MANURE STANDARDS PUBLICATION

Manure data collection - Experiences from pilot farms

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Summary

Reliable information on manure quantity and nutrient content is needed to ensure efficient manure management and use as a fertilizer. The manure data needed can be generated with different methods, the precision of which outlines how well manure management can be planned and implemented and how effectively the nutrients are utilized by the crops.

The project Manure Standards was all about improving the quality of manure data whether the data is generated via manure sampling and analysis or via manure mass balance calculation. To develop, test and compare these two methods, the project worked with 92 pilot farms in nine Baltic Sea countries. The farms represented animal production within the Baltic Sea region (BSR). The results of this cooperation and the comparisons between the two methods are summarized in this report.

We wish to sincerely thank all the pilot farms for their open cooperation during the project activities.

Keywords:

Manure nutrient content, manure sampling, mass balance, manure analysis

Manure Standards is co-funded by the Interreg Baltic Sea Region Programme. It is coordinated by Natural Resources Institute Finland (Luke) and includes partners from 9 countries around the Baltic Sea: Finland, Sweden, Denmark, Germany, Poland, Lithuania, Latvia, Russia and Estonia. The project is a Flagship of the EU Strategy for the Baltic Sea Region. More information at www.luke.fi/manurestandards.

Contents

Manure definitions used

The manure definitions used in this report are taken from the "Glossary of terms on livestock and manure management, 2011" issued by the Association for Technology and Structures in Agriculture (KTBL):

Slurry	Manure (faeces and urine) produced by housed livestock, usually mixed with some bedding material and some water during management to give liquid manure with dry matter content in the range 1-10%.
Solid manure	Manure from housed livestock that does not flow under gravity and cannot be pumped, but can be stacked in a heap. May include manure from cattle, pigs, poultry, horses, sheep, goats and rabbits.
Semi-solid manure	Manure that cannot be pumped or stacked in a heap.
Deep litter	Faeces or droppings and urine mixed with large amounts of bedding and accumulated over a certain time on the floor of animal houses.
Liquid fraction	Varying degrees of separation of solids and liquid may occur during the management of manures, giving rise to liquid and solid fractions. The properties of these liquid fractions vary with the proportion of urine, faeces, bedding and water that they contain.
Solid fraction	See "Liquid fraction" above. The solid fraction may include e.g. solids remaining following drainage or seepage of the liquid fraction from cattle bedded on straw on a sloping floor and solid fibrous material derived from mechanical separation of slurry.

Other terms, please see the Glossary:

http://ramiran.uvlf.sk/doc11/RAMIRAN%20Glossary_2011.pdf

1. Introduction

Reliable information on the quantity and nutrient content of manure is necessary to develop an effective and comprehensive manure and nutrient management plan for farms. The purpose is to maximize the nutrient effectiveness in crop use and growth and to minimize nutrient runoff to waterways. In fertilization planning, animal farms need to estimate how much nutrients they have in manure and how to distribute them efficiently on the farm's fields. They also need sufficient manure storage capacity to meet the requirements set in national legislation aiming to steer manure spreading to periods when the crops can take up the nutrients made available.

Standard default values for manure properties (often referred to as table values) may be nationally available and they can be used for fertilization planning. However, the chemical and physical properties of manure vary greatly between farms, depending on e.g. animal feeding and various options available for manure management, and the farm-specific manure properties may differ a lot from the generalized table values. To generate farm-specific manure data, the alternative methods are chemical analysis from manure samples or manure mass balance calculation. Both methods have their strengths and weaknesses.

As manure is heterogeneous, an appropriate sampling method is crucial for obtaining a representative sample for manure analysis. As sampling is time-consuming, a balance must be struck between sampling accuracy and the labor required. In general, the larger the manure storage, the more subsamples should be taken. Manure sample can be collected either from storage or from several loads during spreading. The latter often gives good accuracy but will not supply data for adjusting immediate fertilizer doses. The results, however, may be used for calculating additional mineral fertilizer quantities.

While the accuracy of manure analysis is only as good as the sample sent to the laboratory, also the manure analysis should be conducted with suitable analysis methods for manure. The laboratories should have knowhow on manure as a matrix to ensure proper sample pre-treatment, correct analysis methods and interpretation of the results.

Manure mass balance calculation can alternatively be used. It means calculation of the quantity and properties of the manure produced starting from animal feeding, uptake of feed and excretion of faeces and urine (manure ex animal), consideration of the manure management practices in the housing (manure ex housing), and inclusion of the practices in manure storage (manure ex storage). The calculation, however, is only as accurate as the input data.

In the project Manure Standards, we compared two methods of providing *farm-specific manure data*, both aimed at improving the quality of manure data and subsequently the utilisation of manure resources. The methods were tested on over 90 pilot farms around the Baltic Sea region and developed further according to the notions made during testing. The final outputs were joint guidelines and tools for manure data generation in the Baltic Sea region, comprising of instructions for manure sampling, recommendations for manure analysis, farm surveys on manure management and farm-scale calculation tool (https://www.luke.fi/manurestandards/en/results/). In this report, most of the pilot farms are shortly described and experiences with the two data provision methods explained.

2. Pilot farms in the project

The pilot farms in the nine Baltic Sea countries were chosen mainly to represent respective average national production (e.g. animal group and manure handling system) and to have simple nutrient flows which could easily be followed from animal to storage. The number of pilot farms per country varied from 5 (Sweden) to 23 (Latvia and Russia)) (Table 2.1). Total number of farms were 94, however, as some farms included several production types (e.g. dairy and pigs or cattle on slurry and on deep litter), the number of sampled housing systems/manure lines amounted 124 (Table 2.1). The pilot farms are described in more detail in Appendix 1.

Analysis results from the sampling can be found in the Manure Standards database of 900 manure analysis with filtering availability for production type, manure handling system, sampling time of the year, sampling spot (ex-animal, ex-housing and ex storage) and analysing laboratory, https://msdb.netlify.com/ . Animal groups and manure systems represented in each country are presented in Table 2.2. The pilot farms are briefly described in the national sections of this chapter.

Table 2.1. The number of pilot farms /manure line per participating country.

Country	Number of pilot farms	Number of animal house system sampled
Denmark	11	11
Estonia	6	6
Finland	7	7
Germany	5	11
Latvia	23	35
Lithuania	6	6
Poland	5	5
Russia	23	38
Sweden	5	5
Total	94	124

Table 2.2. Number of different animal production and manure types per participating country.

Country	Production	Slurry	Deep litter	Solid manure	Semi-solid manure	Dung + urine	Total
Denmark	Broilers				1		1
	Dairy cattle	1					1
	Fattening pigs	7					7
	Fur animals	1					1
	Pigs integrated	1					1
		10			***1***		***11***
Estonia	Beef cattle			2			2
	Broilers			1			1
	Dairy cattle	2					2
	Laying hens			1			1
		2		***4***			***6***
Finland	Beef cattle	1	1				2
	Broilers		1				1
	Dairy cattle	1				1	2
	Fattening pigs	1					1
	Fur animals			1			1
		3	***2***	***1***		***1***	***7***
Germany	Beef cattle	1					1
	Dairy cattle	5		1			5
	Fattening pigs	2		1			2
	Laying hens				1		1
		8		***2***	***1***		***11***
Latvia	Beef cattle	1	2	7			10
	Dairy cattle	13		8			21
	Fattening pigs	1					1
	Pigs integrated	1					1
	Sheep		2				2
		16	***4***	***15***			***35***
Lithuania	Beef cattle		1				1
	Broilers		1				1
	Dairy cattle	1				1	2
	Horses					1	1
	Sheep		1				1
		1	***3***			***2***	***6***
Poland	Beef cattle		1				1
	Broilers				1		1
	Dairy cattle	1					1
	Fattening pigs	1					1
	Sheep		1				1
		2	***2***		***1***		***5***
Russia*	Dairy cattle			9	8		17
	Pigs integrated					3	3
	Laying hens			5			5
	Beef cattle			5	8		13
				19	***16***	***3***	***38***
Sweden	Broilers		1				1
	Dairy cattle	2					2
	Fattening pigs	1					1
	Pigs integrated		1				1
		3	**2**				**5**
Project total		**45**	**13**	**41**	**19**	**6**	**124**

3. Experiences with using the sampling instructions

All pilot farms were sampled for their manure according to the sampling instructions developed by the Manure Standards project, https://www.luke.fi/manurestandards/en/results/. The samples were taken either by the expert in the project partnership, or by the farmer, or both. Sampling parameters included were:

- Sampler (expert in the project or farmer).
- Sampling time (spring, summer or autumn)
- Sampling spot: ex-animal, ex-housing, ex-storage (described further in the Manure Standards sampling instructions, link above).

Taking samples from solid manure types according to the instructions by fork and shovel was very laborious in case there was no manure auger. In most countries augers were not available. Mixing of solid manure with straw bedding was also noted time-consuming when the aim was to get as homogenous sample as possible.

With slurries, the time and efficiency of mixing was noted the most time-consuming step of the sampling. To get a large slurry tank completely mixed (all surface circling) takes time and this may not be sufficiently patiently done. The crust of the slurry tanks may look very different (Figure 3.1) and sometimes enough mixing may be almost impossible. Pig slurry often is thinner and also has a thinner crust and hence is easier to get to circulate when mixing than cattle slurry. However, prone to sedimentation, pig slurry often build up sediments at the bottom of the tank, requiring powerful mixing for homogenise with the liquid fraction. Consequently, the nutrient content in the slurry will often vary significantly during spreading with the dry matter content increasing from first to last load.

Overall, the sampling went well. Some remarks noted were the following:

- Getting representative samples can be very laborious, especially from solid manure storages.
- Slurry tanks are seldom sufficiently mixed (too short a time and/or inefficient mixers).
- Farmers are reluctant to mix the slurry at other times than before spreading – the time window is only a couple of hours and it may be hard to catch an external sampler.
- Accuracy of sampling battles against practical feasibility. In general, farmers concluded the instructions were too laborious. Farmers also noted that they are often stressed at the time of the year of spreading manure and the sampling coincides with it.

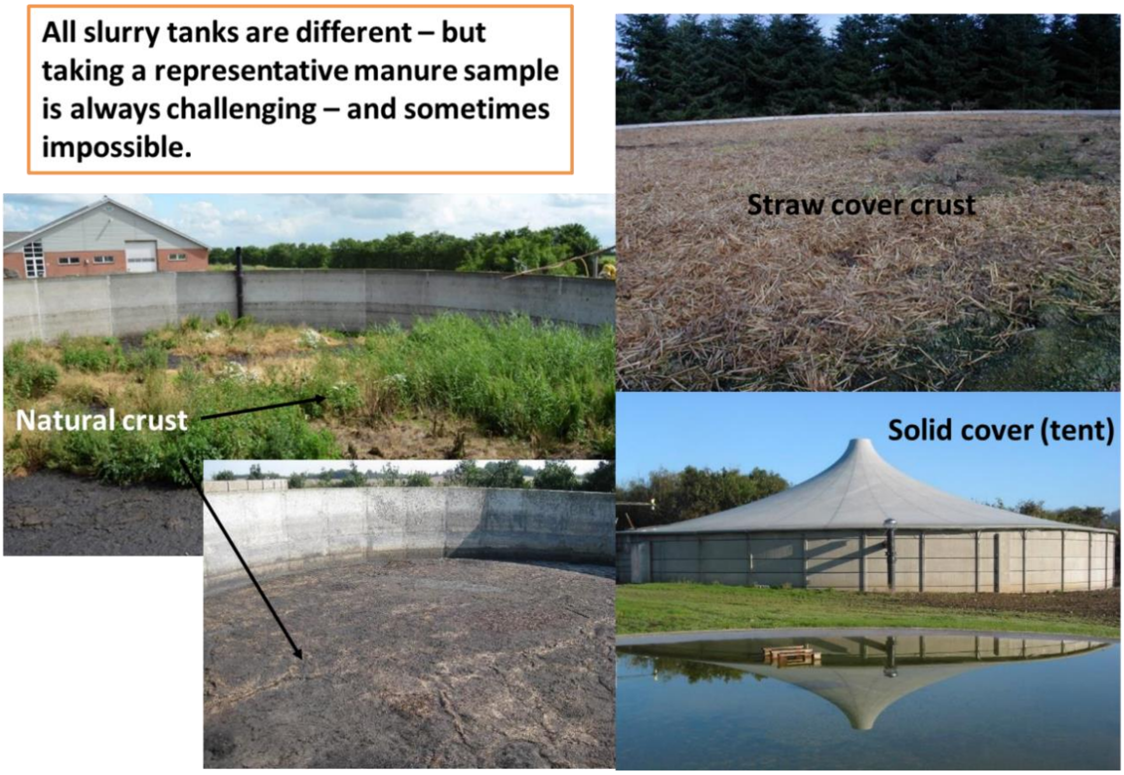

Figure 3.1. Examples of cover of slurry tanks. Pictures: SEGES, Denmark.

4. Experiences with manure analysis

The survey of used methods in 20 laboratories around Baltic Sea shows that there is need for communication and knowledge sharing related to manure analysis. Because laboratories usually analyze many different matrices, the specific properties of manure are not necessarily considered in details by laboratories. Use of international standards and participating in proficiency tests is part of the knowledge sharing between countries and laboratories. Although liquid and solid manure samples are challenging matrices for internal reference samples, laboratories should include proper manure samples in their references.

Analyses of total and ammonia nitrogen concentration are usually the most challenging methods as volatilization of ammonia and microbial activity in the sample can change concentrations. Another challenge for methods is related to certain manure types (e.g. poultry and fur manure) that usually have high nutrient concentrations.

The main findings and recommendations on manure analysis are available online https://www.luke.fi/manurestandards/en/results/. Some issues are highlighted here:

- The methods for sample preparation and for manure analysis currently used in the Baltic Sea Region differed somewhat between the laboratories, also within the same country.
- Not all laboratories have experience with manure as a matrix. This may decrease the reliability of the analysed results as sample preparation (e.g. drying, dilution) may be done in a way that reduces the accuracy of the results. Attention should be paid to diluting solid manure samples which could cause significant error in the results.
- There were differences between laboratories especially in analysis of nitrogen (N). The most important recommendations from the project are both total-N and ammonium-N should be included in the analyses, and ammonium-N analysed from fresh samples (not dried).
- Some laboratories delivered analysis results within a week or two while others took several months. Delay in result delivery is a problem for farmers as it will not supply data for adjusting immediate fertilizer doses, and maybe not even for calculating additional mineral fertilizer quantities. Quicker delivery must be provided.

Total-N:

Most laboratories use Kjeldahl titration for Tot-N.

However, three of the laboratories use dry combustion. Measuring on dry samples with Dumas method (Leco). Total N is then calculated as: NH_4-N + N measured with Dumas method .

+ Dumas method	Easier getting a representative sample
- Dumas method	N might be overestimated in case not all NH_4 disappear during combustion.

Plant available N:

Generally laboratories analyse for ammonia (NH_4)

However, a few laboratories analyse for soluble N and a few only analyse for total-N.

Russia do not analyse for plant available N

+ Soluble N	Plants may to some extent take up also organically bound N.
- Soluble N	Result strongly dependent on mesh size used and extraction solvent. Probably difficult to standardize.

Figure 4.1. Example of differences in nitrogen analysis from manure.

5. Experiences with collecting manure management data

For the purposes of especially national and regional manure data generation, it is important to know the current manure management practices on farms. This information is needed e.g. when making emission inventories and when calculating manure quantities and nutrient contents for a country or a region. It is equally important for farm-scale manure mass balance calculation (see chapter 6).

In the Manure Standards project, a survey form was prepared and tested for the use of the farm-scale manure calculation tool in cooperation with the pilot farms. The questionnaire contained detailed questions on the farm's animal feeding and manure management system.

Mostly the data on manure management (housing technology, storage structure and volume) and number of animals were easily available on the farms, but the data on animal feeding was more difficult to obtain. The level of detail the mass balance calculation requires is rarely practiced in the Baltic Sea countries at the moment. Especially the smaller farms did not precisely know the amounts and contents of the feeds they used, but also in larger farms some of the parameters needed in the calculation tool were not known. It was either not measured (farm-based feeds) or not informed (imported, industrial feeds). In some cases, the feed producers did not even measure the feeds in the parameters and units needed in the calculation tool.

