data in the calculation systems continues and this is expected to improve the system and its results later.

3.2. Pigs

The first results for pig manures are reported for fattening pigs, average sows with piglets (including farrowing, mating and gestating sows), weaned pigs and boars. The results are given per animal place with full annual occupation (Appendix e). While the animal places of sows and boars are practically fully occupied during the year, those of fattening pigs and weaned pigs are not. After discussions with the pork production companies in Finland (A-Tuottajat 2017, HKScan 2017, Snellman 2017), it was decided that the animal places for fattening pigs are assumed to be 95% occupied and those of weaned pigs 80% occupied. The latter could also be higher.

The average Finnish pig manure as slurry and solid manure were calculated per kg/m^3 to enable comparison to the Finnish table values (Table 6). The required conversion from calculated kg/t to kg/m^3 was made assuming that the density of slurry is 1000 kg/m^3 and that of solid manures 639 kg/m^3 (Viljavuuspalvelu 2016). Moreover, the calculated solid manure type presented here is farmyard manure, being the most common solid manure in Finnish pig production. The table values do not distinguish between different solid manure types.

The calculated slurry results are very slightly higher than those of the table values. The difference can most likely be explained by errors in sampling and analysis. For solid manures, the calculated total nitrogen results are higher than in the table values, while soluble nitrogen is only slightly higher. To explain this difference, it can be argued whether the dry matter loss and water evaporation assumed in the calculation system are valid or if the nitrogen losses are higher in practice than in the calculation method. Moreover, the density used is again just one value from one commercial laboratory and it may cause error in the conversion to volume. Representative sampling of solid manures is difficult and analysis is made of small doses, both of which can cause errors in table values. Though solid manures are a minority in pig manure management, their calculation in the normative system obviously requires further development.

Table 6. Comparison of calculated manure properties and table values (1250/2014) for average Finnish pig slurry and solid manure ex storage. The calculated solid manure is given as FYM and deep litter (converted from kg/t to kg/m^3 using the density of 639 kg/m^3).

EX STORAGE (kg/m^3 of manure)	Ntot	Nsol	Ptot	Ktot
PIG SLURRY				
Calculated	3.94	2.66	0.89	1.89
Table value	3.4	2.2	0.8	-
PIG SOLID MANURE				
Calculated (FYM)	7.45	1.59	2.51	4.32
Calculated (Deep litter)	8.49	1.31	2.14	5.53
Table value	4.6	1.2	2.8	-

3.3. Poultry

In this first version of the Finnish normative manure system, poultry manures are reported for laying hen, broilers and turkeys (Appendix f). More specific poultry categorisation can also be calculated (see: Table 2), but is not reported here. The amount of produced batches per broilers is six per year and for turkeys 2.5 per year, resulting in an average occupation of the animal place of 65% for broilers (Finnish Broiler Association 2017) and 87% for turkeys (Länsikalkkuna Ltd 2017). Animal places of laying hen are 100% occupied.

Calculated Finnish broiler manure as deep litter was compared to Finnish table values (Table 7). The required conversion from calculated kg/t to kg/m^3 was made assuming that the density of deep litter is 350 kg/m^3 (an assumption drawn from several measurements and discussions with broiler producers).

Table 7. Comparison of calculated manure properties and table values (1250/2014) for average Finnish broiler manure ex storage. The calculated solid manure is given as deep litter (converted from kg/t to kg/m^3 using the density of 350 kg/m^3).

EX STORAGE (kg/m^3 of manure)	Ntot	Nsol	Ptot	Ktot
Broiler deep litter /calculated	8.50	1.46	4.15	7.39
Broiler solid manure /table value	8.7	2.7	3.4	-

The calculated results are slightly lower for total nitrogen, significantly lower for soluble nitrogen, and somewhat higher for total phosphorus. The feeding and excretion as well as manure management for poultry contains less variation between the farms than e.g. with cattle. The feeding is largely purchased from and its use instructed by the feed industry and its quality is more stable, making excretion simpler to average within the Finnish broiler farms. Moreover, the broilers are of few breeds and their production batches, housing, bedding use and manure storages are largely unified. All this simplifies the background data required for the calculation of manure quantity and quality.

In the calculation, water evaporation was assumed both during broiler housing and storage. There is little measured data to improve the accuracy of this parameter although it affects the manure quantity and quality. Also, some dry matter loss was assumed during manure storage. Again, there is little data to base this on. It is possible that there is some inaccuracy in these parameters in the calculation and it affects the results. Also, in broiler manure, the density to convert manure quantity from mass to volume bares a significant meaning in the calculated result. The basic calculation as mass may produce correct average data, but the density differs farm-specifically and

even per batch on the same farm. Representative sampling of solid manures is difficult and analysis is made of small doses, both of which can cause errors in table values.

3.4. Horses

In this first version of the Finnish normative manure system, horse manures are reported for horses and ponies (Appendix g). More specific horse categorisation can also be calculated (see: Table 2), but is not reported here.

Average Finnish horse manure as solid manure was calculated per kg/m^3 to enable comparison to the Finnish table values (Table 8). The required conversion from calculated kg/t to kg/m^3 was made assuming that the density of solid manure 510 kg/m^3 (Viljavuuspalvelu 2016). Moreover, the calculated solid manure types presented here are farmyard manure and deep litter (FYM more common). The table values do not distinguish between different solid manure types.

Table 8. Comparison of calculated manure properties and table values (1250/2014) for average Finnish horse manure ex storage. The calculated solid manure is given as FYM and deep litter (converted from kg/t to kg/m^3 using the density of 510 kg/m^3).

EX STORAGE (kg/m^3 of manure)	Ntot	Nsol	Ptot	Ktot
Horse FYM / calculated	1.73	0.22	0.36	2.55
Horse Deep litter / calculated	2.08	0.32	0.40	2.82
Horse manure / table value	2.6	0.4	0.5	-

The calculated horse manure produces lower nutrient contents than in the table values. Again, the value for density used when converting from mass to volumes may affect the result. Also, the feeding of horses, especially when used for hobby, may not follow the feeding recommendations behind the normative manure calculation. The bedding use and the time spent on pasture and dry lots vary heavily between stables and also depending on the location of the stables. The large stables in densely populated areas have little area for pastures and dry lots and the horses spend more time in stables than the horses on farms and other rural area. The feeding of these horses is more regulated as they are more often used for sport of riding schools. Their manure is also often transported to centralised processing outside the stables and not directly used on fields. Thus, they most likely make up a smaller share of the manures analysed. This should then be reflected in the table values concentrating more on manure analysis from horses on farms and other rural areas. These factors affect the manure quality and make the comparison between calculated values and table values difficult. Morover, representative sampling of solid manures is difficult and analysis is made of small doses, both of which can cause errors in table values.

4. Total manure quantity in Finland

Finnish normative manure system calculates total masses of manure and its components case-specifically. As an example, the results for total cattle, pig, poultry and horse manures are presented here for Finland. The animal statistics used are from 2014 as the excretion calculations were made for that year. Manure excreted on pasture and dry lot is excluded from the results presented.

Total excreted mass of manures ex housing and ex storage are presented in Tables 9-10 and Figures 6-7. The changes in mass are due to bedding and water additions and losses during manure management. The manures reported make up the most of animal manure in Finland. The quantity of manure from fur animals, goats and sheep are a minority in comparison with the manures reported here (estimates available e.g. in Marttinen et al. 2017).

From the totals, it becomes evident that cattle manure makes up the most of Finnish manure (76% of these animal categories). The share of slurry (cattle, pigs) is the highest of the manure types. Still, the quantity of different solid manures is notably high also with cattle.

Table 9. Total manure directly from housing (ex housing) as tons fresh weight in Finland (2014). Manure excreted on pasture and dry lot excluded.

	Slurry	Deep litter	FYM	Faeces	Urine	TOTAL
Cattle	5996049	648912	2102787	1131814	866807	**10746369**
Pigs	2498836	10735	17249	51141	76752	**2654714**
Poultry	17225	163800	84788	0	0	**265813**
Horses	0	88086	590238	2508	778	**681609**
SUM	**8512109**	**911533**	**2795062**	**1185464**	**944336**	**14348505**

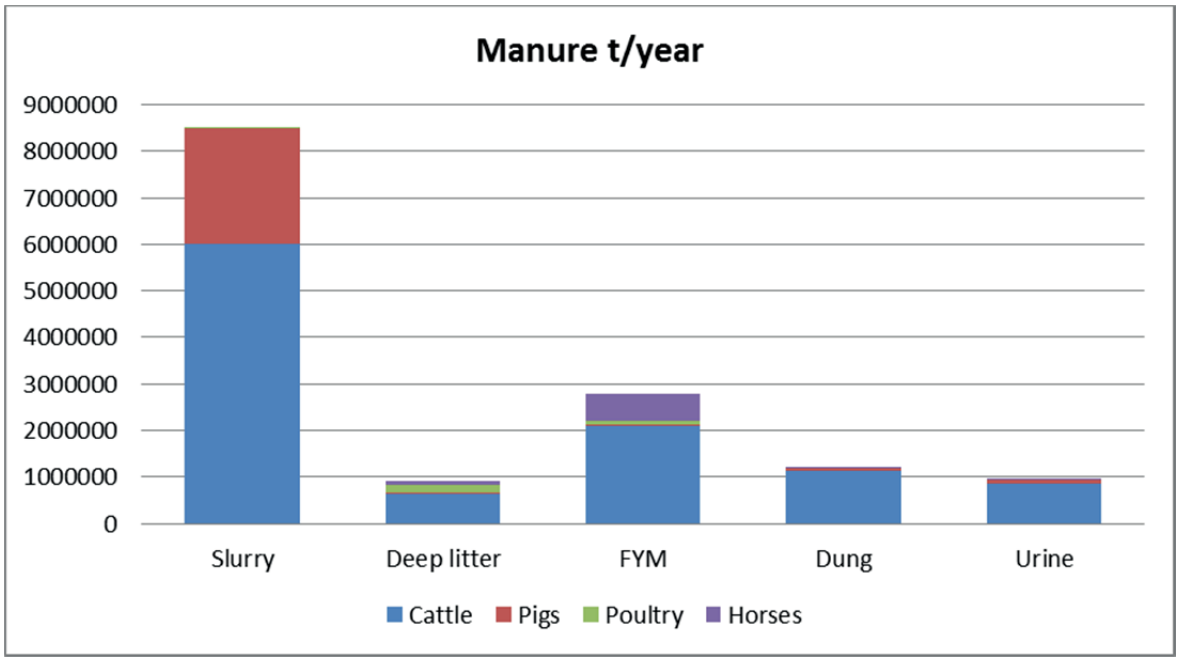

Figure 7. Total manure directly from housing (ex housing) as tons fresh weight in Finland (2014). Manure excreted on pasture and dry lot excluded.