There were also challenges with how to build the questionnaire so clearly that it would be always understood the same. These challenges with constructing a good questionnaire and collecting the data were in detail the following:

- It is difficult to prepare a questionnaire that suits all farms. The amount of and the form of the data available differs very much between countries and farms. The survey (and the calculation tool) may therefore also need national amendments to suit the national production system.
- The farmers may not understand the questions the same. The survey would be best to make as an interview to get adequate and reliable data.
- The units commonly used differ between the countries. Recalculation is often needed.
- Free units may be desirable. The modeler, not the farmer, should carry out the recalculations.
- In case the amount of manure should be estimated, the data is best received from the amounts of manure spread on different times (spring, summer, autumn).
- The amount of bedding material used and wastewaters mixed with urine or slurry are usually not measured on farms.
- The templates made in the project are meant as a baseline from which each country/user can continue into developing a better questionnaire for his/her exact purposes.

6. Experiences with the farm-level manure calculation tool

A farm-level calculation tool for manure mass balance calculation on individual farms was developed in the project Manure Standards (www.luke.fi/manurestandards/en/results/). The tool at ex-animal level is based on the Danish normative manure system (Normtal), but the user is able to add e.g. national housing technologies and to modify e.g. the information on bedding materials, added technological waters and emission coefficients into nationally relevant values instead of the defaults given.

The tool is a mass balance calculation of the farm animals, their feeding, uptake and excretion and the manure management in housing and manure storage. The animal categories included are cattle, pigs and poultry (Table 6.1.)

Table 6.1. Animal categories included into the farm-level manure calculation tool developed in the project Manure Standards.

Cattle
Dairy cows
Heifers (6 months to calving). Available also in subgroups, if necessary.
Beef cattle (6 months to slaughtering). Available also in subgroups, if necessary.
Cow calves (0 to max 6 months)
Bull calves (0 to max 6 months) Suckler cows
Pigs
Fattening pigs. Available also in subgroups, if necessary.
Weaners
Sows
Poultry
Laying hens
Broilers
Young birds

The tool calculates manure amount and composition in three stages of the manure management chain:

1. *Manure ex animal* defines the share of feed ending up in excreted faeces and urine after the animal has taken up the nutrition it needs for its growth, reproduction and yield of products e.g. milk, meat and eggs.

2. *Manure ex housing* is a mass balance of the excreted faeces and urine considering the housing technology used in the housing unit and the subsequent additions into (water, bedding material) and losses from (dry matter, water, gaseous compounds) them.

3. *Manure ex storage* is a mass balance of the manure ex housing after the storage choices (covering, surface area) and conditions (precipitation, evaporation, gaseous losses) on the farm.

The farm-level calculation tool was tested on the pilot farms in each country. In this section, examples of using the tool on the pilot farms are presented. The data collected from the farms (using a draft version of the survey presented in section 5) was fed into the calculation tool as the input data on which the calculation is based. The results were compared to the manure data received directly from the farm (estimation of the manure amount / current manure storage capacity) and from the manure sampling (analyzed dry matter and nutrient content during the project). The advantages and challenges of using the tool and reasons for potential variation between analyzed and calculated data are discussed as a validation for the methods tested.

6.1 Finland

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Farm FI1 - dairy cattle

The farm was situated in South-Western Finland and had 130 dairy cows all together. Lactating cows (115) were kept in dairy barn with slurry and the dry cows and heifers in a separate barn with deep litter manure. Due to the difference in the manure type of the dairy cows, the farm-level calculation was made only for the lactating cows.

The cows were fed with mixed feed ration composed of grass silage, cereals, protein supplement and minerals. Only one mix was used for all lactating cows with extra compound concentrate was given according to the milk yield to fulfill the nutrient requirements.

The feeding data received first from the farm was not sufficient for the requirements of the calculation tool. The survey questions were not quite right to assist in replying and some data needed was not available on the farm. The feeding plans for dairy cows of this herd were later received from an adviser of a commercial feeding company, but the farmer did not remember such details of their feeding at the time of interview (spring sowing season). After getting these plans and by using the results of the feed analyses of the grass silage fed, the daily rations could be calculated. However, all the feeding calculations needed expert knowhow in animal nutrition and feeds. Converting the feeding data available to be suitable for input into the farm-level tool appeared to be too difficult for the farmer. The feeding data should be delivered to the farmer in the correct form to enable his/her independent use of the tool.

The option AFC was used in the calculation tool because no data of energy status of the cows was available. DM digestibility is not used in the Finnish feeding plans and it had to be calculated separately according to the Finnish national excretion calculation tool. Data on the total amount of feeds used per year per herd is also not generally available.

The feed values of the silage were analyzed comprehensively over all harvests and silos and the results were used in feeding planning. Feeding plans were carefully made using all available data about feeds.

With the manure ex housing and ex storage, some adaptation of the tool for the Finnish production would be needed. With this dairy farm it was not directly possible to add dairy cows into two different manure systems as the tool only assumed one housing system for dairy cows. On the pilot farm, lactating cows produced slurry and dry cows were on deep litter. Furthermore, it was not possible to add three manure storages with different covers as the tool only assumes one storage per animal category. On this pilot farm, there were three slurry tanks and only one of them was covered and two with natural crust. Some features of the tool already allowed easy adaptation of the input data. E.g. the characteristics for bedding materials were easy to change for the peat used on this farm.

Overall, the results received from the calculation tool for this dairy farm and its dairy cows seemed to represent the situation on the farm well (Figures 6.1.1 and 6.1.2). The calculated dry matter content was higher in comparison to the analyzed data which may mirror the difficulty of mixing the slurry tanks so thoroughly that all dry matter can be sampled. Also, total nitrogen ex housing was slightly higher with the calculated results than with the analysis. Nitrogen may have fitted the analyzed results better in case the emission coefficients were changed for the Finnish ones. Overall, and considering the ex storage results, the calculated values match the analyzed values very well.

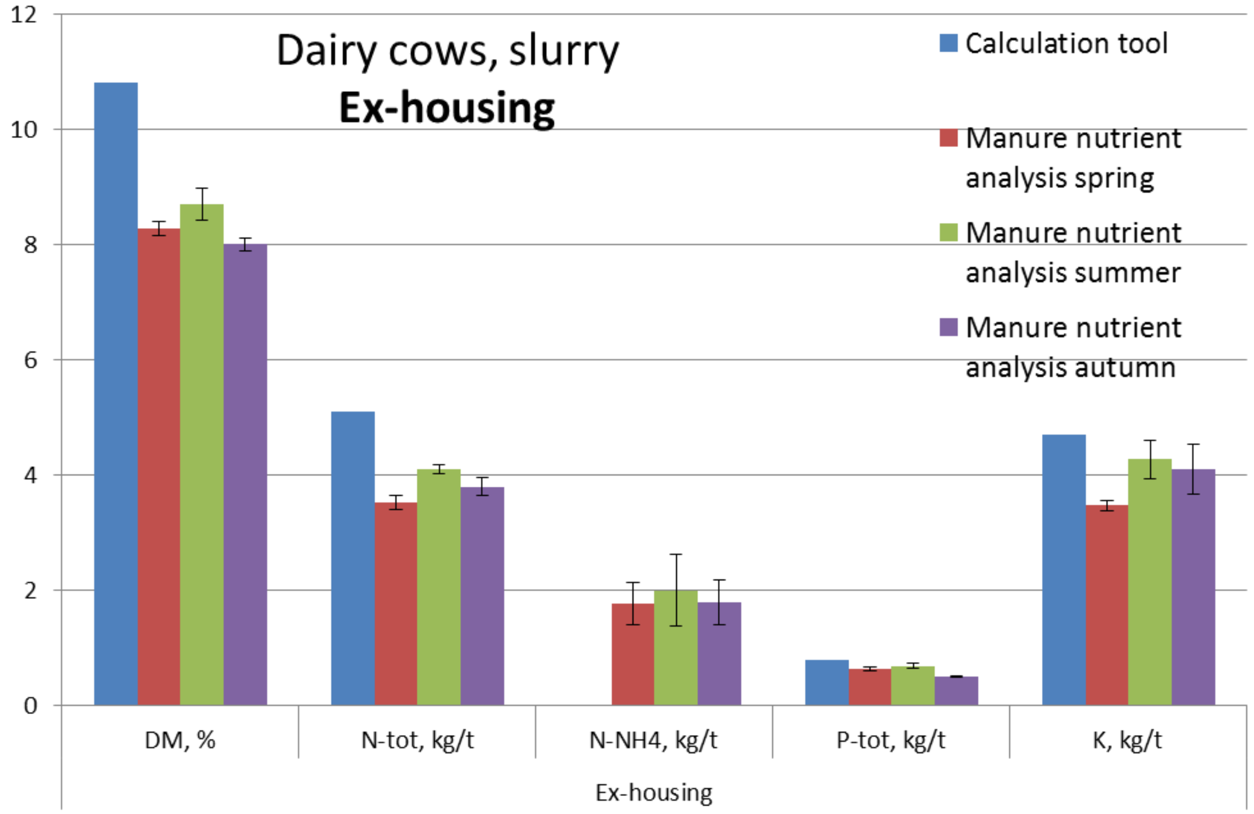

Figure 6.1.1. Results of slurry *ex housing* from the calculation tool and from the analyzed samples in the milking cows of the Finnish dairy farm (farm FI1). The standard deviation bars for the analyzed samples represent the deviation between three laboratories analyzing the same samples taken on the farm in spring, summer and autumn of 2018.

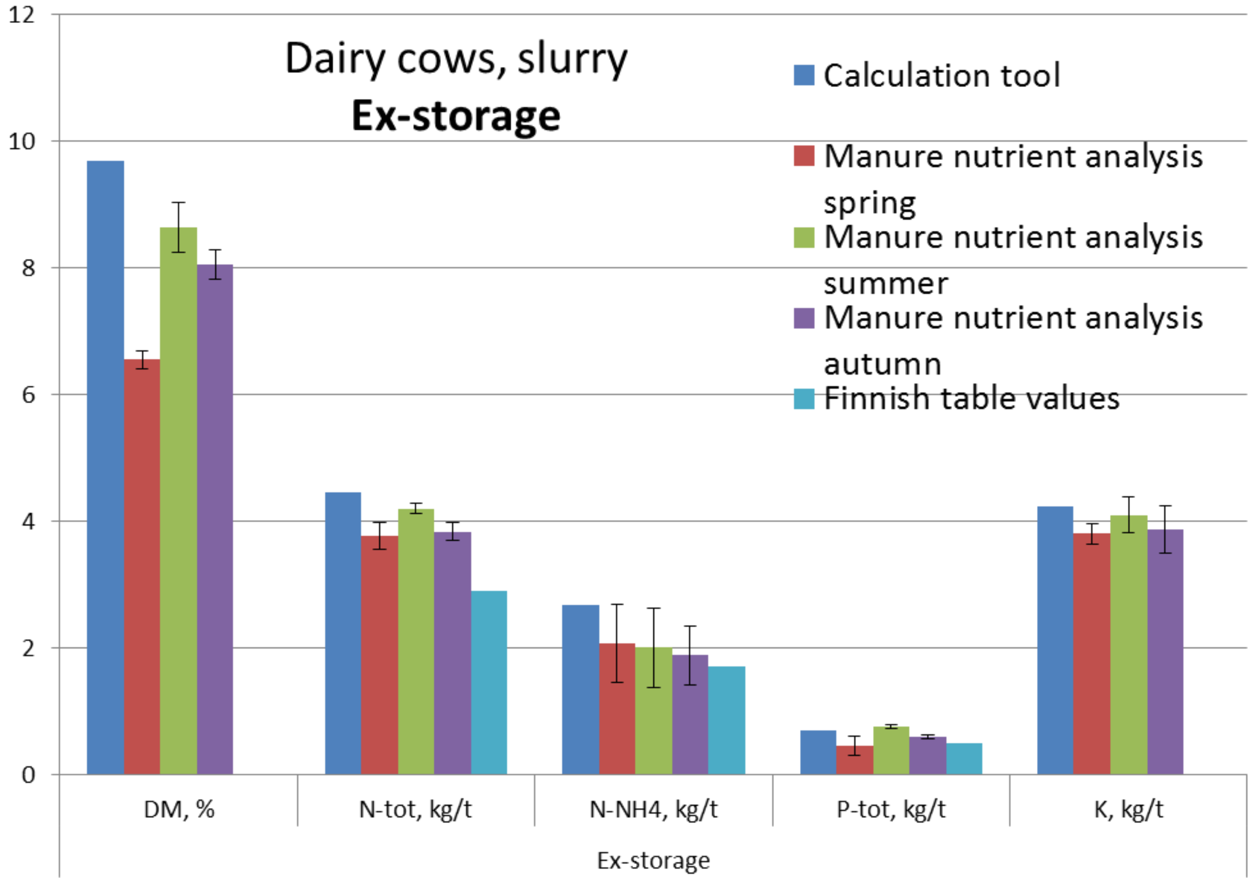

Figure 6.1.2. Results of slurry *ex storage* from the calculation tool and from the analyzed samples in the milking cows of the Finnish dairy farm (farm FI1). The standard deviation bars for the analyzed samples represent the deviation between three laboratories analyzing the same samples taken on the farm in spring, summer and autumn of 2018.

In conclusion, the calculation tool appears to work well for dairy cows in Finland, provided the feeding data is received in a correct and sufficiently detailed form. Thus, to be able to start using such a tool in Finland the feeding data the farmers have should be developed to provide them with the inputs needed by the tool. Currently, they would not be able to use it with the level of details they have for the feeds without an expert assisting. Furthermore, some additional features should be built. E.g. the consideration of several storages with different covers is needed as in Finland the farms have often grown via adding new housing units and storages while still also using the older structures and the versatility of buildings, storages, manure types and location of different cattle categories within one farm can be significant. The calculation tool is not able to handle such versatility in its current form.

Farm FI5 - fattening pigs and weaned pigs

The feeding data from the farm was not sufficient for using the calculation tool which was the main reason for problems with the use of the tool. Some examples of the challenges are described below.

The farmer was not able to produce feeding data in the form that the tool requires. Consideration of the batches for weaned pigs was difficult to produce as the farmer had monthly average feeds for all weaned pigs arriving at different times per month and thus being at different growth periods and consuming different feeds. The data was not divided per weaned pig as the tool required.

Additionally, the digestibility of dry matter and organic matter in the feeds are not available in Finland as the tool requires. The digestibility changes as the pigs grow and their feeds are changed per phase of growth. Also, no data on potassium in feeds is reported for Finnish pig feeds.

After discussions with a pig feeding specialist, the data for feeding weaned pigs was collected as well as it could be. Furthermore, the digestibility of feeds should be measured differently than currently in Finland or an expert should be available for conversions to be able to put it into the tool. Potassium in feeds should be measured to be able to calculate it at all. All-in-all, it became obvious that currently the farmers would not know how to modify the feeding data into the format the tool requires.

For manure management, the tool worked rather well. Only information of technological water was difficult as the farms do not usually measure the water consumed and added to slurry. Due to the difficulties with feeding data and the added water, the calculated results were not very comparable with the analyzed results for dry matter content and nitrogen (Figures 6.1.3-6.1.4). Phosphorus seemed to match rather well, but the calculated result would obviously change if the input data for dry matter would be more reliable than achieved at this point. Potassium could not be calculated at all as the feed potassium content is not available.