Table 10. Total manure after storage (ex storage) as tons fresh weight in Finland (2014). Manure excreted on pasture and dry lot excluded.

	Slurry	Deep litter	FYM	Faeces	Urine	TOTAL
Cattle	6790792	679078	2410160	1360383	1004674	**12245087**
Pigs	2719018	8074	13134	41285	89459	**2870971**
Poultry	18538	171029	93202	0	0	**282770**
Horses	0	86998	622234	2448	778	**712458**
SUM	**9528349**	**945180**	**3138730**	**1404117**	**1094911**	**16111285**

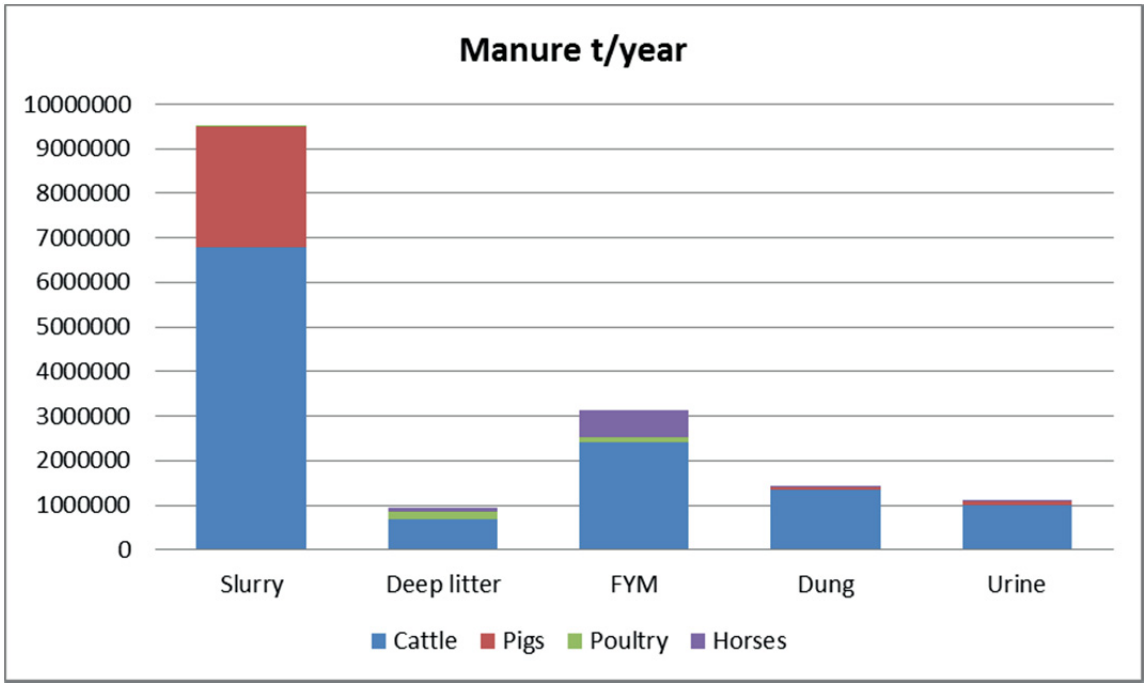

Figure 8. Total manure after storage (ex storage) as tons fresh weight in Finland (2014). Manure excreted on pasture and dry lot excluded.

Similar national totals can be calculated also for dry matter, organic matter, total nitrogen, soluble nitrogen, total phosphorus and total potassium. Here, national totals are given for total nitrogen (Table 11, Figure 9) and total phosphorus (Table 12, Figure 10).

Again, the signifigant share of nutrients in cattle manure (73% of manure nitrogen and 65% of manure phosphorus in these animal categories) and in slurry (55% of manure nitrogen and 53% of manure phosphorus in these animal categories) is evident. The share of nutrients in poultry manure (15% of manure phosphorus in these animal catergories) becomes also clearer though its actual share in total manure (1.8% ex storage) is not as visible. Sheep and goat manure would be of little signifigance, but the share of phosphorus in fur animal manure would play a large role in all manure phosphorus (Luostarinen et al. 2017b).

Table 11. Total nitrogen in Finnish cattle, pig, poultry and horse manure after manure storage (ex storage) as tons of fresh weight (2014). Manure left on pasture and dry lot is excluded.

	Slurry	Deep litter	FYM	Faeces	Urine	TOTAL
Cattle	29614	4209	10250	5495	4246	**53814**
Pigs	10713	107.3	153.1	250.0	309.8	**11534**
Poultry	175.3	3901	1330	0	0	**5406**
Horses	0	355.5	2113	8.16	8.71	**2485**
SUM ALL	**40503**	**8572**	**13846**	**5753**	**4564**	**73239**

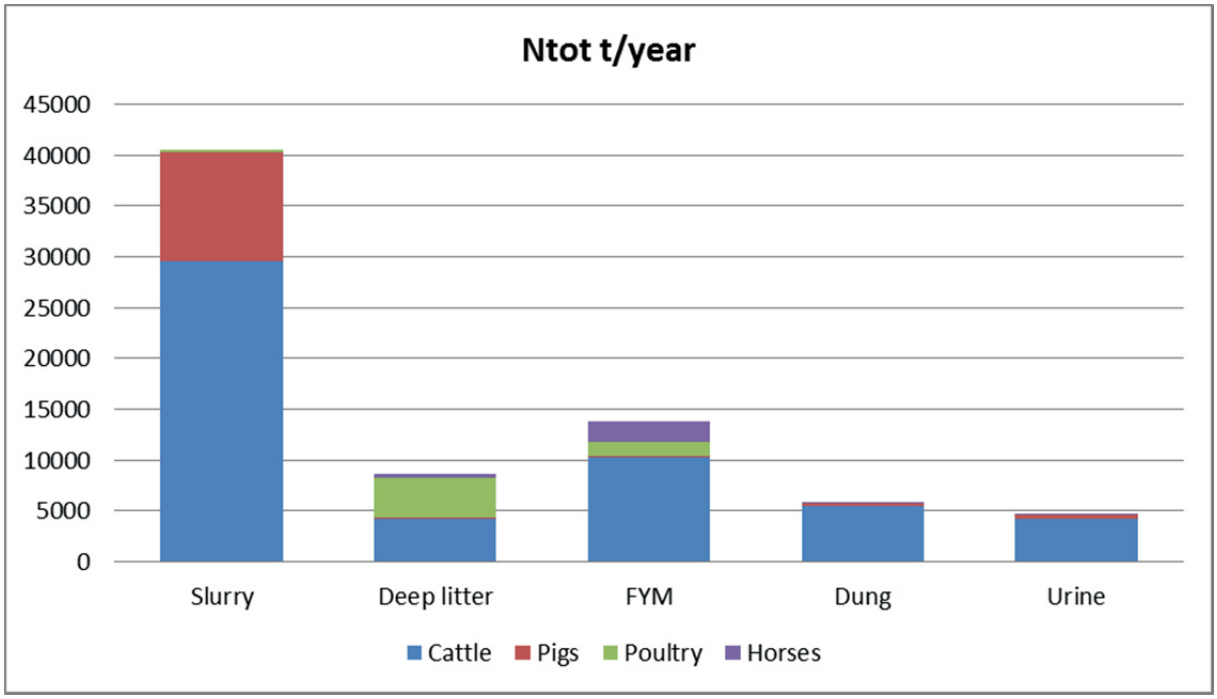

Figure 9. Total nitrogen in Finnish cattle, pig, poultry and horse manure after manure storage (ex storage) as tons (2014). Manure left on pasture and dry lot is excluded.

Table 12. Total phosphorus in Finnish cattle, pig, poultry and horse manure after manure storage (ex storage) as tons of fresh weight (2014). Manure left on pasture and dry lot is excluded.

	Slurry	Deep litter	FYM	Faeces	Urine	TOTAL
SUM cattle	5977	706.9	1865	1787	134.0	**10470**
SUM pigs	2412	27.06	51.69	136.1	13.87	**2640**
SUM poultry	61.39	1807	517.3	0	0	**2386**
SUM horses	0	68.19	441.0	2.99	0	**512.3**
SUM ALL	**8450**	**2609**	**2875**	**1926**	**148.0**	**16009**

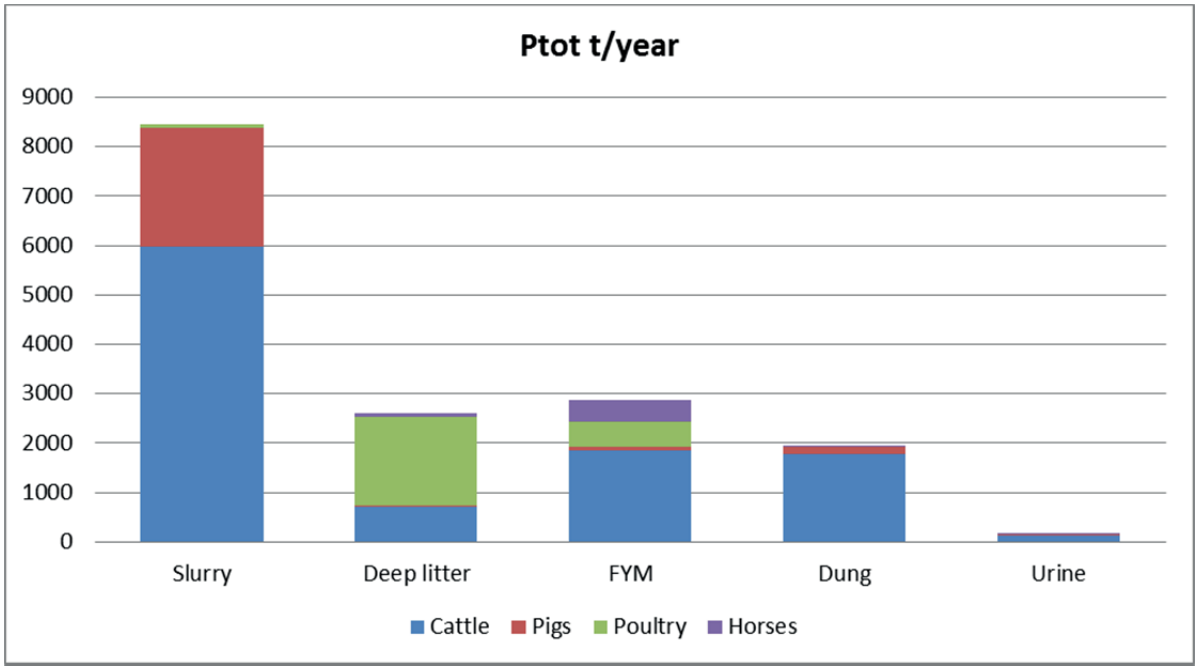

Figure 10. Total phosphorus in Finnish cattle, pig, poultry and horse manure after manure storage (ex storage) as tons (2014). Manure left on pasture and dry lot is excluded.

5. System development needs

In the process of building the first version of the normative manure system reported here, several data gaps were identified and should be improved for system development. Due to these data deficiencies identified, the results per animal category and manure type presented here are subject to change during future development work and research producing the missing data sets. Moreover, annually updated figures are needed in e.g. emission inventories making annual datasets necessary. Thus, the latest updated manure data should always be checked from:

http://www.luke.fi/projektit/normilanta

The most important data gaps and subsequent development needs are discussed in the following sections.

Animal categories

Sheep and fur animals are not included into this documentation yet. Normative manure of fur animals has been developed in a separate project during 2016-2017 (Luostarinen et al. 2017b). Manure calculation for sheep depends on the development of excretion calculation at Luke proceeding during 2017. The normative manure of sheep will be documented and published later.

Further, the more specific animal categories prepared for the normative manure system, but not reported here (Table 2), can mostly already be calculated (e.g. for cattle). However, some still require further work especially on excretion. Such groups include e.g. goats separated by gender and age.

Animal categories are also dependent on the classification made for official statistics as the normative manure system needs the annual animal numbers for the calculation to proceed.

Feeding & excretion

The excretion results presented here are based on excretion calculation from feeding recommendations (2014). Feeding recommendations provide a 'standard' for how the animals should be fed to fulfil their needs for well-being, growth and reproduction as well as high-quality products. However, animal farms may not follow the recommendations. The result may not be farm-specifically valid and to develop farm-specificity in the system, correction coefficients or separate calculators taking into account farm-specific feeding choices and feed quality should be developed. Such a calculator is needed e.g. for intensive rearing og pig and poultry and the related BAT-conclusions on efficient feeding and reduced ammonia emissions.

Further, for national and regional calculation, harmonisation between using the feeding recommendations and data on practical feeding on farms should be developed. With pigs and poultry, feeding recommendations apparently offer better generalised data due to more controlled feeding receipts. The feed is industrially produced to a higher degree and its content thus well-known. However, cattle, sheep, goats, horses and ponies eat mostly farm-specific and widely variable roughage and spend a significant portion of the year grazing or on dry lot, making the difference between feeding recommendations and actual farm-specific feed quality more significant. The consideration of the variable quality of roughage and grazing should be further developed in the normative manure system. This is also important for high quality emission inventories.

Also, the production data on animal growth, production periods and subsequent changes in feeding regime are also subject to changes depending on e.g. market demand. The excretion calculation aims at mimicking the practical production systems on farms and it is important that this data is regularly updated. At the time of developing excretion calculation for this normative manure system, some updating tasks were identified but not yet fully included into the calculation.

For these reasons and to strengthen the national excretion calculation in Luke, new internal Luke working groups for ruminants (cattle, sheep, goats), monogastric animals (pigs, poultry, fur animals)

and horses have been introduced. At the time of writing, the working groups are organising their activities and planning required updates to excretion calculation methods and background data. The work also includes clear documentation of the excretion calculation. Annual calculation procedures are also being organised. Some larger issues already identified are being planned or applied as separate projects.

As these issues are also a challenge in the mass balance-based calculation in other countries, international research cooperation would be beneficial. Some discussion between the countries in the Baltic Sea Region can be facilitated as part of the Interreg project MANURE STANDARDS coordinated by Luke and starting late 2017.

Housing

The available information on bedding quantity and quality on Finnish farms is mostly old and very limited. Also, the ratios of different bedding materials used are based on expert estimates, not real data from farms. These ratios also change due to e.g. availability and price of the bedding materials. As the proportion of bedding material in solid manures is high and it affects e.g. the immobilisation of nitrogen, the poor quality of bedding data weakens the normative manure system. A new farm survey with improved questions on bedding use should be conducted and the farmers motivated to reply. Further, more research on bedding quality is needed.

Data on water addition to slurries (and solid manures, though this is rare) is also old and limited and contains no consideration of potential farm-specific variation. A new farm survey is needed to collect data from practice, including potentially installation of meters on pilot farms to measure water consumption in practice. Also discussions with e.g. companies marketing milking equipment should be organised in order to monitor the water consumption in them.

Loss of dry matter and organic matter during housing of deep litter and storage of all manure types is now considered roughly with coefficients. The phenomenon has a significant effect on manure quantity and quality especially with solid manures and it should be studied more profoundly under the Finnish production conditions.

Also, evaporation of water from solid manures during housing affects manure quantity and quality significantly. It varies between different animal groups and conditions. Especially in warm housing and pigs and poultry, the extent of water evaporation during housing may be significant. In this first version of the normative manure system, a rough assumption of the water evaporation was included to adjust the dry matter content according to analysed manure data. A more sophisticated method for water evaporation rate should be developed.

As these issues are also a challenge in the mass balance-based calculation in other countries, international research cooperation would be beneficial. Some discussion between the countries in the Baltic Sea Region can be facilitated as part of the Interreg project MANURE STANDARDS coordinated by Luke and starting late 2017.

Storage

Manure storage solutions are important especially for gaseous emissions and on rainwater addition to manures. This information also affects the dry matter loss during storage and little information is available on it. The data on manure management is now based on farm surveys made in 2012 and 2013. The dataset should regularly be updated with new surveys and the old survey is beginning to age already. Its updatedness is very important also for the national emission inventories.

Regular updating and validation protocols

It is vital for the normative manure system and all its uses that the background data remains updated and the calculation methods are maintained and validated. This is the only way to ensure current and harmonised manure data for all those needing it.

Annual check-up for updates is needed for all calculation steps. When needed, the calculation will be modified and the changes documented. The results will be simultaneously published and they form the necessary timeseries for emission inventories.

Farm-specific data on practical manure management is collected regularly, e.g. every five years, and with the required precision. This needs to be done in a separate survey directed to animal farms, horse stables and fur farms. Simultaneously a chosen group of pilot farms need to be sampled for their manure, followed by manure analysis. This data is required to validate the normative manure system.

It is important that the calculation is clearly documented and the background data collected in cooperation with farmers and relevant organisations and companies. Transparency guarantees the acceptability of the results in their various uses.

At the time of writing the updating and maintenance protocols with necessary resources are not established. The system is now developed in various projects.

Motivating farmers to participate

The farmers need to be motivated to participate in the data collection and making the calculation system as solid and representative as possible. They should see the system as a tool for their benefit via equal treatment of animal farms in all manure-related issues. The more they are willing to share information on their practical manure management on farms, the more accurate the system and thus also its use as basis for e.g. regulative actions and compulsory national emission inventories becomes. These policy actions will direct manure management on farms.

6. Final conclusions

The Finnish normative manure systems documented in this report is a well-functioning system which provides unified, scientifically-based data on manure quantity and quality. Such data has not been previously available in Finland. Though the system can still benefit greatly from improved background data (see 3.6), the calculation system itself works and provides many types of data for different stakeholders to use.

The data provided by the system is increasingly needed to reach the international and national targets and requirements for enhanced manure management, nutrient recycling, maintenance of organic matter in field soils and emission reductions. The system is already connected to the national model for agricultural air pollutant emissions and its use in agricultural greenhouse gas inventory and nutrient balances is being discussed. It is important that such systems rely on comparable data.

The data provided by the normative manure system can also be attached to other tools supporting circular economy. Already at the time of writing, normative manure system provides data on manure quantity and quality to two novel Finnish tools aiming at serving the stakeholders within circular economy with spatial information on organic biomasses in Finland and their potential uses in different regions. 'Biomass atlas' provides open-source data online on the quantities and locations of different biomasses in Finland and its manure data is derived from the normative manure system. 'Nutrient calculator' is being developed to support regional authorities in planning actions to enhance nutrient recycling on their regions. It calculates the quantity, quality and location of biomasses on municipal level, allows for processing the biomasses with different technologies / technology chains and estimates were the nutrients can be used as fertilisers. Data on manure is again based on the normative manure system. Further, a connection between these tools and the national model for nutrient loading to waters is being planned.

Moreover, the calculation system serves as a solid basis for other, simplified tools for use in farm-scale. Such tools could include e.g. calculators for excretion to be used in optimising animal feeding, or for ammonia emissions to improve farm-scale nitrogen use. It is seen important that all tools used in support of regulation and voluntary actions, whether by decision makers, authorities or farmers, should be based on the same manure calculation principles. Otherwise the tools are not comparable and the farmers treated equally.