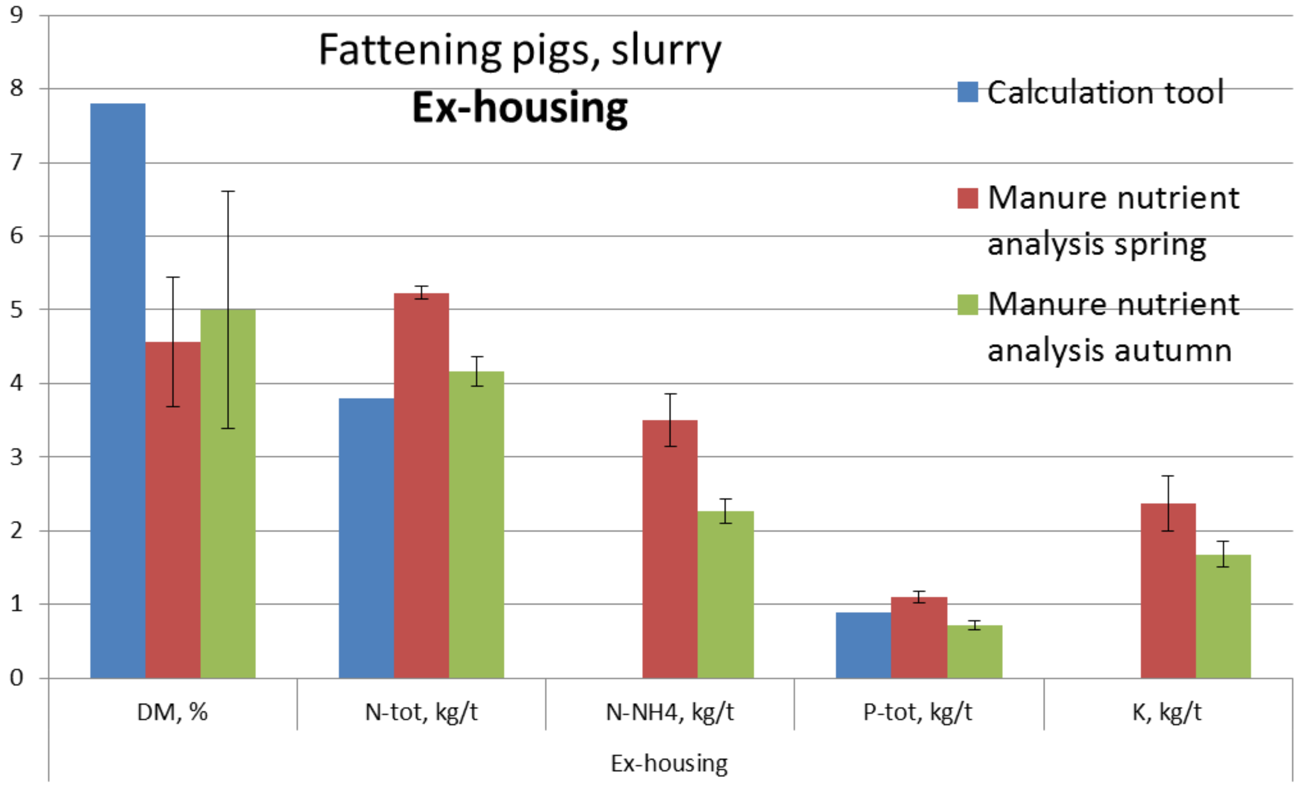

Figure 6.1.3. Results of slurry *ex housing* from the calculation tool and from the analyzed samples in the pig farm rearing weaned pigs and fattening pigs (farm FI5). The standard deviation bars for the analyzed samples represent the deviation between three laboratories analyzing the same samples taken on the farm in spring, summer and autumn of 2018.

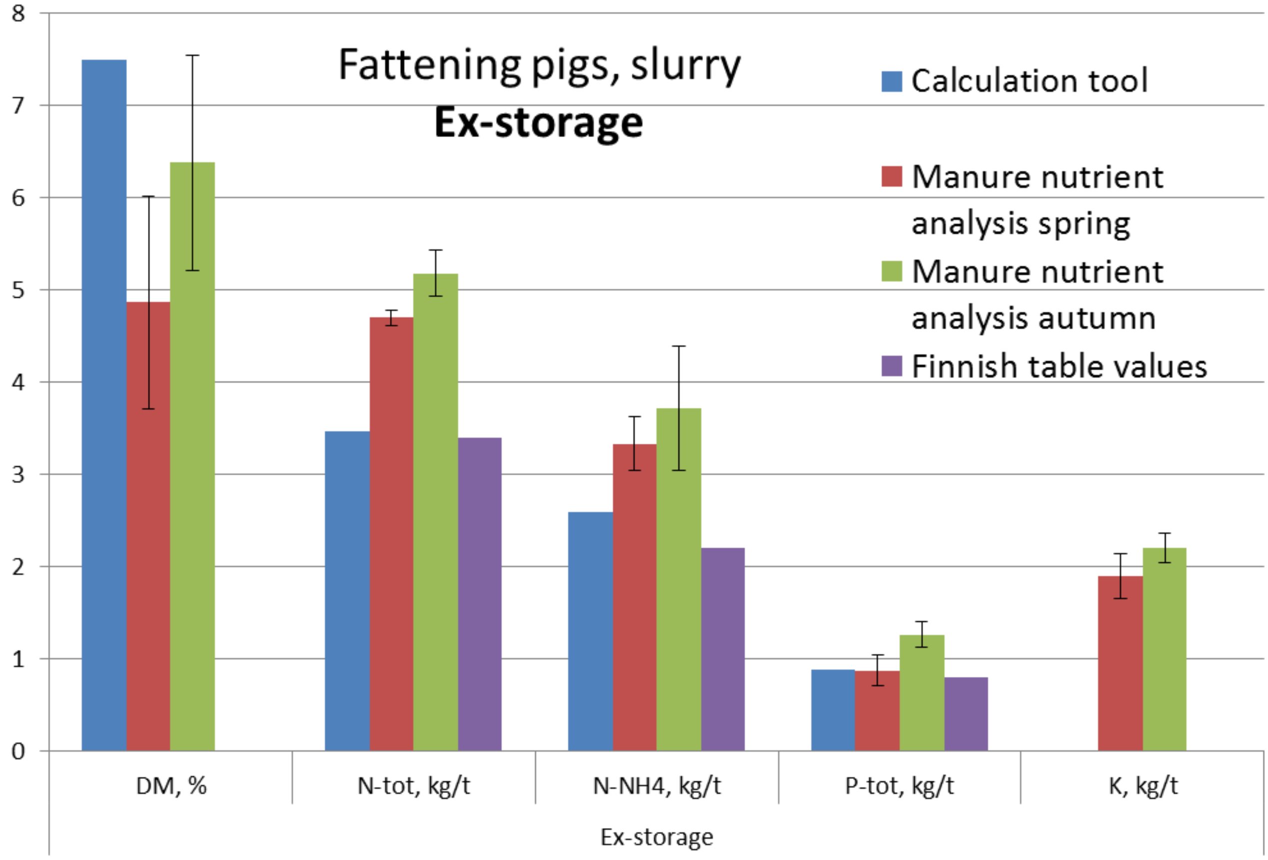

Figure 6.1.4. Results of slurry *ex storage* from the calculation tool and from the analyzed samples in the pig farm rearing weaned pigs and fattening pigs (farm FI5). The standard deviation bars for the analyzed samples represent the deviation between three laboratories analyzing the same samples taken on the farm in spring, summer and autumn of 2018.

The calculation tool could be developed for the use on Finnish pig farms, but in its current form the farmers are not able to use it due to mainly difficulty in getting fitting feeding data.

6.2 Sweden

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Pilot farm SE3 – slaughter pigs

The farm is situated in eastern Sweden and has 3 050 animal places. The intensity is three rounds per year. This means that they produce 9 100 slaughter pigs in one year (see chapter 2.2).

Availability of sufficient data needed to carry out the calculations was a problem. On this farm, the farmer had only knowledge about the amount of each component in kg per pig and day, and about the nutrient content in the premix. Thus, Swedish table values for nutrient content in the other components in the feed were used in the calculation. When it came to feed digestibility, information from the calculation tool manual was used. Dry matter contents in the different components were estimated. Furthermore, the option AFC in the calculation tool was used since there was no knowledge about how the farmer adapted the feeding due to different rearing phases.

The same production data were also used to make calculations in the Swedish farm-scale calculation tool Vera. The Swedish advisors use Vera within the advisory project *Focus on Nutrients* and the software is also used by advisors, consultants and authorities working with environmental permits and inspections. It gives the user a possibility to make both manure calculations based on standard feeding rations and a farm-specific barn balance based on the actual feeding on the farm.

In Figure 6.2.1, we show the differences between i) Vera – standard, ii) Vera – barn balance, iii) the calculation tool developed in this project and iv) manure analysis during spring in the project. Vera and the calculation tool give approximately the same results, but both tools seem to underestimate especially the nitrogen concentration compared to analysis. One reason for this can be an overestimation of the amount of manure. Both Vera and the calculation tool give around 8 000 tons of manure produced on the farm in a year. But according to the farmer his storage, which is in total 4 850 m^3, is enough to store manure for 10.5 months. This would give an annual manure production of approximately 5 500 tons. If the amount of manure produced in a year is smaller than estimated by the tools, the concentration in the manure will naturally be higher in reality compared to the calculated values.

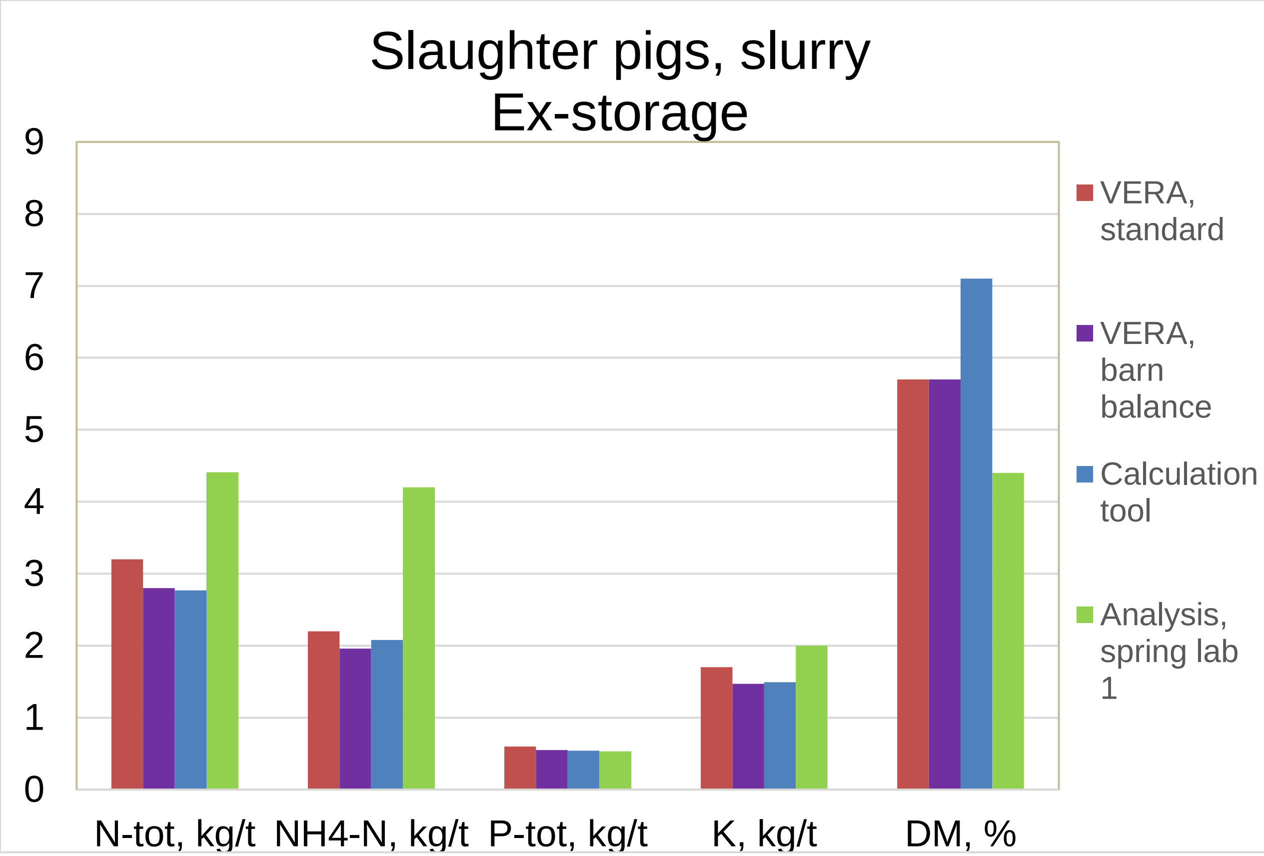

Figure 6.2.1. Results of calculations and manure analysis of dry matter content and concentration of total nitrogen, ammonia nitrogen, phosphorus and potassium in slurry ex-storage from pilot farm SE3. Calculations are made in the Swedish calculation tool Vera and in the calculation tool developed in this project.

The dry matter content appeared lower in the slurry according to analysis as compared to the results from the calculation tool and from Vera. However, since both calculations are based on estimated amounts of technical water, it is hard to say anything about the correctness. The samplers also said that it was a problem to get the slurry properly mixed to ensure representative samples. The differences in the amounts of slurry can also depend on the digestibility of the feed and the use of bedding material. Perhaps the digestibility was underestimated in the calculations.

Pilot farm SE1 – dairy farm

The farm is situated in eastern Sweden and they have 55 dairy cows with recruitment and one bull (see chapter 2.2).

Availability of sufficient data needed to carry out the calculations was a problem also on this farm. The farmer only knew the amount of fodder used in each barn but not the distribution between the different groups in each barn. This generated some problems when using the calculation tool since feeding data for each group is needed. Therefore, in this report we only show the results from the calculation of slurry, since it was easier to estimate the missing data for the dairy cow barn. There were no analyses made of the fodder components so the nutrient content was only known for the concentrate. Swedish table values for nutrient content in the other components in the feed were used. When it came to digestibility, information from the calculation tool manual was used and the dry matter contents in the different feed components were estimated.

Water flows are measured on the farm, but at the time of writing the data was not available. Therefore, the amount of technical water is estimated to match the analyzed value of dry matter content of the slurry.

The production data was also used to make calculations in the Swedish calculation tool Vera. In Figure 6.2.2 we show the differences between i) Vera – standard, ii) Vera – barn balance, iii) the calculation tool developed in Manure Standards and iv) sampling and analyses during spring and summer during the project.

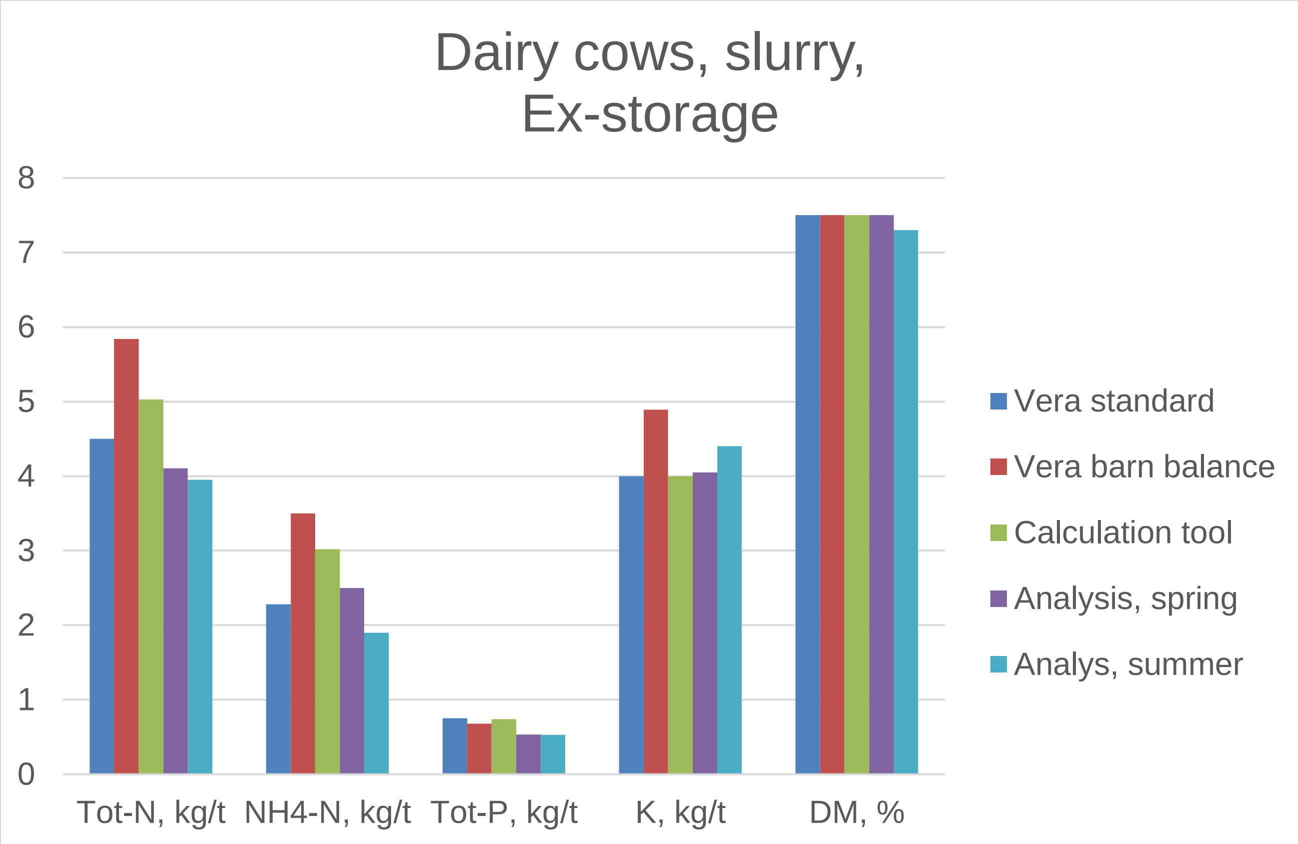

Figure 6.2.2. Results of calculations and manure analysis of dry matter content and concentration of total nitrogen, ammonia nitrogen, phosphorus and potassium in slurry ex-storage from pilot farm SE1. Calculations are made in the Swedish calculation tool Vera and in the calculation tool developed in this project.

Since there are a lot of estimations in the calculation, it is difficult to make proper comparisons with the analyzed values. It is surprising that there is quite a big difference between the calculation tool and Vera barn balance. Since these calculations are based on the same production data and the calculation of the amount of manure is approximately the same in the two tools, the results of nutrients ought to be more similar. When taking a closer look, the differences in nitrogen concentration seem to originate from different emission factors in Vera and the Manure Standards calculation tool. The calculation tool uses higher emission factors both when calculating losses from housing and from storage. Thus, by adjusting the emission factors in the calculation tool with the national Swedish factors might reduce or remove the difference. The reason why analyzed values of nutrient concentration are a bit lower compared to calculated values could also be an overestimation of the nutrient contents in the feed when doing the calculations. The emission factors may also differ to some extent depending on farm-specific conditions.

6.3 Denmark

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Slaughter pigs

Table 6.3.1 shows the values analyzed in the slurry tanks in percent of what was calculated with the Manure Standards calculation tool for the 7 pilot farms with slaughter pigs over a period of approximately one year from spring 2017 to spring 2018.

Table 6.3.1. Comparison of manure data analyzed and calculated as percent of the results analyzed (green) and concentrations (white) on the Danish pilot farms. The lower the percentage, the more deviation there was between the results.

Farmer	Quantity	DM	N	NH4-N	P	K	N	NH4-N	P	K	version	
	t	%	t per year	t per year	t per year	t per year	kg/t	kg/t	kg/t	kg/t		
2	73	78	97	99	78	116	133	136	112	159	5.2	
4	160	37	127	135	79	107	81	85	51	66	5.2	
1	68	30	57	59	34	48	84	87	51	70	5.2	
3	96	47	82	80	66	78	85	83	69	82	5.2	
7	61	30	50	53	15	61	82	88	25	101	5.2	only 15% left
5	81	90	81	71	88	68	99	87	108	83	5.2	
6	78	45	65	72	23	91	83	92	29	117	5.2	
Average	**88**	**51**	**80**	**81**	**55**	**81**	**92**	**94**	**64**	**97**		
std	**34**	**26**	**26**	**28**	**27**	**28**	**24**	**24**	**35**	**40**		

It was expected that tons N, P and K per year should be the same for the calculation tool and analyzed values. However, that was far from being the case. Especially for P the match was very poor since the analysis showed only 15 – 79% of the calculated values (average 55% and standard deviation 27%). This means that on average only about half of the expected (calculated) amount of P was found in the analyzed sample, and even worse, on some farms only even lower proportion of calculated P was found in the slurry samples.

Total N, NH_4-N and K values analyzed were on average around 80% of the calculated values, but also for these nutrients the standards deviation was as high as 26–28% - meaning there was a huge difference between the farms.

There can be a number of reasons for these huge deviations between the farms in analyzed and calculated values, such as the following:

i) Problems related to sampling

The samples were taken with a bottle from the top layers of the slurry tanks after mixing. However, even if all slurry tanks were mixed for at least one hour before sampling, this was probably not enough to get an even distribution of material from top to bottom. In earlier studies by SEGES, it has been shown that DM, P and other non-soluble minerals are very difficult to move away from the bottom layers of the tanks with pig slurry. The tanks had a height of 3.5-5 m and a capacity of 1800-5500 m^3. However, in the present data there seems to be no correlation between the size of the tanks and the low P concentration in the samples taken after mixing.

SEGES has performed several studies on the sedimentation of nutrients in slurry tanks. These studies show that the dry matter and phosphorus content of animal slurry is inhomogeneous distributed, with a high concentration in the top and bottom layer (Figure 6.3.1).

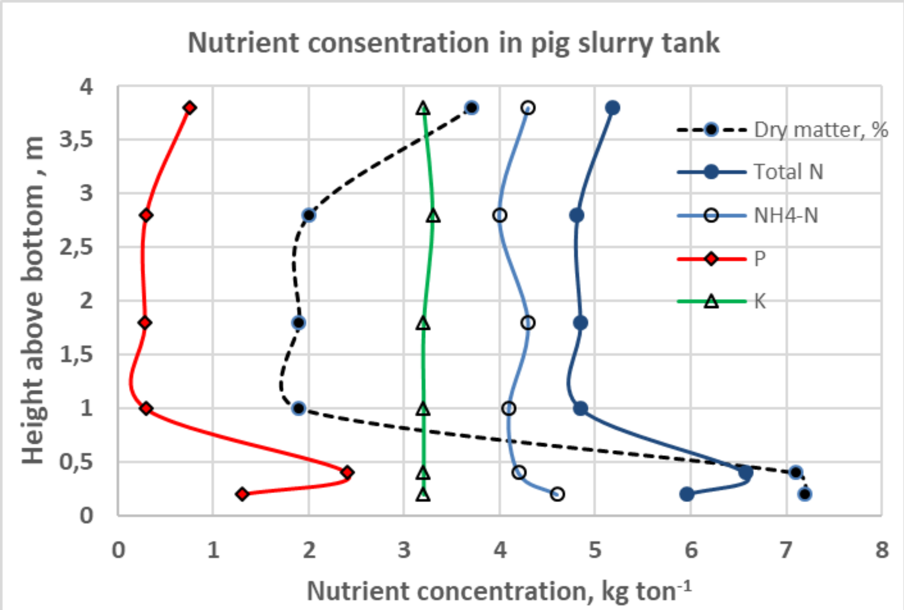

Figure 6.3.1. The measured concentration of nutrients and dry matter in different depths of a slaughter pig slurry tank before mixing. Especially the dry matter and the phosphorous content of the slurry are heterogeneously distributed.

Inadequate mixing before manure sampling will cause incorrect estimation of concentration of, in particular, dry matter and phosphorous concentration. So, even though the slurry concentration in the Danish sampling took place after the slurry tanks had been seemingly thoroughly mixed, it may have been inadequate to ensure an adequate mixing of the slurry phosphorous content before the sampling took place.

ii) Problems related to chemical analyses

In the present work on Danish pilot farms, two samples per manure storage tank at each pilot farm were divided into three identical subsamples. Each of these subsamples was sent to three different accredited analytical laboratories. All three analytical labs are commonly used by Danish farmers for analyses of manure samples.

In general, only minor differences were seen between the analyzed results at the different laboratories. The highest difference was observed for analyses of phosphorous content in slurry samples. However, even here only minor deviations were observed (Figure 6.3.2).

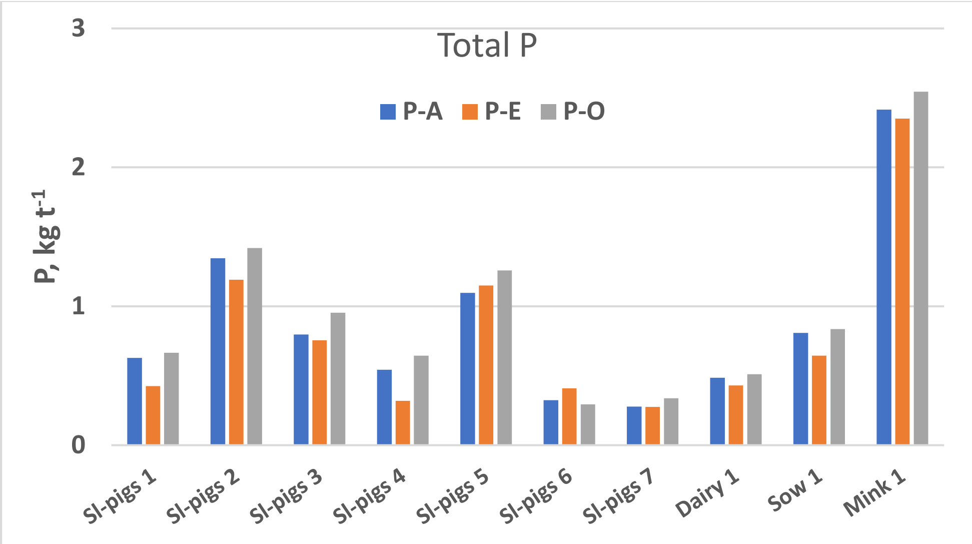

Figure 6.3.2. The analyzed concentration of phosphorous content in identical slurry samples taken at the different pilot farms. The analyses were performed at three different accredited analytic laboratories.

iii) Imprecise information on the amount of slurry produced due to emptying the tanks in the preceding spring. The amount used was based on

a. the amount of slurry on the day of sampling (rather precise measurement made by the same consultant who took samples on all pilot farms)
b. amount of slurry removed since the emptying the preceding spring – not all farmers had a precise logging of this information
c. the date of emptying in the preceding spring – rather precise on all farms
d. the amount left in the tank in the preceding spring – not very precise because the farmer had to give an estimate for this more than a year late (on some farms this may have given an error of at least 10% - equivalent to 40 cm more or less left over in a 4 m deep tank)

Since the amount of slurry cannot be predicted accurately in the calculation tool, the concentrations (kg/t) of N, P and K cannot be predicted accurately either. Therefore, it was rather surprising that the analyzed concentrations of N, P and K were less underestimated than the yearly amount of N, P and K.

Regarding the amount of slurry and DM (%), it was known beforehand that it would not be accurate in the calculation tool, because the amount of water added to the slurry could not be predicted precisely. The amount of water depends on spillage from drinking nipples or troughs in the barn, washing of barns, rain falling into the storage tanks without cover and evaporation of water from the storage tanks without cover.

Dairy cows

Comparisons between analyzed and calculated values for a Danish dairy farm are shown in Table 6.3.2. In cattle slurry, the thickest part with high DM content forms a crust in the top layer during slurry storage. This top layer (natural crust) is easier to mix up in the whole tank than the bottom layer formed in easily settling in pig slurry. Despite this fact, also for cattle slurry the total amount of

P analyzed was only 64% of the calculated value, and P concentration analyzed was only 69% of the calculated value. For the amount of N, NH_4-N and K the measured amount was only 67–77% of the amount calculated, which is lower than for pig slurry. The measured concentrations of N, NH_4-N and K were only 73–81% of the amount calculated, which was also lower than for pig slurry.

Table 6.3.2. Manure and nutrient production in the slurry from a Danish dairy farm. In the bottom line values are shown as values analyzed in slurry tanks in percent of values from calculation tool.

CATTLE SLURRY

Cattle slurry	Quantity	DM	N	NH_4-N	P	K	N	NH_4-N	P	K
	t	%	t				kg/t			
Slurry - calc. Tool	8066	9.3	41.7	25.0	5.8	23.9	5.2	3.1	0.7	3.0
Measured in tank	7713	6.2	29.1	18.2	3.7	18.4	3.8	2.4	0.5	2.4
Mesured/calculated	96	67	70	73	64	77	73	77	69	81

Corrections of values from Calculation Tool in practice

For the use of the calculation tool in practice, it may be beneficial to adjust the calculation of manure amount with national data on measured manure quantity. This may have corrected the calculated N, P and K concentrations in the Danish case.

An example of such measurement could be the following:

Make a log book to follow the slurry production by measuring the height of slurry in the tank. From the height and the diameter of the tank the volume of slurry is calculated. Before removing slurry from the tank, the slurry production since the last emptying is calculated. This value is compared to the expected value from the calculation tool. If for instance the actual production has been 2500 m^3, whereas it was expected to be 2000 m^3 the calculated concentration of N, P and K from the tool should be multiplied by 0.8 (equivalent to 2.000/2.500) to get the N, P and K concentration in the slurry, because it has been diluted with more water than expected.

This method is used by Danish consultants who make the fertilizer plans that Danish farmers have to send to the authorities every year. They use the mass balance calculation of the Danish Normative values which are every year calculated in the same manner by the Aarhus University based on data from practice (average feed intake, feed composition and productivity data for all categories of farm animals). The normative values are multiplied with the number of animals of each category at the farm, and the normative values for the actual housing and storage technologies are used in the same manner as in the calculation tool from this project.

In Denmark, it is mandatory to use these normative values, which means it is not allowed to make fertilizer plans based on manure analysis. The reasoning behind this is that the authorities do not take the risk that some farmers might deliberately or by chance analyze samples with a lower N and P content than is actually the real content, because there is an upper limit for the use of N and P to the crops. The analyses in table 6.3.1 strongly indicate that even when it is attempted to take representative samples before applying the slurry, the content can be far off the calculated value which is seen more reliable in Denmark. This was especially prominent in the slaughter pig slurry where most of the DM and therefore most of P is in the bottom section of the tanks. However, it is an even bigger problem that P will build up in the bottom of the slurry tank and the fields will lack this P.

Potential errors related to use of the Calculation Tool values

Above, the problems about analyzing the concentration and annual production of nutrients in manure have been elucidated. Obviously, there are also drawbacks when calculating these values with the calculation tool based on information on nutrient intake, nutrient retention in the animals, losses of N from barn and storage, and input with bedding material.

In general, the retention in animals is rather precise when the production of milk, meat and eggs are known, because the contents of N, P and K per kg of the products are rather constant. N output in milk is calculated very accurately from the amount of milk sold and the protein content in the milk.

The amount of feed and the content of N, P and K in feed can have some uncertainty. However, the uncertainty is closely related to how the amount of feed is registered and which data are available for the feed composition.

For the 7 slaughter pig pilot farms, the amount of feed used during the year of slurry production was known very exactly, because it was based on registration of feed purchased and own feed used during the year. The concentration of N, P and K were values declared by the feed companies, and table values for home grown grains. This information is rather accurate.

For the cattle farm, feed intake was based on feed intake measured only during a few days in the one year period. Therefore, this value could be some %-units off the real value. The concentration of the nutrients was based on analyses of the homegrown silage used on the measuring days, and table values for the dry ingredients in the feed. Also these values could be some %-units off the real value.

In Table 6.3.3 a hypothetical example has been made to show how big the error in the values from the calculation tool would be in a ‘worst case scenario’. In this scenario the total effect is calculated if the amount of feed and the content of N, P and K in feed were overestimated by 10%, if N loss in barn was underestimated by 10% and N loss from storage was underestimated by 7% - all at the same time. If all the errors by accident ‘pointed in the same direction’, theoretically, the production of N, NH_4-N, P and K in manure would be overestimated by 22-37%. The concentration of these nutrients would be overestimated by 16-32%.

Table 6.3.3. Theoretical example of the reduction in amounts and concentrations of nutrients calculated by the calculation tool in a 'worst case scenario' where the amount of feed and the content of N, P and K in feed were overestimated by 10%, N loss in barn was underestimated by 10% and N loss from storage was underestimated by 7% - all at the same time.