The normative manure system could serve as an overall official tool for providing manure data. Currently, a lot of manure-related development work is being done in research, within business and in educational facilities. As these organisations use very variable manure data in their work, the results provided are not comparable. This is a major shortcoming for the efficiency of these actions. Further, to have several systems for manure data provision is inefficient, confusing and unequal to those affected by their use. It is of vital importance that the manure data used in Finland is controlled and harmonised. The normative manure system is a tool for this harmonisation.

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Appendix a: Manure management, grazing and manure storage data for 2015

Values: % of manure per animal category.

	Dairy cows	Suckler cows	Heifers	Bulls	Calves <1 yr	Goats	Horses
Manure management							
Treated as slurry (%)	70	6	54	57	40	0	0
Treated as deep litter (%)	0	29	9	11	16	50	13
Treated as solid manure (%), of which	30	65	37	32	44	50	87
urine not separated -> farmyard manure (%)	23	91	58	88	63	100	99
urine separated -> dung & urine (%)	77	9	42	12	37	0	1
Grazing							
Grazing period (days)	112	171	134	161	127	153	180
Grazed animals (%)	69	92	69	9	31	90	97
Animals inside in nights (%)	100	100	100	100	100	100	100
Time inside at night (h)	11	1	1,5	1	2	2	6
Manure excreted on pasture (%)	12	41	24	4	10	35	36

	Sows	Fattening pigs	Boars	Weaned pigs	Laying hen	Broilers	Chickens	Cockerels	Broiler hen	Turkeys	Other poultry
Manure management											
Treated as slurry (%)	82	98	82	90	9	0	0	0	0	0	0
Treated as deep litter (%)	0	1	0	4	22	100	40	50	100	100	40
Treated as solid manure (%), of which	18	1	18	6	69	0	60	50	0	0	60
urine not separated -> farmyard manure (%)	30	18	30	11	-	-	-	-	-	-	-
urine separated -> dung & urine (%)	70	82	70	89	-	-	-	-	-	-	-

Values: % of manure per each manure type and animal category.

	SLURRY			DEEP LITTER				
	Cattle	Pigs	Poultry	Cattle	Pigs	Poultry	Goat	Horses
Animal shelter (% of manure)								
Improved cleaning of surfaces	13	14	0	-	-	-	-	-
Flushing	1	2	0	-	-	-	-	-
Manure removed more frequently	3	3	-	-	-	-	-	-
Rapid urine separation	-	-	-	-	-	-	-	-
Biological or chemical air scrubbers	0	1	-	-	-	-	-	-
Cooling of manure channels	0	6	-	-	-	-	-	-
Drying of manure on manure belt	-	-	-	-	-	-	-	-
Non-leaking drinking system	-	-	-	-	-	37	-	-
Manure storage (% of manure)								
No measures	0	38	38	62	62	62	62	45
Tight roof (concrete)	2	3	3	-	-	-	-	-
Semi-tight roof (floating covers)	5	27	27	-	-	-	-	-
Natural crust	73	0	0	-	-	-	-	-
Tent, roof	20	32	32	-	-	-	-	-
Solid manure covering	-	-	-	38	38	38	38	55
Filling of storage from the bottom	92	78	78	-	-	-	-	-
Additional information								
Percentage of deep litter stored after removal from animal shelter	-	-	-	20	20	20	20	20

Values: % of manure per each manure type and animal category.

	FARMYARD MANURE					DUNG		URINE	
	Cattle	Pigs	Poultry	Goat	Horses	Cattle	Pigs	Cattle	Pigs
Animal shelter (% of manure)									
Improved cleaning of surfaces	13	11	5	1	15	13	11	13	11
Flushing	-	-	-	-	-	-	-	-	-
Manure removed more frequently	3	2	27	0	0	3	2	-	-
Rapid urine separation	1	5	0	0	0	-	-	1	1
Biological or chemical air scrubbers	0	1	4	0	0	0	1	0	1
Cooling of manure channels	-	-	-	-	-	-	-	-	-
Drying of manure on manure belt	-	-	-	-	-	-	-	-	-
Non-leaking drinking system	-	-	-	-	-	-	-	-	-
Manure storage (% of manure)									
Tight roof (concrete)	-	-	-	-	-	-	-	7	8
Natural crust	-	-	-	-	-	-	-	-	-
Tent, roof, floating cover	-	-	-	-	-	-	-	65	71
Solid manure covering	44	44	44	44	61	44	44	-	-
Filling of storage from the bottom	33	49	0	0	0	38	49	-	-

Appendix b: Shares of animal housing on Finnish cattle farms

Manure type	Housing type	Dairy cow	Suckler cow	Heifer >1 yr	Bulls >1 yr	Calf <1 yr
Slurry	Tied stall	31 %	38 %	28 %	10 %	15 %
	Loose warm	45 %	24 %	48 %	30 %	60 %
	Loose semiwarm	23 %	8 %	12 %	30 %	20 %
	Loose cold	1 %	30 %	12 %	30 %	5 %
Deep litter	Tied stall	23 %	0 %	1 %	0 %	6 %
	Loose warm	0 %	2 %	5 %	5 %	30 %
	Loose semiwarm	24 %	3 %	19 %	5 %	25 %
	Loose cold	53 %	95 %	75 %	90 %	39 %
Farmyard manure	Tied stall	62 %	4 %	20 %	7 %	14 %
	Loose warm	9 %	1 %	8 %	3 %	35 %
	Loose semiwarm	2 %	6 %	8 %	4 %	20 %
	Loose cold	27 %	89 %	64 %	86 %	31 %
Urine	Tied stall	88 %	30 %	75 %	80 %	40 %
	Loose warm	8 %	0 %	11 %	8 %	37 %
	Loose semiwarm	1 %	1 %	4 %	4 %	10 %
	Loose cold	3 %	69 %	10 %	8 %	13 %
Dung	Tied stall	88 %	30 %	75 %	80 %	40 %
	Loose warm	8 %	0 %	11 %	8 %	37 %
	Loose semiwarm	1 %	1 %	4 %	4 %	10 %
	Loose cold	3 %	69 %	10 %	8 %	13 %

Appendix c: Quantities of bedding materials per manure types

CATTLE

MANURE TYPE	HOUSING TYPE	BEDDING	DAIRY COW	SUCKLER COW	HEIFER >1 yrs	BULL >1 yrs	CALF <1 yrs
		m^3/animal(place)/year)					
SLURRY	Tied stall	Straw loose					
		Straw baled					
		Straw shredded	0.033	0.033	0.016	0.016	0.0082
		Peat	0.033	0.033	0.016	0.016	0.0082
		Saw dust					
		Wood shavings	0.033	0.033	0.016	0.016	0.0082
		Straw pelleted					
		TOTAL	**0.098**	**0.098**	**0.048**	**0.048**	**0.025**
	Loose warm	Straw loose					
		Straw baled					
		Straw shredded	0.304	0.304	0.152	0.152	0.076
		Peat	0.304	0.304	0.152	0.152	0.076
		Saw dust					
		Wood shavings	0.304	0.304	0.152	0.152	0.076
		Straw pelleted					
		TOTAL	**0.91**	**0.91**	**0.46**	**0.46**	**0.23**
	Loose semiwarm	Straw loose					
		Straw baled					
		Straw shredded	0.405	0.405	0.202	0.202	0.101
		Peat	0.405	0.405	0.202	0.202	0.101
		Saw dust					
		Wood shavings	0.405	0.405	0.202	0.202	0.101
		Straw pelleted					
		TOTAL	**1.21**	**1.21**	**0.61**	**0.61**	**0.30**
	Loose cold	Straw loose					
		Straw baled					
		Straw shredded	0.405	0.405	0.202	0.202	0.101
		Peat	0.405	0.405	0.202	0.202	0.101
		Saw dust					
		Wood shavings	0.405	0.405	0.202	0.202	0.101
		Straw pelleted					
		TOTAL	**1.21**	**1.21**	**0.61**	**0.61**	**0.30**

MANURE TYPE	HOUSING TYPE	BEDDING	DAIRY COW	SUCKLER COW	HEIFER >1 yrs	BULL >1 yrs	CALF <1 yrs
		m^3/animal(place)/year)					
DEEP LITTER	Tied stall	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**
	Loose warm	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**
	Loose semiwarm	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**
	Loose cold	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**

MANURE TYPE	HOUSING TYPE	BEDDING	DAIRY COW	SUCKLER COW	HEIFER >1 yrs	BULL >1 yrs	CALF <1 yrs
		m^3/animal(place)/year)					
FARMYARD MANURE	Tied stall	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**
	Loose warm	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**
	Loose semiwarm	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**
	Loose cold	Straw loose					
		Straw baled	48	28	48	24	24
		Straw shredded					
		Peat					
		Saw dust					
		Wood shavings					
		Straw pelleted					
		TOTAL	**48**	**28**	**48**	**24**	**24**

MANURE TYPE	HOUSING TYPE	BEDDING	DAIRY COW	SUCKLER COW	HEIFER >1 yr	BULL >1 yr	CALF <1 yr
		m^3/animal(place)/year)					
DUNG & URINE	Tied stall	Straw loose					
		Straw baled		6.7		4.7	6
		Straw shredded	3.2		3.2		
		Peat	1.1	1.3	1.1	3.1	
		Saw dust					
		Wood shavings	1.1	0.87	1.1	0,87	
		Straw pelleted					
		TOTAL	**5.3**	**8.7**	**5.3**	**8.7**	**6.0**
	Loose warm	Straw loose					
		Straw baled		6.7		4.7	6
		Straw shredded	3.2		3.2		
		Peat	1.1	1.3	1.1	3.1	
		Saw dust					
		Wood shavings	1.1	0.87	1.1	0,87	
		Straw pelleted					
		TOTAL	**5.3**	**8.7**	**5.3**	**8.7**	**6.0**
	Loose semiwarm	Straw loose					
		Straw baled		6.7		4.7	6
		Straw shredded	3.2		3.2		
		Peat	1.1	1.3	1.1	3.1	
		Saw dust					
		Wood shavings	1.1	0.87	1.1	0,87	
		Straw pelleted					
		TOTAL	**5.3**	**8.7**	**5.3**	**8.7**	**6.0**
	Loose cold	Straw loose					
		Straw baled		6.7		4.7	6
		Straw shredded	3.2		3.2		
		Peat	1.1	1.3	1.1	3.1	
		Saw dust					
		Wood shavings	1.1	0.87	1.1	0,87	
		Straw pelleted					
		TOTAL	**5.3**	**8.7**	**5.3**	**8.7**	**6.0**

PIGS

MANURE TYPE	BEDDING	FARROWING SOW + PIGLETS	GESTATING SOW	MATING SOW	BOAR	FATTENING PIG	WEANED PIGS
	m^3/animal(place)/year						
SLURRY	Straw loose						
	Straw baled						
	Straw shredded	0.092	0.092	0.092	0.02	0.02	0.02
	Peat	0.092	0.092	0.092	0.02	0.02	0.02
	Saw dust						
	Wood shavings	0.092	0.092	0.092	0.02	0.02	0.02
	Straw pelleted						
	TOTAL	**0.275**	**0.275**	**0.275**	**0.06**	**0.06**	**0.06**
DEEP LITTER	Straw loose						
	Straw baled	0.64	0.64	0.64	0.36	0.36	0.28
	Straw shredded						
	Peat	0.08	0.08	0.08	0.12	0.12	0.035
	Saw dust						
	Wood shavings	0.08	0.08	0.08	0.12	0.12	0.035
	Straw pelleted						
	TOTAL	**0.8**	**0.8**	**0.8**	**0.6**	**0.6**	**0.35**
FARMYARD MANURE, DUNG	Straw loose						
	Straw baled	0.75	0.75	0.75	0.25	0.25	0.375
	Straw shredded						
	Peat	0.25	0.25	0.25	0.125	0.125	0.125
	Saw dust						
	Wood shavings				0.125	0.125	
	Straw pelleted						
	TOTAL	**1**	**1**	**1**	**0.5**	**0.5**	**0.5**

POULTRY

MANURE TYPE	BEDDING	LAYING HEN	BROILER	GROWING TURKEY
	m^3/animal(place)/year)			
DEEP LITTER	Straw loose			
	Straw baled			
	Straw shredded			
	Peat	0.005	0.007	0.03
	Saw dust			
	Wood shavings			
	Straw pelleted			
	TOTAL	**0.005**	**0.007**	**0.03**

HORSES

MANURE TYPE	BEDDING	HORSE	PONY
	m^3/animal(place)/year)		
DEEP LITTER	Straw loose		
	Straw baled	13.23	6.615
	Straw shredded		
	Peat	6.47	3.235
	Saw dust	1.96	0.98
	Wood shavings	6.9	3.45
	Straw pelleted		
	TOTAL	**28.6**	**14.3**
FARMYARD MANURE	Straw loose		
	Straw baled	13.23	6.615
	Straw shredded		
	Peat	6.47	3.235
	Saw dust	1.96	0.98
	Wood shavings	6.9	3.45
	Straw pelleted		
	TOTAL	**28.6**	**14.3**

SHEEP & GOATS

MANURE TYPE	BEDDING	SHEEP	GOAT
	m^3/animal(place)/year)		
DEEP LITTER	Straw loose		
	Straw baled	2.03	2,03
	Straw shredded		
	Peat		
	Saw dust		
	Wood shavings		
	Straw pelleted		
	TOTAL	**2.03**	**2.03**
FARMYARD MANURE	Straw loose		
	Straw baled	2.03	2.03
	Straw shredded		
	Peat		
	Saw dust		
	Wood shavings		
	Straw pelleted		
	TOTAL	**2.03**	**2.03**

Appendix d: Results for cattle manure

Dairy cow (milk yield 8463 kg, live weight 640 kg)

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Dairy cow (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Dairy cow	12829.81	8394.20	135.54	23.87	126.43	1833.71	377.27	1588.98	113.21

Manure ex housing of Dairy cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Dairy cow	Slurry	23.46	124.55	69.80	23.89	126.71	2265.17	1750.96	5.31	2.98	1.02	5.40	96.57	74.65
	FYM	25.54	146.87	72.98	26.03	186.91	6314.98	5395.78	5.75	2.86	1.02	7.32	247.22	211.23
	Deep litter	19.80	127.84	21.51	26.03	186.91	5683.48	4764.29	6.46	1.09	1.31	9.44	286.99	240.58
	Dung	14.67	71.09	17.31	22.12	53.02	2222.68	1890.06	4.85	1.18	1.51	3.61	151.53	128.86
	Urine	9.31	60.62	57.90	1.92	76.87	382.18	166.62	6.51	6.22	0.21	8.26	41.07	17.91

Manure ex storage of Dairy cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Dairy cow	Slurry	25.37	117.59	68.31	23.89	126.71	2038.65	1524.44	4.64	2.69	0.94	5.00	80.37	60.10
	FYM	28.33	124.36	21.28	26.03	186.91	5683.48	4764.29	4.39	0.75	0.92	6.60	200.63	168.18
	Deep litter	19.80	125.61	19.28	26.03	186.91	5115.13	4195.94	6.34	0.97	1.31	9.44	258.35	211.93
	Dung	16.41	65.62	4.91	22.12	53.02	2000.41	1667.79	4.00	0.30	1.35	3.23	121.92	101.65
	Urine	10.79	55.11	52.39	1.92	76.87	382.18	166.62	5.11	4.86	0.18	7.13	35.44	15.45

Dairy cow (milk yield 8463 kg, live weight 640 kg)

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Dairy cow (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Dairy cow	12829.81	8394.20	135.54	23.87	126.43	1833.71	377.27	1588.98	113.21

Manure ex housing of Dairy cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Dairy cow	Slurry	19.21	99.68	55.83	19.12	101.41	1822.76	1410.36	5.19	2.91	1.00	5.28	94.89	73.42
	FYM	21.30	121.37	58.38	21.26	161.61	5872.57	5055.18	5.70	2.74	1.00	7.59	275.74	237.36
	Deep litter	16.45	106.11	17.17	21.26	161.61	5285.31	4467.93	6.45	1.04	1.29	9.82	321.29	271.60
	Dung	11.84	57.28	13.85	17.73	43.10	1856.74	1582.80	4.84	1.17	1.50	3.64	156.78	133.65
	Urine	7.88	48.49	46.31	1.54	61.49	305.71	133.28	6.15	5.87	0.19	7.80	38.78	16.91

Manure ex storage of Dairy cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Dairy cow	Slurry	21.83	98.65	54.65	21.02	103.78	1778.02	1345.22	4.52	2.50	0.96	4.75	81.45	61.62
	FYM	24.61	107.89	17.00	23.16	163.98	5422.84	4585.06	4.38	0.69	0.94	6.66	220.34	186.30
	Deep litter	17.44	108.87	15.39	23.16	163.98	4894.31	4056.53	6.24	0.88	1.33	9.40	280.57	232.55
	Dung	14.29	57.43	3.93	19.63	45.47	1808.60	1514.26	4.02	0.27	1.37	3.18	126.52	105.93
	Urine	9.14	44.08	41.90	1.54	61.49	305.71	133.28	4.82	4.59	0.17	6.73	33.46	14.59

Suckler cow (milk yield 1600 kg, live weight 681 kg)

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Suckler cow (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Suckler cow	8864.59	5668.29	78.95	7.90	87.77	1197.27	224.94	1060.58	88.64

Manure ex housing of Suckler cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Suckler cow	Slurry	16.42	72.90	42.08	7.92	88.04	1475.31	1197.01	4.44	2.56	0.48	5.36	89.86	72.91
	FYM	17.05	82.37	40.50	9.16	123.05	3816.20	3303.82	4.83	2.37	0.54	7.22	223.79	193.74
	Deep litter	13.26	74.10	12.87	9.16	123.05	3434.58	2922.20	5.59	0.97	0.69	9.28	259.01	220.37
	Dung	10.56	41.95	9.63	7.74	41.52	1834.69	1608.93	3.97	0.91	0.73	3.93	173.77	152.39
	Urine	6.61	33.53	32.00	0.46	53.36	233.07	121.28	5.07	4.84	0.07	8.08	35.27	18.35

Manure ex storage of Suckler cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Suckler cow	Slurry	17.77	68.73	40.99	7.92	88.04	1327.78	1049.48	3.87	2.31	0.45	4.96	74.74	59.07
	FYM	18.95	69.85	11.79	9.16	123.05	3434.58	2922.20	3.69	0.62	0.48	6.49	181.23	154.19
	Deep litter	13.30	72.77	11.54	9.16	123.05	3091.13	2578.74	5.47	0.87	0.69	9.26	232.51	193.97
	Dung	11.79	38.89	2.72	7.74	41.52	1651.22	1425.47	3.30	0.23	0.66	3.52	140.10	120.94
	Urine	7.66	30.48	28.95	0.46	53.36	233.07	121.28	3.98	3.78	0.06	6.97	30.43	15.84

Suckler cow (milk yield 1600 kg, live weight 681 kg)

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Suckler cow (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Suckler cow	8864.59	5668.29	78.95	7.90	87.77	1197.27	224.94	1060.58	88.64

Manure ex housing of Suckler cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Suckler cow	Slurry	9.19	36.77	21.14	3.99	44.37	767.75	625.27	4.00	2.30	0.43	4.83	83.56	68.05
	FYM	9.82	47.03	20.35	5.23	79.38	3108.64	2732.07	4.79	2.07	0.53	8.08	316.48	278.14
	Deep litter	7.55	42.82	6.41	5.23	79.38	2797.78	2421.21	5.67	0.85	0.69	10.52	370.70	320.81
	Dung	5.72	22.73	4.84	4.04	24.41	1243.08	1097.52	3.97	0.85	0.71	4.27	217.33	191.88
	Urine	4.22	16.85	16.08	0.23	26.81	117.11	60.94	4.00	3.81	0.05	6.36	27.78	14.46