VARIATIONS IN MASS BALANCE CALCULATIONS. MANURE EX STORAGE

Ring channel with flushing. 16% loss of N ex anim.
Storage with natural crust. 3.4% N loss of TAN (DK value)

		10% less feed, N, P and K **10% ekstra loss in barn** **7% ekstra loss in storage** With Calc. 10.515 EKM	pct reduction	actual deviation dairy farm 11.706 EKM
Quantity	t/year	3574	-7	
DM	%	7.56	-2	
N	t/year	8.84	-37	-30
NH4-N	t/year	5.92	-32	-27
P	t/year	1.62	-27	-36
K	t/year	8.20	-22	-23
N	kg/t	2.47	-32	
NH4-N	kg/t	1.66	-27	
P	kg/t	0.45	-22	
K	kg/t	2.29	-16	

The actual deviation is probably NOT because there was an error in ALL inputs for the MASS BLANCE CALC. Sampling problems and maybe errors in amount of slurry is MORE likely

In the example with this dairy farm, the total of these errors could in theory account for the actual deviation found for N, NH_4-N and K between the analyzed and calculated results. For P, these deviations could in theory account for 27%, whereas the actual deviation noted was 36%.

Even if the total effect of these potential errors could theoretically account for deviations of the same order as found for the dairy farm, it is unlikely that so many errors changing the amount of nutrients in the same direction should occur at the same time. Therefore, we conclude that errors in the input data for the mass balance calculation are probably not the major reason for the deviation between the analyzed and calculated values, meaning that also for cattle slurry representative sampling can be a challenge.

6.4 Germany

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The first step to use the farm level calculation tool of manure quantity and quality in Germany was to adjust the model parameters to German conditions. Most of the national data fed into the tool were collected from Horlacher et al. (2014), DLG (2014) and Thünen Report 57 (2018).

In Table 6.4.1 and 6.4.2 different NH_3-N and N_2O-N loss coefficients are listed to show the differences between the originally used Danish default parameters and the German parameters in the tool. In Tables 6.4.3 and 6.4.4 the nutrient contents of different bedding materials and animal products used in the calculation are shown. In Table 6.5.5 utilized dry matter contents of faeces and urine depending on animal category are listed.

Table 6.4.1. Comparison of Danish (default in the calculation tool) and German coefficients for NH_3-N losses at ex housing level depending on keeping technology.

Animal category	Keeping technology	NH_3-N loss [%] Ex housing		Farms
		DE	DK	
Dairy cows; heifers; bulls	Loose housing – slurry	19.7	12.0	DE1+DE3
Calves	Loose housing – solid manure	19.7	-	DE1
Fattening pigs	Drained and slatted floor - slurry	30.0	20.9	DE4+DE5

Table 6.4.2. Comparison of Danish (default in the calculation tool) and German coefficients for NH_3-N and N_2O-N losses at ex storage level depending on storage technology.

Storage technology	NH_3-N loss [%] Ex storage		N_2O-N loss [%] Ex storage		Pilot Farm[1]
	DE	DK	DE	DK	
Lagoon, slurry natural crust	4.5	-	0.5	0.1	Farm DE3 –Dairy cows
Storage, slurry natural crust	4.5	-	0.5	0.1	Farm DE3 – Bulls, Farm DE1 – Mix slurry, Farm DE5 – Fatteners/biogas
Storage, slurry floating cover	3.0	-	0.5	0.1	Farm DE4 – Fatteners
Heap, natural crust	60	-	1.3	2.0	Farm DE1 – Calves

[1]Emissions factors for manure storage are only used in the calculation for farm DE4 because manure samples in WP2 were only taken at ex storage level on farm DE4. For all others farms (DE1, DE3 and DE5), samples were taken at ex housing level and thus, emission factors for manure storage were not needed for the comparison of measured and calculated values.

Table 6.4.3. Nutrient contents of different bedding material in the German manure calculations.

Type	DM [%]	N [g/kg DM]	P [g/kg DM]	K [g/kg DM]	Source
Straw DLG (feed)	86	7.8	1.4	13.0	DLG, Vol. 199
Straw KTBL (bedding)	86	6.7	1.7	16.2	KTBL, Vol. 502

Table 6.4.4. Nutrient contents of different animal products used in the German manure calculations.

Type	N [g/kg]	P [g/kg]	K [g/kg]	Source
Dairy Cow – Gain	25.0	6.0	1.9	DLG, Vol. 199
Bulls – Gain	27.0	6.5	1.9	DLG, Vol. 199
Fattening pigs - Gain	25.6	5.1	2.0	DLG, Vol. 199
Milk	5.3	1.0	1.5	DLG, Vol. 199

Table 6.5.5. Dry matter content of faeces and urine depending on animal category used in the German manure calculations.

Animal category	Faeces [%]	Urine [%]	Source
Dairy cows	20	2	KTBL, Vol. 502
Bulls	20	2	KTBL, Vol. 502
Fattening pigs	25	2	KTBL, Vol. 502

Farm DE1

The feeding data were not exactly known. Therefore, some assumptions were made suing typical German data (Table 6.4.6). Fodder analyses typically do not include values for the content of potassium and thus default values based on KTBL are used. The amount of grassland was estimated based on average data given in the calculation tool manual but it was acknowledged that it has high uncertainty. For calves, the amount of milk substitutes (derived from DLG, 199) is assumed for the first 5 weeks. Afterwards, the farm specific calculation of feed ration is utilized.

Table 6.4.6. Feeding data and sources for related nutrient contents for pilot farm DE1.

Feeds	Source
Grass silage, cut 1	Delivery note of farm (average values for 2017 used) -> used for heifers
Grass silage, cut 2	Farm specific calculation of feed ration
Mineral feed	Farm specific calculation of feed ration
Calves starter	Delivery note of farm
Milk substitutes	Default values from KTBL
Grassland	KTBL (dataset sent by Horlacher)

In Tables 6.47 and 6.4.8, production details of farm DE1 are shown.

Table 6.4.7. Production details for heifers of pilot farm DE1.

Feature	Unit	Input Data	Source
Animals	Number	52	Survey
Calving age	months	27	Survey
Starting weight	kg	150	Default value
Final weight	kg	650	Default value
Grazing	Days per year	180	Survey
Duration	Hours per day	24	Survey
Keeping technology		Cubicles with solid floor	Survey -> selection based on tool option
Bedding	kg/animal and day	0	Survey
Technological water	t/animal and year	0.365 (2 l/animal and day for 365/2 days)	KTBL, Vol. 502, Table 2.1-1
Storage technology		Storage, natural crust	Survey -> selection based on tool option

Table 6.4.8. Production details for calves of pilot farm DE1.

Feature	Unit	Input data	Source
Animals	Number	21	Survey
Starting weight	kg	45	Default value
Final weight	kg	150	Default value
Keeping technology fitting		Solid manure (loose housing)	Survey -> selection based on tool option
Bedding	kg/animal and day	2.14	Survey
Technological water	t/animal and year	0	Survey
Storage technology fitting		Heap, natural crust	Survey -> selection based on tool option

Digestibility of dry matter (DM) was calculated based on KTBL data. Feed ratio properties depending on animal category are listed in Table 6.4.9. Male and female calves are calculated together due to the same feed ratio. The amount of grassland was estimated based on the tool manual. A comment for the farm is that the amount for calves relatively high.

Table 6.4.9. Feed ratio properties depending on animal category for pilot farm DE1.

Animal category	DM [kg]	DM digestibility [%]	CP [g/kg DM]	P [g/kg DM]	K [g/kg DM]
Heifers	1.651	71.1	173.2	3.7	27.2
Calves	1.351	73.2	151.8	4.3	17.8

The results of the calculation tool with Danish (DK) and German (DE) coefficients in comparison to the analyses of different laboratories (1,2,3) and sampling dates (spring, summer, autumn) are shown in Table 6.4.10-6.4.11 and Figures 6.4.1-6.4.2. Most parameters are significantly higher with the calculation tool. Only DM and P values were found in the expected range. The cause for the higher calculated results is probably the inaccuracy of feeding data, unknown amount of technological water and bedding material as well as unknown water evaporation and DM losses during storage of manure. On the other hand, large variabilities of all analyzed parameters can be seen within one year, which cannot be calculated with the tool.

Table 6.4.10. Comparison of analysis results and calculated values for heifer slurry ex housing of pilot farm DE1.

	DM [%]	N [kg/t]	NH_4-N [kg/t]	P [kg/t]	K [kg/t]
Analyzed spring					
1	9.80	4.02	1.28	0.85	4.72
2	9.67	3.10	1.20	0.98	4.92
3	9.94	3.66	0.78	0.84	4.74
Analyzed summer					
1	5.70	1.98	0.746	0.48	2.48
2	5.67	1.90	0.70	0.48	2.20
3	5.79	2.03	0.64	0.47	2.51
Analyzed autumn					
1	8.30	2.29	0.77	0.55	2.79
2	8.35	2.10	0.80	0.54	2.71
3	8.57	2.87	0.89	0.57	2.98
Calculated values					
DK	12.9	7.60	4.60	1.00	10.3
DE	11.1	7.00	4.20	0.90	9.40

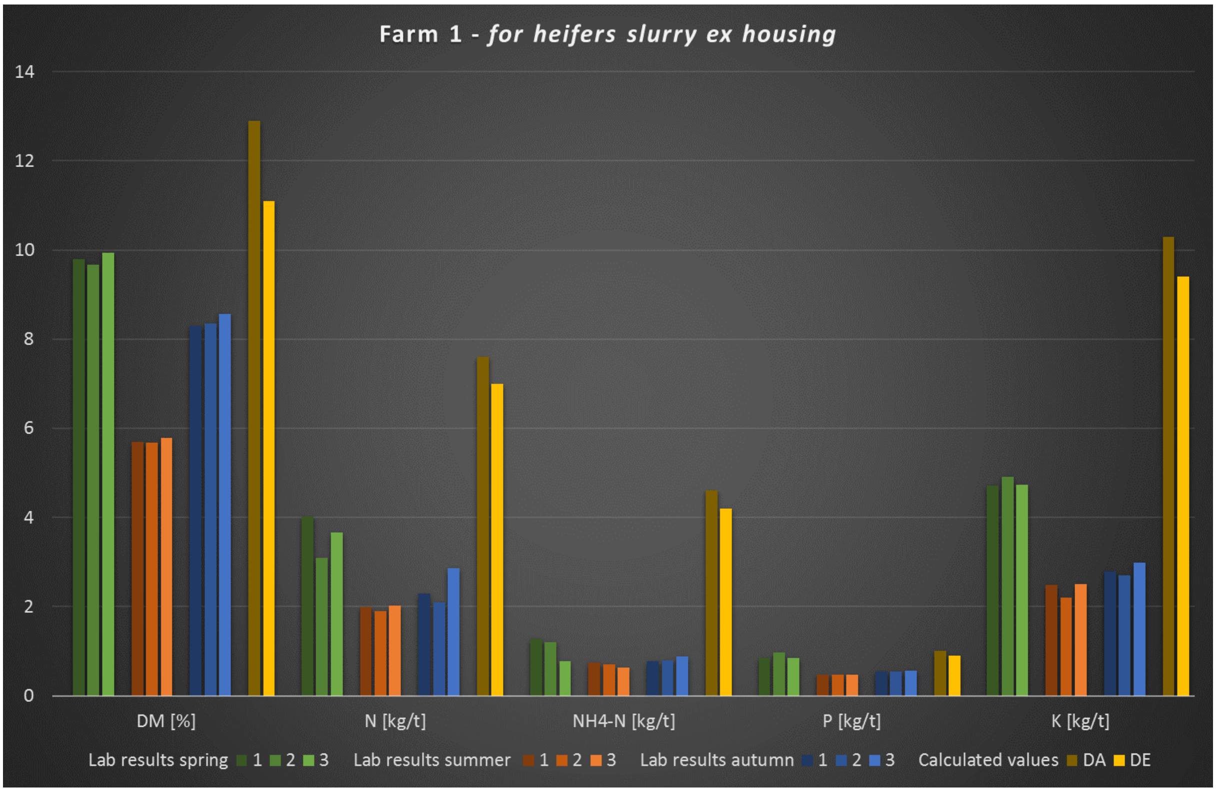

Figure 6.4.1. Comparison of analysis results and calculated values (DK – Danish values; DE – German values) for heifer slurry ex housing of pilot farm DE1.

Table 6.4.11. Comparison of analysis results and calculated values for calves solid ex housing of pilot farm DE1.

	DM [%]	N [kg/t]	NH4-N [kg/t]	P [kg/t]	K [kg/t]
Analyzed summer					
1	17.80	3.08	0.40	0.72	3.19
2	18.00	3.50	0.30	0.83	3.49
3	17.05	2.33	0.10	0.71	3.50
Analyzed autumn					
1	19.70	3.40	0.28	0.77	7.08
2	18.40	3.80	0.20	0.70	6.14
3	18.36	4.11	0.10	0.64	6.79
Calculated values					
DK	19.00	6.90	1.70	1.20	7.30
DE	17.60	6.40	1.60	1.20	7.20

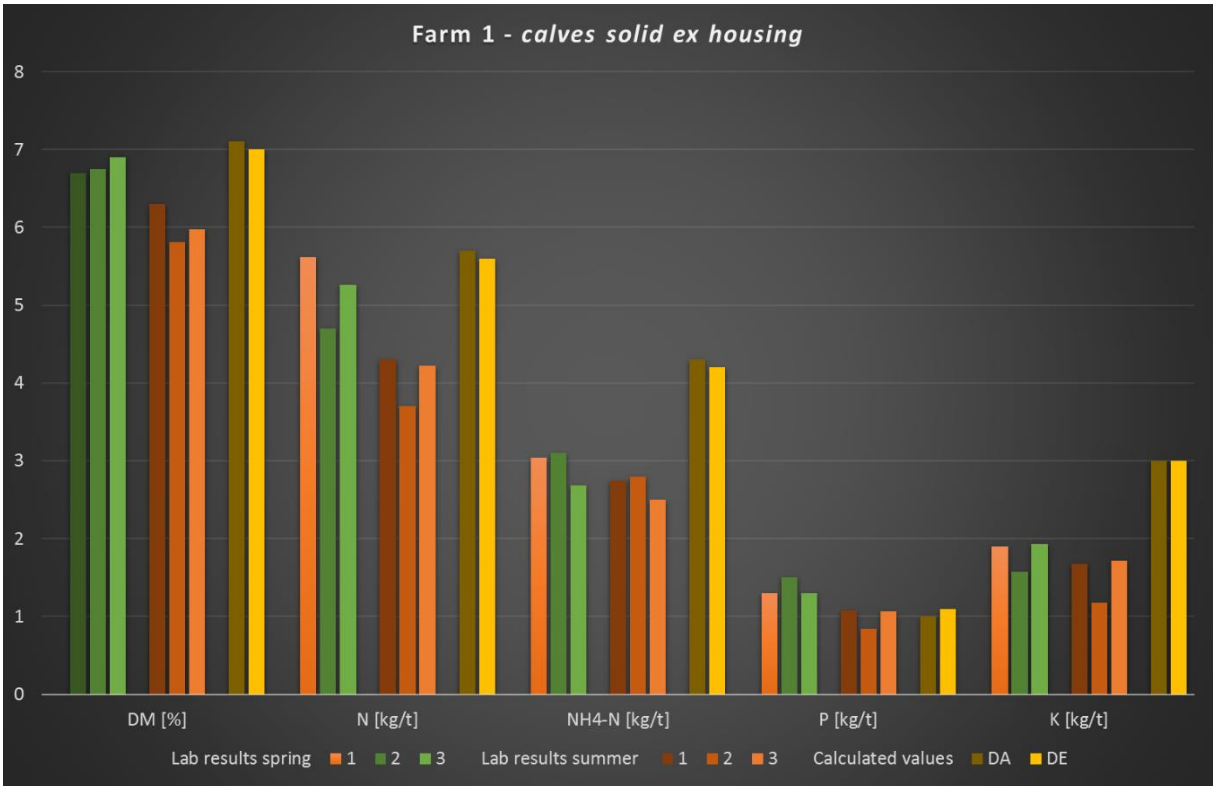

Figure 6.4.2. Comparison of analysis results and calculated values (DE – Danish values; DE – German values) for calves solid ex housing of pilot farm DE1.

Farm DE3

Table 6.4.12 shows the feeding data of farm DE3. For dairy cows, grazing is not considered and the feed ration is calculated for 365 days. In consequence, changes of these assumptions would change the results.

Table 6.4.12. Feeding data and sources for related nutrient contents for pilot farm DE3.