Manure ex storage of Suckler cow

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Suckler cow	Slurry	10.68	37.22	20.61	4.64	46.02	780.77	626.89	3.49	1.93	0.43	4.31	73.13	58.72
	FYM	11.55	43.26	5.90	5.88	81.03	2887.57	2499.61	3.74	0.51	0.51	7.01	249.92	216.34
	Deep litter	8.21	44.70	5.75	5.88	81.03	2607.80	2219.83	5.44	0.70	0.72	9.87	317.60	270.35
	Dung	7.09	23.73	1.36	4.69	26.05	1208.57	1051.62	3.35	0.19	0.66	3.68	170.49	148.35
	Urine	4.89	15.31	14.55	0.23	26.81	117.11	60.94	3.13	2.98	0.05	5.49	23.97	12.47

Heifer > 1 year (weighted mean of different breeds in Finland)

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Heifer >1 yr (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Heifer >1 yr	4646.01	4135.43	57.40	8.24	59.08	719.90	146.53	625.06	45.17

Manure ex housing of Heifer >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Heifer >1 yr	Slurry	10.63	52.20	32.11	8.25	59.22	893.94	694.99	4.91	3.02	0.78	5.57	84.13	65.41
	FYM	13.10	71.37	31.99	10.40	119.56	4970.43	4363.83	5.45	2.44	0.79	9.13	379.38	333.08
	Deep litter	9.98	64.25	9.89	10.40	119.56	4473.38	3866.79	6.43	0.99	1.04	11.98	448.05	387.29
	Dung	5.91	28.87	7.88	7.85	26.62	1111.49	958.69	4.88	1.33	1.33	4.50	187.94	162.11
	Urine	5.22	27.30	26.30	0.56	35.92	148.82	66.03	5.23	5.04	0.11	6.89	28.53	12.66

Manure ex storage of Heifer >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Heifer >1 yr	Slurry	11.50	49.06	30.98	8.25	59.22	804.54	605.59	4.26	2.69	0.72	5.15	69.93	52.64
	FYM	14.36	61.46	9.28	10.40	119.56	4473.38	3866.79	4.28	0.65	0.72	8.33	311.60	269.35
	Deep litter	9.82	63.22	8.86	10.40	119.56	4026.05	3419.45	6.44	0.90	1.06	12.17	409.95	348.18
	Dung	6.59	26.39	2.25	7.85	26.62	1000.34	847.54	4.00	0.34	1.19	4.04	151.71	128.54
	Urine	6.05	24.80	23.80	0.56	35.92	148.82	66.03	4.10	3.94	0.09	5.94	24.61	10.92

Heifer > 1 year (weighted mean of different breeds in Finland)

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Heifer >1 yr (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Heifer >1 yr	4646.01	4135.43	57.40	8.24	59.08	719.90	146.53	625.06	45.17

Manure ex housing of Heifer >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Heifer >1 yr	Slurry	7.79	35.41	21.76	5.60	40.17	614.48	478.81	4.54	2.79	0.72	5.15	78.85	61.44
	FYM	10.27	54.62	21.67	7.75	100.51	4690.97	4147.66	5.32	2.11	0.75	9.79	456.80	403.90
	Deep litter	7.75	49.73	6.63	7.75	100.51	4221.88	3678.56	6.42	0.86	1.00	12.97	545.03	474.89
	Dung	4.18	20.22	5.34	5.37	19.15	880.03	763.81	4.83	1.28	1.28	4.58	210.35	182.57
	Urine	4.11	18.49	17.82	0.38	24.34	100.82	44.73	4.49	4.33	0.09	5.91	24.50	10.87

Manure ex storage of Heifer >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Heifer >1 yr	Slurry	8.82	34.95	20.99	6.26	41.28	607.03	463.45	3.96	2.38	0.71	4.68	68.80	52.53
	FYM	11.55	49.53	6.26	8.42	101.61	4275.87	3724.65	4.29	0.54	0.73	8.79	370.07	322.36
	Deep litter	7.93	50.71	5.95	8.42	101.61	3853.68	3302.46	6.40	0.75	1.06	12.82	486.23	416.68
	Dung	5.04	20.20	1.52	6.04	20.25	846.02	721.90	4.01	0.30	1.20	4.02	167.99	143.34
	Urine	4.77	16.80	16.12	0.38	24.34	100.82	44.73	3.52	3.38	0.08	5.10	21.14	9.38

Bull > 1 year (weighted mean of different breeds in Finland; slaughter weight 341 kg)

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Bull >1 yr (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Bull >1 yr	6063.71	5019.87	78.23	11.73	75.57	947.93	191.10	821.33	56.91

Manure ex housing of Bull >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Bull >1 yr	Slurry	12.94	70.02	42.94	11.75	75.76	1176.47	911.94	5.41	3.32	0.91	5.85	90.89	70.46
	FYM	13.24	79.72	43.13	12.81	105.81	3191.03	2725.05	6.02	3.26	0.97	7.99	240.95	205.76
	Deep litter	10.28	70.86	13.73	12.81	105.81	2871.92	2405.94	6.90	1.34	1.25	10.30	279.49	234.14
	Dung	8.03	40.58	10.86	11.20	35.67	1669.31	1445.70	5.05	1.35	1.39	4.44	207.92	180.07
	Urine	5.97	37.64	36.30	0.83	45.95	194.54	84.89	6.31	6.08	0.14	7.70	32.59	14.22

Manure ex storage of Bull >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Bull >1 yr	Slurry	14.01	65.81	41.44	11.75	75.76	1058.82	794.30	4.70	2.96	0.84	5.41	75.60	56.71
	FYM	14.70	66.44	12.59	12.81	105.81	2871.92	2405.94	4.52	0.86	0.87	7.20	195.43	163.72
	Deep litter	10.28	69.44	12.31	12.81	105.81	2584.73	2118.75	6.75	1.20	1.25	10.29	251.41	206.08
	Dung	8.94	37.16	3.10	11.20	35.67	1502.38	1278.77	4.16	0.35	1.25	3.99	168.14	143.12
	Urine	6.92	34.19	32.84	0.83	45.95	194.54	84.89	4.94	4.75	0.12	6.64	28.12	12.27

Bull > 1 year (weighted mean of different breeds in Finland; slaughter weight 341 kg)

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Bull >1 yr (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Bull >1 yr	6063.71	5019.87	78.23	11.73	75.57	947.93	191.10	821.33	56.91

Manure ex housing of Bull >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Bull >1 yr	Slurry	11.60	61.54	37.73	10.32	66.59	1038.21	805.34	5.31	3.25	0.89	5.74	89.51	69.44
	FYM	11.90	71.22	37.89	11.39	96.64	3052.77	2618.45	5.99	3.18	0.96	8.12	256.57	220.07
	Deep litter	9.21	63.43	12.05	11.39	96.64	2747.50	2313.17	6.88	1.31	1.24	10.49	298.21	251.07
	Dung	7.19	36.16	9.54	9.87	32.07	1554.67	1349.40	5.03	1.33	1.37	4.46	216.25	187.70
	Urine	5.46	33.07	31.89	0.73	40.37	170.93	74.59	6.05	5.84	0.13	7.39	31.29	13.65

Manure ex storage of Bull >1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Bull >1 yr	Slurry	13.05	60.09	36.41	11.27	68.01	1005.49	762.07	4.60	2.79	0.86	5.21	77.06	58.40
	FYM	13.68	61.79	11.06	12.34	98.06	2818.59	2373.71	4.52	0.81	0.90	7.17	206.02	173.50
	Deep litter	9.70	64.42	10.80	12.34	98.06	2543.84	2098.96	6.64	1.11	1.27	10.11	262.30	216.43
	Dung	8.49	35.40	2.72	10.82	33.49	1470.30	1254.48	4.17	0.32	1.27	3.94	173.13	147.72
	Urine	6.33	30.04	28.86	0.73	40.37	170.93	74.59	4.74	4.56	0.11	6.38	27.00	11.78

Calf < 1 year (weighted mean of different breeds and genders in Finland)

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Calf <1 yr (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Calf <1 yr	3076.33	3118.71	40.16	5.66	39.58	505.64	103.50	436.15	28.72

Manure ex housing of Calf <1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Calf <1 yr	Slurry	8.02	36.15	21.87	5.66	39.66	626.01	480.05	4.51	2.73	0.71	4.94	78.04	59.84
	FYM	8.36	45.92	22.02	6.74	69.82	2661.15	2311.68	5.50	2.64	0.81	8.36	318.51	276.68
	Deep litter	6.42	41.18	6.89	6.74	69.82	2395.03	2045.56	6.42	1.07	1.05	10.88	373.18	318.73
	Dung	4.24	21.32	5.23	5.51	22.99	1042.67	905.60	5.03	1.23	1.30	5.42	246.00	213.66
	Urine	4.36	18.12	17.41	0.42	24.06	104.98	43.93	4.16	4.00	0.10	5.53	24.10	10.09

Manure ex storage of Calf <1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Calf <1 yr	Slurry	8.69	34.00	21.15	5.66	39.66	563.41	417.45	3.91	2.43	0.65	4.56	64.83	48.04
	FYM	9.21	39.11	6.40	6.74	69.82	2395.03	2045.56	4.25	0.70	0.73	7.58	260.16	222.20
	Deep litter	6.36	40.47	6.18	6.74	69.82	2155.53	1806.06	6.36	0.97	1.06	10.98	338.86	283.92
	Dung	4.70	19.66	1.48	5.51	22.99	938.40	801.34	4.18	0.32	1.17	4.89	199.62	170.46
	Urine	5.05	16.46	15.75	0.42	24.06	104.98	43.93	3.26	3.12	0.08	4.77	20.80	8.70

Calf < 1 year (weighted mean of different breeds and genders in Finland)

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Calf <1 yr (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Calf <1 yr	3076.33	3118.71	40.16	5.66	39.58	505.64	103.50	436.15	28.72

Manure ex housing of Calf <1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Calf <1 yr	Slurry	6.88	29.52	17.85	4.62	32.39	514.04	394.60	4.29	2.59	0.67	4.71	74.68	57.33
	FYM	7.22	39.26	17.97	5.70	62.54	2549.19	2226.23	5.44	2.49	0.79	8.67	353.25	308.50
	Deep litter	5.52	35.38	5.61	5.70	62.54	2294.27	1971.31	6.41	1.02	1.03	11.33	415.77	357.24
	Dung	3.57	17.88	4.27	4.55	20.14	950.00	828.23	5.01	1.20	1.27	5.64	266.14	232.03
	Urine	3.89	14.79	14.21	0.34	19.64	85.69	35.85	3.81	3.66	0.09	5.05	22.05	9.23

Manure ex storage of Calf <1 yr

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Calf <1 yr	Slurry	7.71	28.95	17.27	5.08	33.13	500.56	375.33	3.75	2.24	0.66	4.30	64.91	48.67
	FYM	8.18	34.88	5.22	6.15	63.29	2332.19	2003.45	4.27	0.64	0.75	7.74	285.16	244.96
	Deep litter	5.70	35.98	5.03	6.15	63.29	2102.76	1774.02	6.32	0.88	1.08	11.11	369.04	311.34
	Dung	4.20	17.71	1.21	5.01	20.88	892.93	765.36	4.21	0.29	1.19	4.97	212.40	182.06
	Urine	4.50	13.43	12.86	0.34	19.64	85.69	35.85	2.98	2.85	0.08	4.36	19.03	7.96

Appendix e: Results for pig manure

Sow (with piglets)

An average of farrowing, gestating and mating sow.