Feeds	Source
Rye-corn-mix	Delivery note of farm
Rapeseed coarse meal	KTBL
Mineral feed	KTBL
Straw	KTBL
Grassilage	KTBL
Corn silage	KTBL
grazing	Not used at the moment

In Tables 6.4.13 and 6.4.14 production details of farm DE3 are shown. For dairy cows, technological water is divided into housing (cleaning water for milk lines + KTBL = 14.6 t/animal and year) and storage (outdoor area = 2.5 t/animal and year).

Table 6.4.13. Production details for dairy cows of pilot farm DE3.

Feature	Unit	Input Data WP3	Source
Animals	Number	100	Survey
Milk production	kg/cow	9.565	Survey
Protein content	%	3.38	Survey
Fat content	%	4.05	Survey
Starting weight	kg	600	Default value
Final weight	kg	640	Default value
Grazing	Days per year	120	Survey
Duration	Hours per day	6	Survey
Keeping technology		Cubicles with slatted floor (manure channel, continuous removal)	Survey -> selection based on tool option
Bedding	kg/animal and day	0.3	Survey
Technological water	t/animal and year	17.1	Survey + KTBL, Vol. 502, Table 2.1-1
Storage technology		Lagoon, natural crust	Survey -> selection based on tool option

Table 6.4.14. Production details for bulls of pilot farm DE3.

Feature	Unit	Input data WP3	Source
Animals	Number	50	Survey
Starting weight	kg	200-250	Survey
Final weight	kg	720	Survey
Starting age	months	8	Survey
Final age	months	22	Survey
Keeping technology		Cubicles with slatted floor (manure channel, continuous removal)	Survey -> selection based on tool option
Bedding	kg/animal and day	0	Survey
Technological water	t/animal and year	0.5475	Survey + KTBL, Vol. 502, Table 2.1-1
Storage technology		Storage, natural crust	Survey -> selection based on tool option

The calculated feed ratio properties depending on animal category for pilot farm DE3 are presented in Table 6.4.15.

Table 6.4.15. Feed ratio properties depending on animal category for pilot farm DE3.

Animal category	DM [kg]	DM digestibility [%]	CP [g/kg DM]	P [g/kg DM]	K [g/kg DM]
Cow	8.453	73.1	162.4	3.97	16.6
Bulls	4.800	69.9	115.9	2.80	17.6

When comparing the calculated and measured values of Table 6.4.16 and 6.4.17 (see also Figure 6.4.3 and 6.4.4), the calculations indicate also an overestimation but the results are more or less in a similar range. One reason for this can be that rain water addition for dairy cow slurry could be higher and it is not included so far at ex housing level.

Table 6.4.16 Comparison of analysis results and calculated values for dairy cow slurry ex housing of pilot farm DE3.

	DM [%]	N [kg/t]	NH4-N [kg/t]	P [kg/t]	K [kg/t]
Analyzed spring					
1	5.00	3.04	1.38	0.51	2.18
2	5.21	2.50	1.40	0.57	1.85
3	5.28	3.46	1.09	0.52	2.26
Analyzed summer					
1	6.80	2.63	1.24	0.58	2.65
2	6.24	2.60	1.10	0.61	2.21
3	6.40	2.69	0.96	0.59	2.71
Analyzed autumn					
1	4.70	2.28	1.26	0.41	1.97
2	4.41	2.30	1.30	0.39	1.65
3	4.51	3.47	1.40	0.42	2.16
Calculated values					
DK	7.70	3.80	2.30	0.60	3.00
DE	8.60	4.60	2.70	0.70	3.80

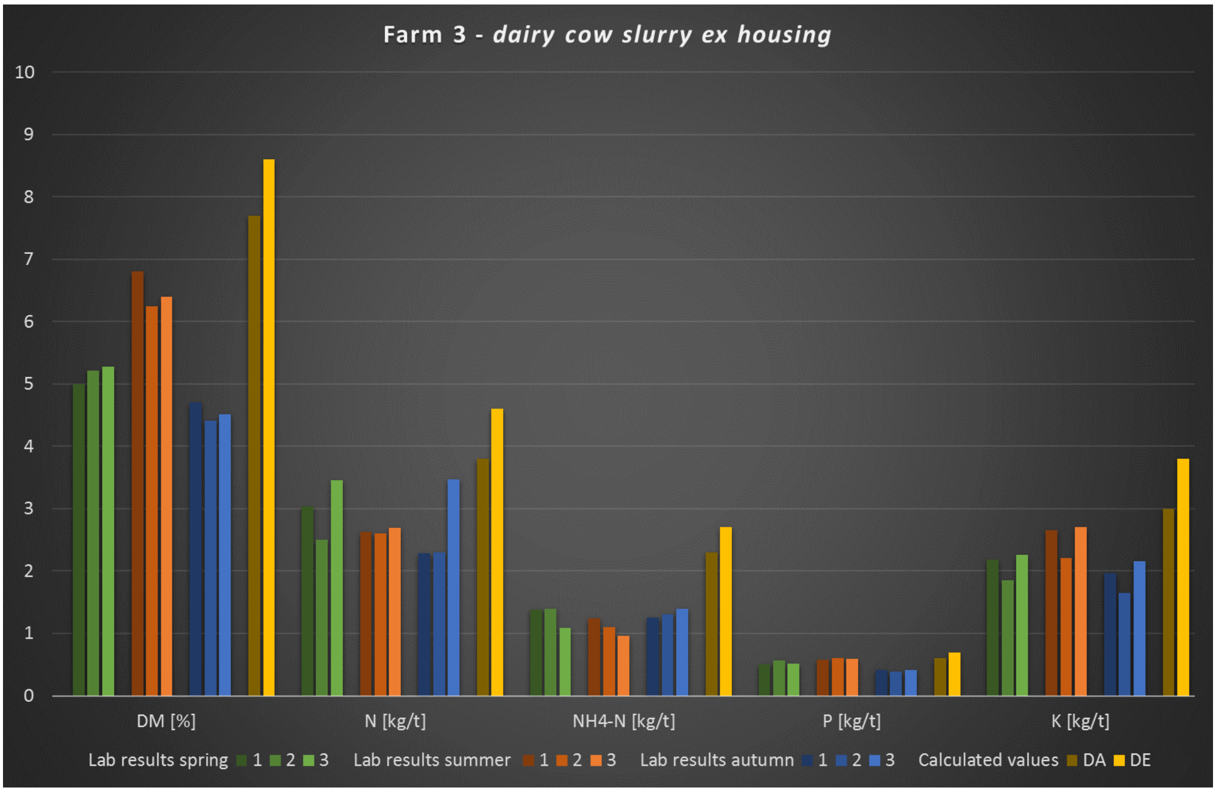

Figure 6.4.3. Comparison of analysis results and calculated values (DE – Danish values; DE – German values) for dairy cow slurry ex housing of pilot farm DE3.

Table 6.4.17. Comparison of analysis results and calculated values for bulls slurry ex housing of pilot farm DE3.

	DM [%]	N [kg/t]	NH4-N [kg/t]	P [kg/t]	K [kg/t]
Analyzed summer					
1	9.40	4.70	2.37	0.90	5.19
2	9.18	4.50	2.40	0.93	4.91
3	9.38	4.58	2.00	0.90	5.55
Analyzed autumn					
1	6.80	3.03	1.50	0.69	3.88
2	6.88	3.70	1.50	0.64	3.33
3	6.72	3.98	1.51	0.65	3.97
Calculated values					
DK	14.40	6.50	3.90	1.00	7.40
DE	13.40	6.10	3.60	1.00	7.40

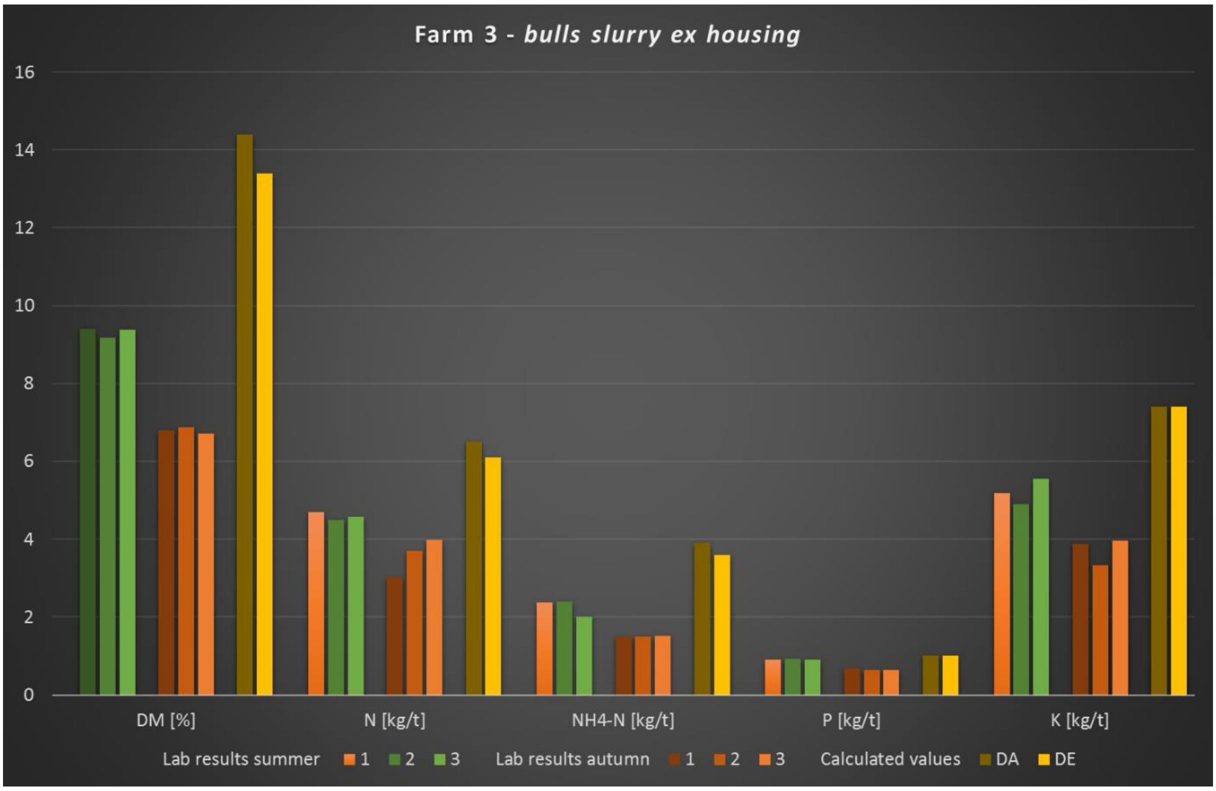

Figure 6.4.4. Comparison of analysis results and calculated values (DE – Danish values; DE – German values) for bulls slurry ex housing of pilot farm DE3.

Farm DE4

Table 6.4.18 lists the feeding data of farm DE4. All data were delivered from the farmer except K, which is taken from KTBL. It is assumed that share of pre-fattening feed is 30%.

Table 6.4.18. Feeding data and sources for related nutrient contents for pilot farm DE4.

Feeds	Source
Pre-fattening	Delivery note from farm
fattening	Delivery note from farm

In Table 6.4.19 production details of farm DE4 are shown. For the final weight of pigs on sale, a mean value was calculated. We assumed a water evaporation of 50% and a DM loss of 2%. Precipitation for 2017 was suitable for spring analyses (for summer and autumn, lower precipitation was assumed).

Table 6.4.19. Production details for fattening pigs of pilot farm DE4.

Feature	Unit	Input data WP3	Source
Animals	Produced per year	3.309	Survey
Starting weight	kg	28.9	Survey
Final weight	kg	124.9	Survey
Rearing period	days	103	Survey
Keeping technology		Drained and slatted floor (33/67)	Survey -> selection based on tool option
Bedding	kg/animal and day	0	Survey
Technological water	t/animal and year	0.1	Survey + KTBL, Vol. 502, Table 2.1-1
Storage technology		Storage, floating cover	Survey -> selection based on tool option
Storage – open surface area	m^2	314	Estimated based on google maps
Precipitation in 2017	mm	1.094	Nearest weather station

The calculated feed ratio properties depending on animal category for pilot farm DE4 are given in Table 6.4.20.

Table 6.4.20. Feed ratio properties depending on animal category for pilot farm DE4.

Animal category	Amount [kg]	DM [%]	DM [kg]	DM digestibility [%]	CP [g/kg DM]	P [g/kg DM]	K [g/kg DM]
Fattening pigs	255.4	88	224.8	82.4	168.0	4.8	8.0

Compared to other pilot farms, data quality as well as accuracy of calculated values in comparison to measured values for farm DE4 is really good (see Table 21 and Fig. 5).

Table 6.4.21. Comparison of analysis results and calculated values for fattening pig slurry ex storage of pilot farm DE4.

	DM [%]	N [kg/t]	NH4-N [kg/t]	P [kg/t]	K [kg/t]
Analyzed spring					
1	4.50	5.51	3.95	1.23	2.87
2	4.50	4.70	3.50	1.34	2.07
3	4.59	5.75	3.30	1.25	2.84
Analyzed summer					
1	7.20	5.36	4.24	1.64	2.94
2	6.64	5.30	4.20	1.33	2.47
3	6.28	6.04	3.71	1.54	3.16
Analyzed autumn					
1	7.70	5.47	4.43	1.66	3.21
2	6.34	5.80	4.30	1.37	2.37
3	6.84	6.88	4.79	1.81	3.20
Calculated values					
DK 2017	6.50	4.36	3.27	0.88	2.31
DE 2017	6.40	4.21	3.15	0.92	2.32

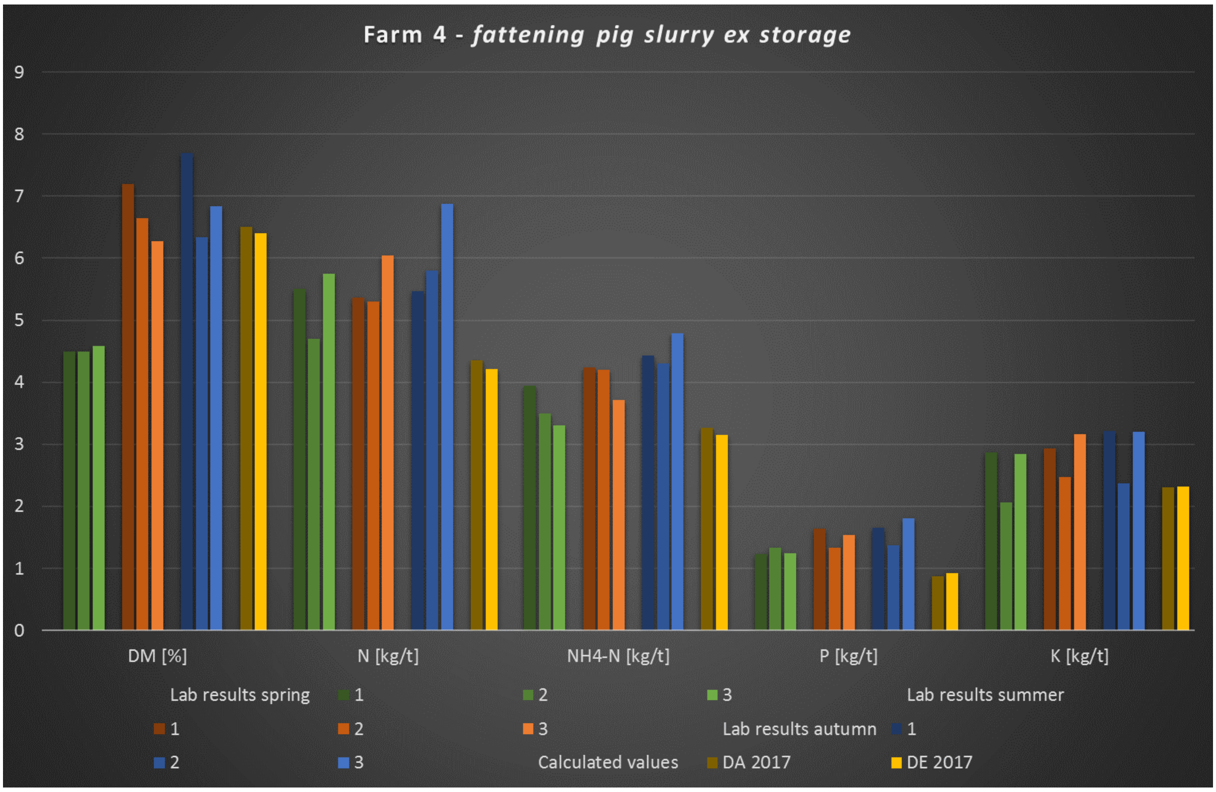

Figure 6.4.5. Comparison of analysis results and calculated values (DK – Danish values; DE – German values) for fattening pig slurry ex storage of pilot farm DE4.