Excretion of Sow (with piglets) (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Sow (with piglets)	974.83	3854.96	29.95	6.53	9.45	280.46	58.49	232.41	42.01

Manure ex housing of Sow (with piglets)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Sow (with piglets)	Slurry	5.71	25.06	18.17	6.54	9.55	359.30	292.74	4.39	3.18	1.14	1.67	62.90	51.25
	FYM	1.98	25.15	17.90	6.57	10.40	424.57	351.49	12.71	9.04	3.32	5.25	214.55	177.62
	Deep litter	1.63	20.66	4.29	6.56	10.26	365.16	293.96	12.69	2.63	4.03	6.30	224.19	180.48
	Dung	1.74	11.02	4.11	5.91	4.40	365.51	307.51	6.34	2.36	3.40	2.54	210.40	177.02
	Urine	3.02	14.25	13.91	0.66	5.99	59.06	43.97	4.72	4.61	0.22	1.99	19.58	14.57

Manure ex storage of Sow (with piglets)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Sow (with piglets)	Slurry	6.23	23.59	17.39	6.54	9.55	323.37	256.81	3.79	2.79	1.05	1.53	51.92	41.23
	FYM	1.51	18.52	4.11	6.57	10.40	382.11	309.03	12.28	2.73	4.36	6.89	253.31	204.87
	Deep litter	1.23	20.10	3.72	6.56	10.26	328.64	257.44	16.32	3.02	5.33	8.33	266.88	209.06
	Dung	1.29	9.47	0.92	5.91	4.40	328.96	270.96	7.34	0.71	4.58	3.41	254.97	210.02
	Urine	3.52	13.37	13.03	0.66	5.99	59.06	43.97	3.80	3.70	0.19	1.70	16.79	12.50

Boar (>50 kg)

Excretion of Boar (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Boar (50- kg)	868.32	2222.45	20.36	4.39	6.03	233.91	40.70	197.35	29.05

Manure ex housing of Boar

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Boar (50- kg)	Slurry	3.17	17.16	11.73	4.39	6.05	279.05	230.40	5.42	3.70	1.39	1.91	88.14	72.77
	FYM	1.67	17.38	11.55	4.42	6.68	355.06	298.80	10.43	6.93	2.65	4.01	212.98	179.23
	Deep litter	1.29	14.40	2.76	4.41	6.49	291.14	238.04	11.13	2.13	3.41	5.02	225.07	184.02
	Dung	1.45	8.21	2.65	4.16	3.09	312.03	266.57	5.66	1.83	2.87	2.13	214.99	183.67
	Urine	1.75	9.25	8.98	0.26	3.59	43.04	32.24	5.27	5.12	0.15	2.05	24.53	18.37

Manure ex storage of Boar

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Boar (50- kg)	Slurry	3.44	16.20	11.32	4.39	6.05	251.15	202.49	4.71	3.29	1.27	1.76	72.92	58.80
	FYM	1.25	13.10	2.65	4.42	6.68	319.55	263.30	10.44	2.11	3.52	5.33	254.75	209.90
	Deep litter	0.98	14.03	2.39	4.41	6.49	262.02	208.93	14.35	2.45	4.51	6.64	267.96	213.66
	Dung	1.11	7.20	0.59	4.16	3.09	280.82	235.36	6.51	0.53	3.76	2.80	253.86	212.76
	Urine	2.05	8.68	8.41	0.26	3.59	43.04	32.24	4.24	4.11	0.13	1.75	21.04	15.76

Fattening pig (>50 kg)

ASSUMING ANIMAL PLACE IS FULL ALL YEAR (theoretical, compatible with animal statistics)

For calculation per animal place considering batch production and production pauses. the animal place is occupied on average 95 % of the year (A-tuottajat 2017, HKScan 2017, Snellman 2017).

Excretion of Fattening pig (50- kg) (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Fattening pig (50- kg)	691.38	2309.33	16.87	2.89	6.22	211.72	51.48	179.35	40.72

Manure ex housing of Fattening pig (50- kg)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Fattening pig (50- kg)	Slurry	3.08	14.48	8.74	2.89	6.24	267.64	224.07	4.71	2.84	0.94	2.03	87.01	72.85
	FYM	1.62	14.75	8.61	2.92	6.87	343.65	292.48	9.10	5.32	1.80	4.24	212.09	180.51
	Deep litter	1.29	12.47	2.04	2.91	6.69	280.86	232.85	9.68	1.58	2.26	5.19	218.14	180.85
	Dung	1.18	7.62	1.98	2.73	2.59	253.20	215.95	6.44	1.67	2.30	2.19	213.97	182.50
	Urine	1.81	6.98	6.69	0.18	3.96	50.22	40.32	3.85	3.69	0.10	2.18	27.71	22.24

Manure ex storage of Fattening pig (50- kg)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Fattening pig (50- kg)	Slurry	3.35	13.76	8.59	2.89	6.24	240.87	197.30	4.11	2.57	0.86	1.87	71.98	58.96
	FYM	1.24	11.55	1.97	2.92	6.87	309.28	258.11	9.35	1.59	2.37	5.56	250.33	208.92
	Deep litter	0.95	12.20	1.77	2.91	6.69	252.78	204.77	12.86	1.87	3.07	7.05	266.52	215.90
	Dung	0.90	6.86	0.43	2.73	2.59	227.88	190.63	7.61	0.48	3.02	2.87	252.62	211.33
	Urine	2.11	6.55	6.27	0.18	3.96	50.22	40.32	3.10	2.97	0.09	1.87	23.77	19.08

Weaned pig (20-50 kg)

ASSUMING ANIMAL PLACE IS FULL ALL YEAR (theoretical, compatible with animal statistics)

For calculation per animal place considering batch production and production pauses. the animal place is occupied on average 80 % of the year (A-tuottajat 2017, HKScan 2017, Snellman 2017).

Excretion of Weaned pig (20-50 kg) (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Weaned pig (20-50 kg)	265.21	1331.28	7.89	1.43	3.80	84.14	23.59	69.65	18.52

Manure ex housing of Weaned pig (20-50 kg)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Weaned pig (20-50 kg)	Slurry	1.78	7.16	4.36	1.47	4.75	193.35	165.23	4.02	2.44	0.82	2.67	108.50	92.72
	FYM	0.71	6.86	4.29	1.45	4.28	150.54	126.70	9.64	6.03	2.03	6.01	211.50	178.01
	Deep litter	0.54	5.72	1.02	1.44	4.16	123.25	100.77	10.57	1.89	2.66	7.69	227.81	186.26
	Dung	0.68	3.67	0.98	1.33	2.05	170.98	147.49	5.44	1.46	1.97	3.03	253.07	218.29
	Urine	1.04	3.45	3.33	0.13	2.70	22.37	17.74	3.32	3.21	0.13	2.61	21.54	17.09

Manure ex storage of Weaned pig (20-50 kg)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Weaned pig (20-50 kg)	Slurry	1.93	6.80	4.28	1.47	4.75	174.02	145.90	3.52	2.21	0.76	2.46	89.94	75.40
	FYM	0.54	5.27	0.98	1.45	4.28	135.49	111.65	9.83	1.83	2.70	7.99	252.94	208.43
	Deep litter	0.41	5.59	0.89	1.44	4.16	110.93	88.45	13.48	2.14	3.48	10.04	267.77	213.51
	Dung	0.61	3.30	0.21	1.33	2.05	153.89	130.39	5.37	0.35	2.17	3.34	250.72	212.44
	Urine	1.21	3.24	3.12	0.13	2.70	22.37	17.74	2.68	2.58	0.11	2.24	18.48	14.66

Appendix f: Results for poultry manure

Laying hen (female)

Excretion of Laying hen (female) (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Laying hen (female)	52.50	0.00	0.76	0.19	0.29	10.71	0.00	8.05	0.00

Manure ex housing of Laying hen (female)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Laying hen (female)	Slurry	0.053	0.56	0.33	0.19	0.29	10.71	8.05	10.69	6.36	3.56	5.49	203.95	153.35
	FYM	0.032	0.57	0.35	0.19	0.29	10.71	8.05	18.19	10.99	5.94	9.15	339.92	255.59
	Deep litter	0.032	0.58	0.14	0.19	0.29	11.14	8.44	18.21	4.43	5.83	8.98	346.96	262.87
	Dung													
	Urine													

Manure ex storage of Laying hen (female)

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Laying hen (female)	Slurry	0.057	0.53	0.33	0.19	0.29	9.64	6.98	9.45	5.84	3.31	5.10	170.55	123.54
	FYM	0.035	0.49	0.12	0.19	0.29	9.64	6.98	14.02	3.47	5.40	8.32	278.19	201.50
	Deep litter	0.034	0.53	0.09	0.19	0.29	10.02	7.32	15.54	2.69	5.44	8.38	291.29	212.84
	Dung													
	Urine													

Broiler

ASSUMING ANIMAL PLACE IS FULL ALL YEAR (theoretical, compatible with animal statistics)

For calculation per animal place considering batch production and production pauses, the animal place is occupied on average 65 % of the year (Siipikarjaliitto 2017).