Farm 5

Table 6.4.22 lists the feeding data of farm DE5. All data were delivered from the farmer except K, which is taken from KTBL. DM content values were recalculated to 88% DM. It was unclear, if nutrient contents are based on fresh or dry matter.

Table 6.4.22. Feeding data and sources for related nutrient contents for pilot farm DE5.

Feeds	Source
Pre-fattening	Delivery note from farm
Mid fattening	Delivery note from farm
End fattening	Delivery note from farm

In Table 6.4.23 production details of farm DE3 are shown. Cleaning water value is taken from farm DE3 (0.3 l/animal and day) and drinking water comes from KTBL. We assumed 10% pre-, 30% mid- and 60% end-fattening.

Table 6.4.23. Production details for fattening pigs of pilot farm DE5.

Feature	Unit	Input data	Source
Animals	Produced per year	9.500	Survey
Starting weight	kg	27	Survey
Final weight	kg	120	Survey
Rearing period	days	112	Survey
Keeping technology		Drained and slatted floor (33/67)	Survey -> selection based on tool option
Bedding	kg/animal and day	0	Survey
Technological water	t/animal and year	0.09	Estimated
Storage technology		Storage, natural crust -> then biogas plant	Survey -> not used in tool (ex housing)
Storage – volume	m^3	150	Survey (pumping pit)

The calculated feed ratio properties depending on animal category for pilot farm DE5 are given in Table 6.4.24.

Table 6.4.24. Feed ratio properties depending on animal category for pilot farm DE5.

Animal category	Amount [kg]	DM [%]	DM [kg]	DM digestibility [%]	CP [g/kg DM]	P [g/kg DM]	K [g/kg DM]
Fattening pigs	292.3	257.2	88	85.7	157.4	4.2	7.7

The calculated results of farm DE5 partly were in line with the dataset of measured values from different laboratories (See Table 6.4.25 and Figure 6.4.6).

Table 6.4.25. Comparison of analysis results and calculated values for fattening pig slurry ex housing of pilot farm DE5.

	DM [%]	N [kg/t]	NH4-N [kg/t]	P [kg/t]	K [kg/t]
Analyzed spring					
1	6.70	5.62	3.04	1.30	1.90
2	6.75	4.70	3.10	1.50	1.57
3	6.90	5.26	2.68	1.30	1.93
Analyzed summer					
1	6.30	4.30	2.75	1.08	1.68
2	5.81	3.70	2.80	0.84	1.18
3	5.97	4.22	2.50	1.07	1.72
Analyzed autumn					
1	6.40	4.87	3.31	0.86	2.08
2	5.93	4.70	3.40	0.73	1.48
3	5.82	5.29	3.47	0.87	2.18
Calculated values					
DK	7.10	5.70	4.30	1.00	3.00
DE	7.00	5.60	4.20	1.10	3.00

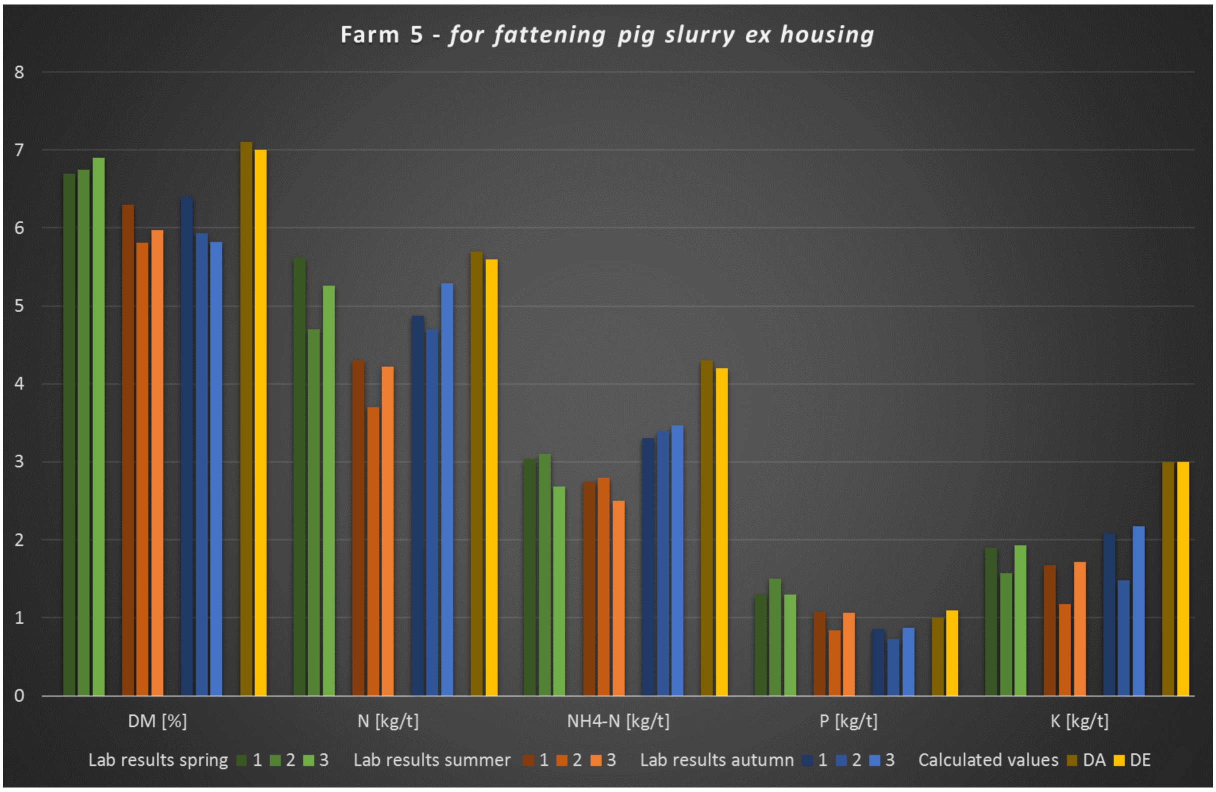

Figure 6.4.6. Comparison of analysis results and calculated values (DK – Danish values; DE – German values) for fattening pig slurry ex housing of pilot farm DE5

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6.5 Poland

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Farm PL7

The farm with dairy cattle is situated in the Southern Mazovia, Central-Eastern part of Poland and in 2018 had 60 dairy cows, 40 heifers and 20 calves, 120 animals altogether. The dairy cows and young animals were kept in the new tie stall barn, with shallow bedding and a concrete floor, cleaned daily. The solid manure and urine were separately collected. The feeding system used in the farm is TMR but with regard to a lack of some data concerning feeding in all animal categories in the calculation tool, AFC feeding system was selected. The missing data included data on the energy status of the cows. TMR feeding is different in summer and winter. During the winter period, the cows received TMR composed of 50% corn silage, 34% grass and lucerne silage, 10% brewers grain, 8% cereals and proteins, and minerals. During the summer period, the cows received TMR composed of 25% corn silage, 17% grass and lucerne silage, 33% grazing grass, 7% brewers grain, 8% cereals and proteins, and minerals. The concentrated feed is prepared by a service company having the relevant equipment, based on the farms' own cereal. Complimentary mineral mixtures are purchased from external sources.

The feeding data were developed and submitted by a qualified employee (zootechnician) working on a farm; the questionnaire was nearly complete, while some missing data were replenished during a telephone conversation with a responsible person. Some information about individual parameters of feeds was provided by responsible employees on the farm, while the missing data were completed based on data given in tables. Summing up, completing the data related to feed composition was the most time-consuming because some of them are not commonly used in the Polish animal feeding systems. The data pertaining to animal keeping (bedding quantity, manure management and technological water) and climate conditions (nearby weather station of the Institute of Soil Science and Plant Cultivation) were fully available. The data were introduced to the calculation tool by the employees of the Institute of Soil Science and Plant Cultivation who participated in the WP3 stage of the Manure Standard project. Once the input data had been completed, they could be entered into the calculation tool without any problems. Default values related to technology from the calculation tool were used for the calculations. The use of specific domestic data was planned for further stages of the calculation tool's validation.

The results for total nitrogen content obtained from the calculation tool for the dairy farm were similar (5% higher) to the Polish table values (Figure 6.5.1.). Small differences between the data obtained from the calculation tool were also observed for the dry matter content – analysis of manure sampled in summer (-3%), total nitrogen – in autumn (12%), and potassium – in summer (3%) and autumn (-2%). Phosphorus content in the analyzed manure was much higher than the values obtained in the calculation tool (37-47%). Similarly, high differences were observed for the content of dry matter (20%), nitrogen (37%) and potassium (41%) in the samples collected in spring.

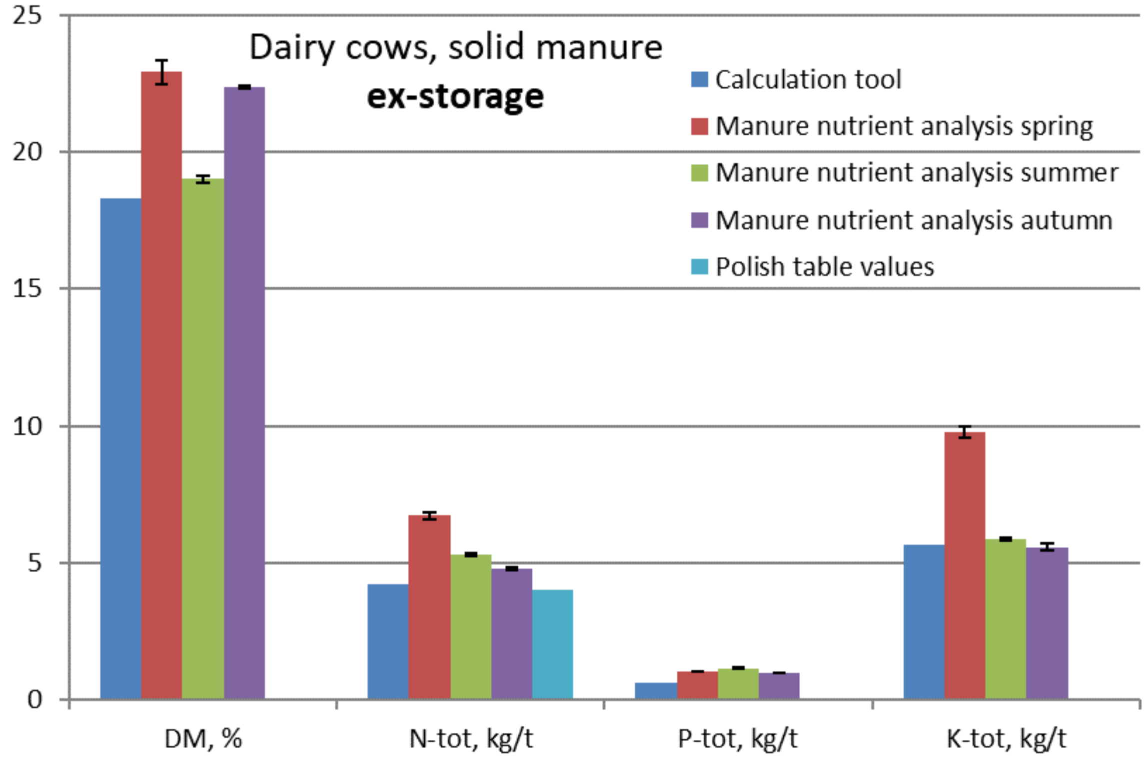

Figure 6.5.1. Results of solid manure ex storage from the calculation tool and from the analyzed samples in the dairy cows of the Polish dairy farm (farm PL7). The standard deviation bars for the analyzed samples represent the deviation between two laboratories analyzing the same samples taken on the farm in spring, summer and autumn of 2018.

Summing up for PL7 cattle farm, the calculation tool results can be regarded as correct. The availability of highly accurate input data concerning animal feeding was the key factor in this case. Such data are available in farms where the level of animal production is very high, and which cooperate with scientific institutes. The competence level of the persons responsible for filling the questionnaires was of pivotal significance because they were able to trace and retrieve the missing data.

Entering precise domestic data on production technology, emissions, bedding chemical composition and nutrient content in animal products could be another aspect which should contribute to a higher accuracy of the calculation tool. Still, the calculation tool’s complexity does not allow its full implementation in individual farms because it is too complicated for a farmer to use and requires a lot of data which are usually not available for a farmer and not useful in their everyday work on the farm. In its current form, the calculation tool requires a farmer's collaboration with a professional advisor. The method of entering the data on animal feeding should also be more flexible and take into account the deviations from standard feeding technologies and the presence of different animal groups in one farm. If the calculation tool was supposed to be used by farmers, it could be a better idea to use its simplified form.

Farm PL1

This farm produces fattening pigs. The farm is situated in the Wielkopolska Region – Central Western part of Poland. Weaning pigs weighing 30 kg are purchased from specialized breeding and fattened to 115-120 kg. The fattening cycle lasts 95 days plus 5 days between batches, it means 3.5 cycle a year, which after deducting losses gives 1,400 units sold. A farmer runs a business and it would be difficult for him to use full turnover or piglet rearing. Both weaned and fattening pigs were kept in shallow litter barn with pens. 10 to 30 animals were placed in pens the size of which differs from 16 to 25 square meters. Solid manure was removed out once a day. Fatteners were kept on shallow litter too in big pens 20-40 pigs, and the solid manure was removed once a day too. Between littering, surfaces were flushed to the handheld tank. Straw consumption was 1500 big bales per year (350 tons).

This is a farm with intensive fattening of pigs but with regard to a lack of all feeding phases for each animal group, the method used for calculations was AFC. Animal feeding consisted of only two stages: weaners 30-50 kg and fattening pigs 50-120 kg. Due to the fact that the farm purchases piglets weighing about 30 kg, previous fattening stages are neglected. Weaners received fixed doses determined by an advisor from a feed company which contained: 12% of protein starter composition,12% of maize and F1 rye, and 33% of spring barley and winter wheat. The dose for fatteners was as follows: protein finisher composition - 30%, 10% maize and winter wheat, and 25% of spring barley and rye F1. The feed is prepared in the farm using own equipment (crusher and mixer), based on raw materials from own plant production (maize, F1 rye, spring barley, winter wheat). Complete protein and mineral mixtures are purchased from a feed producer who also prepares dosing guidelines.

The data concerning feeding were obtained based on a questionnaire filled by an agricultural advisor in the presence of the farm owner. Initially, a significant part of the questionnaire was incomplete and required adding significant amounts of items related to animal feeding and keeping. The farm owner submitted some information about the share of feed parameters, whereas the missing data were taken from tables. The data were entered to the questionnaire by the employees of the Institute of Soil Science and Plant Cultivation who participated in the Manure Standard project, following consultations with agricultural advisors collaborating with the farm owner. Default values related to technology from the calculation tool were used for the calculations. The use of specific domestic data was planned for further stages of the calculation tool validation.

The results obtained from the calculation tool for a swine farm for manure and urine differed significantly from the results of laboratory analyses (38-97%) and Polish table values (ca. 80%) for total nitrogen (Figure 6.5.2.). The calculation tool results were in most cases underestimated as compared to laboratory analyses and Polish table values. The values were higher only for ammonium nitrogen.

Insufficient accuracy of the data concerning feeding and nutrient content in feed was the greatest problem in the case of this farm. Table values had to be used for a number of items.