Excretion of Broiler (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Broiler	30.79	0.00	0.51	0.18	0.32	9.89	0.00	8.34	0.00

Manure ex housing of Broiler

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Broiler	Slurry													
	FYM													
	Deep litter	0.014	0.40	0.10	0.18	0.32	10.49	8.88	27.43	6.63	12.27	21.84	724.43	613.41
	Dung													
	Urine													

Manure ex storage of Broiler

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
	Slurry													
	FYM													
	Deep litter	0.015	0.36	0.06	0.18	0.32	9.44	7.84	24.29	4.18	11.86	21.12	630.39	523.04
	Dung													
	Urine													

Turkey

ASSUMING ANIMAL PLACE IS FULL ALL YEAR (theoretical, compatible with animal statistics)

For calculation per animal place considering batch production and production pauses, the animal place is occupied on average 87 % of the year (Länsikalkkuna 2017).

Excretion of Turkey (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Turkey	66.17	0.00	1.71	0.48	0.74	21.44	0.00	18.08	0.00

Manure ex housing of Turkey

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Turkey	Slurry													
	FYM													
	Deep litter	0.039	1.34	0.32	0.48	0.74	24.02	20.40	34.26	8.26	12.43	19.05	616.44	523.45
	Dung													
	Urine													

Manure ex storage of Turkey

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Turkey	Slurry													
	FYM													
	Deep litter	0.041	1.22	0.21	0.48	0.74	21.62	18.00	30.03	5.15	11.89	18.23	530.87	441.89
	Dung													
	Urine													

Appendix g: Results for horse manure

Horse

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Horse (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Horse	6997.41	2827.28	53.73	10.07	53.91	1399.48	226.18	1272.27	0.00

Manure ex housing of Horse

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Horse	Slurry													
	FYM	13.43	58.80	28.73	11.02	71.46	4039.67	3444.87	4.38	2.14	0.82	5.32	300.86	256.57
	Deep litter	13.02	54.69	10.35	11.02	71.46	3635.70	3040.91	4.20	0.79	0.85	5.49	279.18	233.50
	Dung	7.30	25.34	8.21	9.50	16.72	1381.53	1208.66	3.47	1.12	1.30	2.29	189.31	165.62
	Urine	2.53	28.38	27.48	0.56	37.19	244.13	63.61	11.23	10.88	0.22	14.72	96.62	25.17

Manure ex storage of Horse

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Horse	Slurry													
	FYM	14.22	48.59	7.03	11.02	71.46	3635.70	3040.91	3.42	0.49	0.77	5.03	255.68	213.85
	Deep litter	12.92	53.50	9.16	11.02	71.46	3272.13	2677.34	4.14	0.71	0.85	5.53	253.21	207.18
	Dung	7.16	23.69	3.27	9.50	16.72	1243.38	1070.50	3.31	0.46	1.33	2.34	173.66	149.52
	Urine	2.53	28.30	27.40	0.56	37.19	244.13	63.61	11.20	10.84	0.22	14.72	96.62	25.17

Horse

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Horse (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Horse	6997.41	2827.28	53.73	10.07	53.91	1399.48	226.18	1272.27	0.00

Manure ex housing of Horse

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Horse	Slurry													
	FYM	9.90	42.02	18.42	7.41	52.12	3456.43	2988.43	4.24	1.86	0.75	5.26	349.06	301.80
	Deep litter	9.56	39.34	6.59	7.41	52.12	3110.79	2642.78	4.12	0.69	0.78	5.45	325.52	276.54
	Dung	4.68	16.25	5.26	6.09	10.72	885.88	775.03	3.47	1.12	1.30	2.29	189.31	165.62
	Urine	1.62	18.20	17.62	0.36	23.84	156.55	40.79	11.23	10.88	0.22	14.72	96.62	25.17

Manure ex storage of Horse

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Horse	Slurry													
	FYM	10.44	35.45	4.49	7.41	52.12	3110.79	2642.78	3.40	0.43	0.71	4.99	297.99	253.16
	Deep litter	9.44	38.58	5.84	7.41	52.12	2799.71	2331.70	4.09	0.62	0.78	5.52	296.62	247.04
	Dung	4.59	15.19	2.10	6.09	10.72	797.29	686.44	3.31	0.46	1.33	2.34	173.66	149.52
	Urine	1.62	18.15	17.57	0.36	23.84	156.55	40.79	11.20	10.84	0.22	14.72	96.62	25.17

Pony

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Pony (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Pony	3419.82	1352.29	25.92	4.83	26.61	683.96	108.18	621.72	0.00

Manure ex housing of Pony

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Pony	Slurry													
	FYM	6.57	28.60	13.76	5.31	35.38	1999.15	1708.03	4.35	2.09	0.81	5.38	304.14	259.85
	Deep litter	6.37	26.63	4.95	5.31	35.38	1799.23	1508.11	4.18	0.78	0.83	5.55	282.31	236.63
	Dung	7.16	24.34	3.93	5.52	25.78	3088.65	2763.24	3.40	0.55	0.77	3.60	431.25	385.82
	Urine	1.21	13.61	13.17	0.27	18.38	117.50	31.09	11.22	10.86	0.22	15.17	96.93	25.64

Manure ex storage of Pony

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Pony	Slurry													
	FYM	6.96	23.71	3.37	5.31	35.38	1799.23	1508.11	3.41	0.48	0.76	5.08	258.54	216.71
	Deep litter	6.32	26.06	4.38	5.31	35.38	1619.31	1328.19	4.12	0.69	0.84	5.60	256.13	210.08
	Dung	6.85	23.49	1.51	5.52	25.78	2779.79	2454.38	3.43	0.22	0.80	3.76	405.62	358.14
	Urine	1.21	13.57	13.12	0.27	18.38	117.50	31.09	11.19	10.83	0.22	15.17	96.93	25.64

Pony

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Pony (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Pony	3419.82	1352.29	25.92	4.83	26.61	683.96	108.18	621.72	0.00

Manure ex housing of Pony

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Pony	Slurry													
	FYM	4.86	20.50	8.83	3.58	25.84	1714.95	1484.97	4.22	1.82	0.74	5.32	352.79	305.48
	Deep litter	4.69	19.21	3.15	3.58	25.84	1543.46	1313.48	4.10	0.67	0.76	5.51	329.12	280.08
	Dung	5.88	19.93	2.52	3.88	22.83	2846.61	2551.34	3.39	0.43	0.66	3.88	483.71	433.54
	Urine	0.78	8.73	8.44	0.17	11.79	75.34	19.93	11.22	10.86	0.22	15.17	96.93	25.64

Manure ex storage of Pony

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Pony	Slurry													
	FYM	5.12	17.35	2.15	3.58	25.84	1543.46	1313.48	3.39	0.42	0.70	5.04	301.28	256.39
	Deep litter	4.63	18.85	2.79	3.58	25.84	1389.11	1159.13	4.07	0.60	0.77	5.58	300.01	250.34
	Dung	5.60	19.36	0.94	3.88	22.83	2561.95	2266.68	3.46	0.17	0.69	4.08	457.47	404.75
	Urine	0.78	8.70	8.42	0.17	11.79	75.34	19.93	11.19	10.83	0.22	15.17	96.93	25.64

Appendix h: Results for goat manure

Goat (doe + goatlings)

ALL MANURE IS EXCRETED INHOUSE (theoretical, no grazing or dry lots)

Excretion of Goat (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Goat	376.76	732.25	9.71	1.66	7.02	146.94	51.42	127.00	30.45

Manure ex housing of Goat

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Goat	Slurry													
	FYM	1.19	8.82	5.08	1.70	8.15	275.50	226.88	7.41	4.26	1.43	6.85	231.47	190.62
	Deep litter	1.16	8.13	1.85	1.70	8.15	247.95	199.33	6.99	1.59	1.47	7.01	213.26	171.44
	Dung													
	Urine													

Manure ex storage of Goat

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Goat	Slurry													
	FYM	1.32	7.17	1.40	1.70	8.15	247.95	199.33	5.42	1.06	1.29	6.17	187.58	150.80
	Deep litter	1.17	7.93	1.66	1.70	8.15	223.15	174.53	6.77	1.41	1.46	6.96	190.57	149.05
	Dung													
	Urine													

Goat (doe + goatlings)

MANURE LEFT ON PASTURE AND DRY LOT EXCLUDED

Excretion of Goat (kg/ap/a)

Category	Faeces	Urine	Ntot	Ptot	Ktot	DM_{faeces}	DM_{urine}	OM_{faeces}	OM_{urine}
Goat	376.76	732.25	9.71	1.66	7.02	146.94	51.42	127.00	30.45

Manure ex housing of Goat

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Goat	Slurry													
	FYM	0.81	5.89	3.32	1.13	5.73	206.90	172.43	7.31	4.12	1.40	7.10	256.48	213.74
	Deep litter	0.79	5.44	1.21	1.13	5.73	186.21	151.74	6.92	1.54	1.44	7.29	236.91	193.05
	Dung													
	Urine													

Manure ex storage of Goat

		Total manure	Kg/ap/a						Kg per ton of manure					
Category	Manure type	tn/ap/a	Ntot	Nsol	Ptot	Ktot	DM	VS	Ntot	Nsol	Ptot	Ktot	DM	VS
Goat	Slurry													
	FYM	0.89	4.82	0.91	1.13	5.73	186.21	151.74	5.39	1.02	1.26	6.41	208.32	169.75
	Deep litter	0.79	5.31	1.08	1.13	5.73	167.59	133.12	6.73	1.37	1.43	7.25	212.21	168.55
	Dung													
	Urine													

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