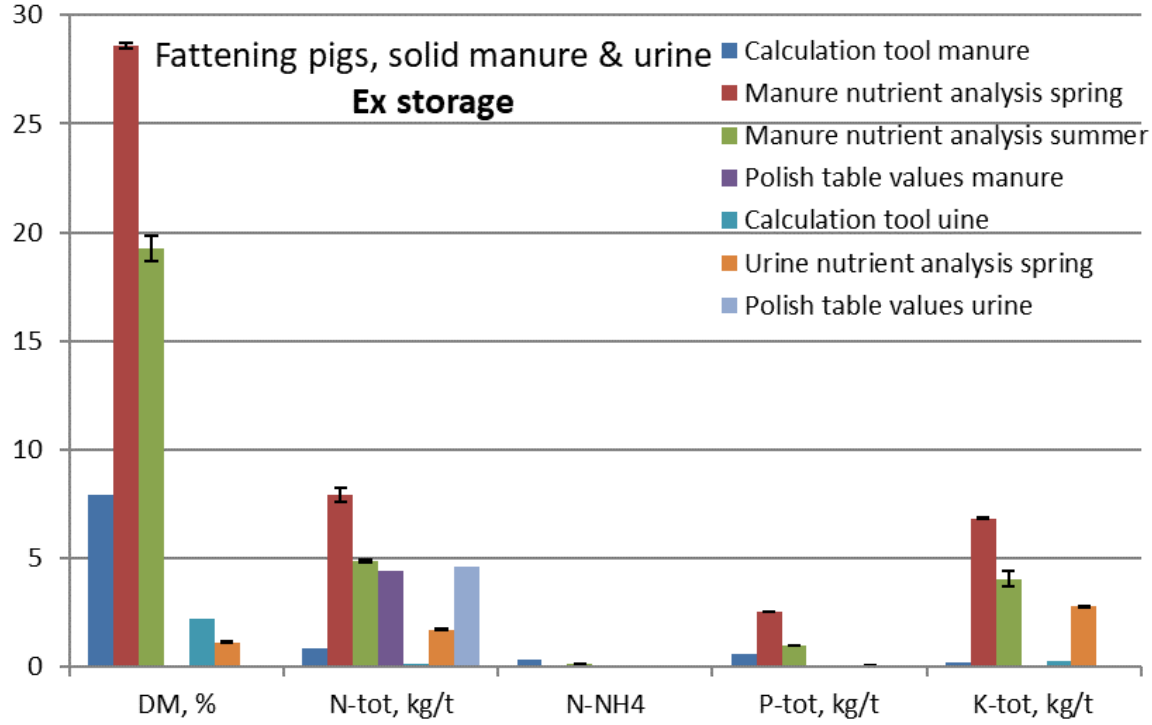

Figure 6.5.2. Results of solid manure & urine, ex storage from the calculation tool and from the analyzed samples in the fattening pigs of the Polish swine farm (farm PL1). The standard deviation bars for the analyzed samples represent the deviation between two laboratories analyzing the same samples taken on the farm in spring and summer of 2018.

6.6 Lithuania

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Farm LT3

The farm is situated in Central-West Lithuania and there were 127 dairy cows on the farm. The cows were fed with mixed ration composed of grass, cereals, protein supplement and minerals. The dairy cows were kept without bedding material (on rubber mattresses in the standing places).

The feeding data received first from the farm was not sufficient for the requirements of the calculation tool. It was received amounts of feeds in kg/day per animal for one group of cattle – dairy cows. However, feed composition data were not complete and remaining information was taken from a national handbook with analysis results for various feeds. The handbook does not have any data for dry matter digestibility; therefore, it was taken from other available sources.

Overall, the results received from the calculation tool for this dairy farm and its milking cows seemed to represent the situation on the farm (Figure 6.6.1 and 6.6.2). Dry matter content was higher with the calculated results in comparison to the analyzed data. In addition, total nitrogen ex housing was slightly higher with the calculated results than with the analysis and total nitrogen ex storage was considerably higher. These differences in ex storage nitrogen could mean that real losses of N were higher compared to calculated value. Nitrogen may have fitted the analyzed results better in case the emission coefficients were adjusted for Lithuanian conditions. Overall, considering the ex storage results, the calculated values match the analyzed values very well.

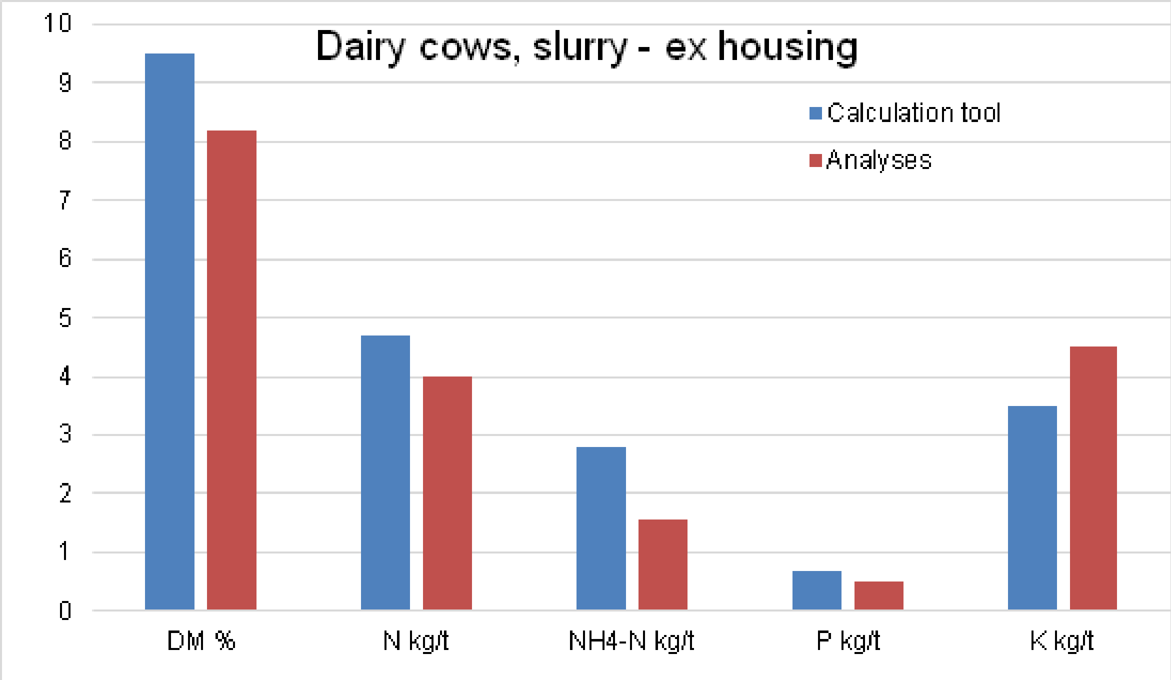

Figure 6.6.1. *Ex housing* results of the calculation tool and analyzed samples for farm LT3.

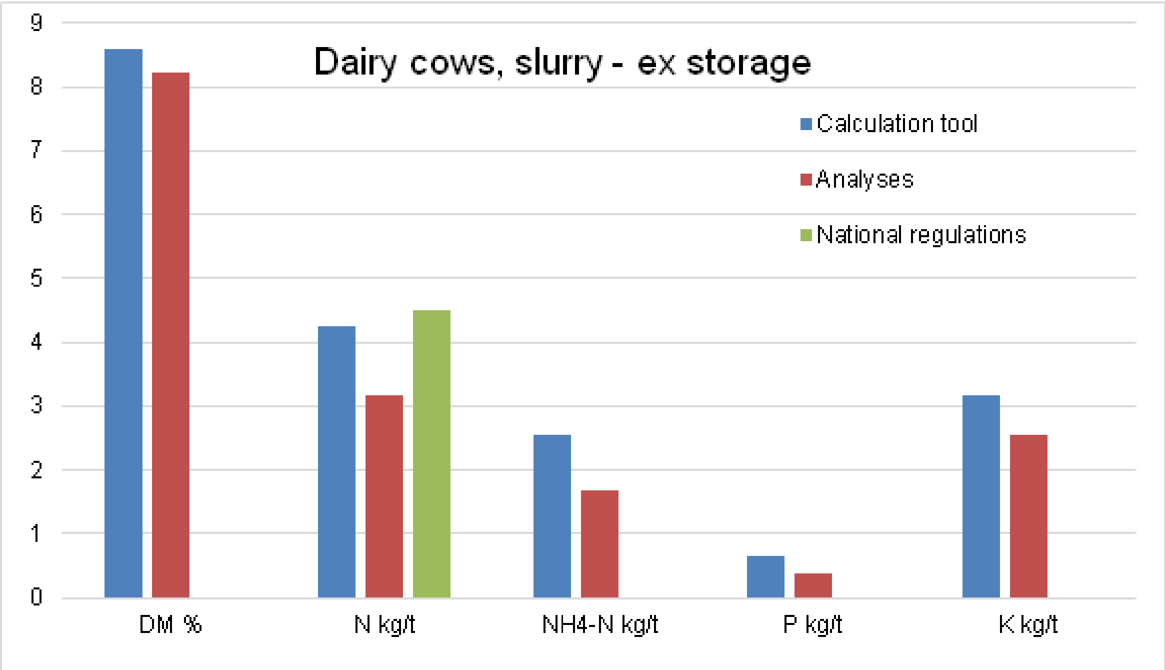

Figure 6.6.2. *Ex storage* results of the calculation tool, the analyzed samples and national regulations for farm LT3.

Farm LT5

The farm produces organic beef cattle. Their manure type is deep litter. The farm is located in the Central-East of Lithuania. The farm had 60 nursing cows, 24 heifers, 60 calves and 41 bulls. All animals were kept in a loose housing with a deep litter (straw bedding) except for 6-month grazing period. Beef cattle are fed mostly with own grown and prepared cereal ration mixtures. Animals were kept in a loose housing with one side open. Deep litter is removed once a year and is used for compost production. Comparison of the analysed and calculated manure data are in Figures 6.6.3 and 6.6.4.

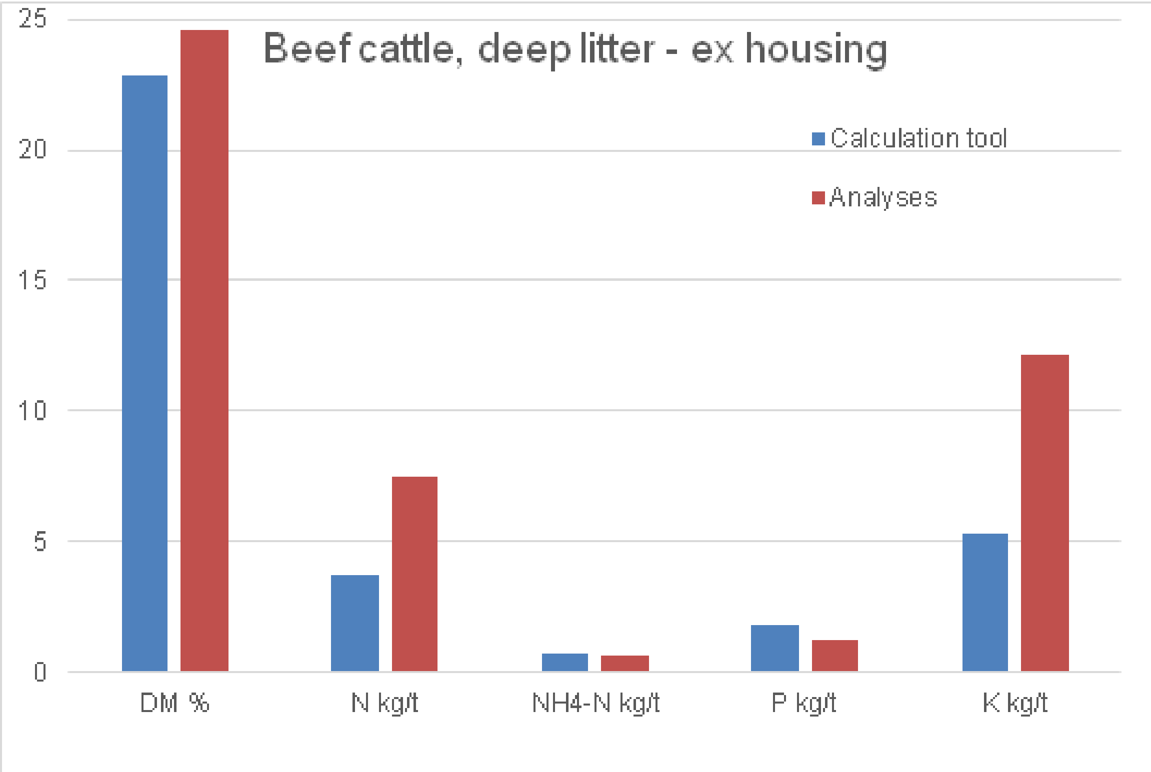

Figure 6.6.3. *Ex housing* results of the calculation tool and analyzed samples for farm LT4.

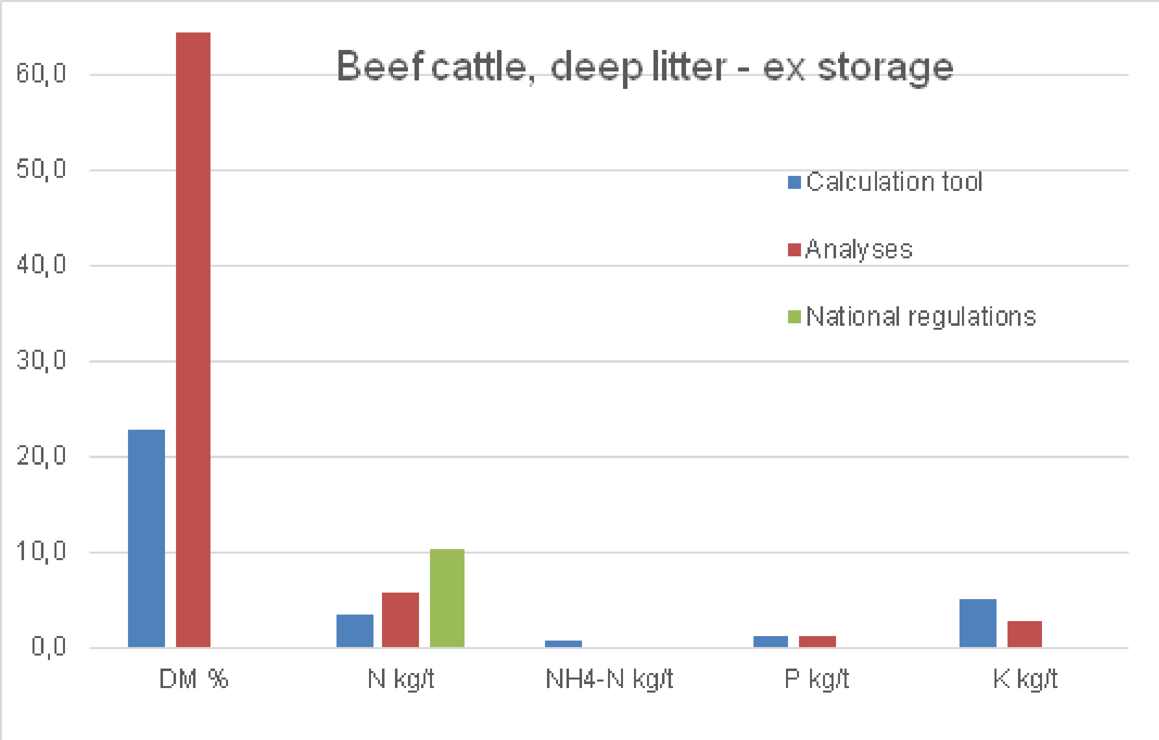

Figure 6.6.4. *Ex storage* results of the calculation tool and analyzed samples for farm LT4.

The farm did not have any feed laboratory analyses, so handbook with analysis results for various feeds was used.

Ex housing values for DM were quite similar as well as ammonium nitrogen and somewhat phosphorus content. Larger differences were in nitrogen and potassium content – that could be caused by feeding data being very inaccurate.

Ex storage results gives a large difference in dry matter content, nitrogen and potassium. DM and nitrogen values are largely underestimated and potassium content is overestimated. Reason for this could be that calculation tool is not adjusted for aerated compost heaps. It seems that during composting process substrate lost a lot of water and heaps were quite protected from precipitation hence DM content is high. Loss of potassium was considerably higher than estimated and nitrogen was quite well preserved.

6.7 Latvia

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A large problem with using the farm-level calculation tool was the availability of the necessary input data to carry out the calculations. To illustrate this problem, out of the 22 pilot farms surveyed in Latvia, 8 did not have any of the data required. The surveys asked a large amount of data, and in the three farms we went with completed calculations and focused questions, the farms could answer them.

Farm LV2

The farm is a dairy cattle farm, which did have all the data and gave good results.

The farm has dairy cows, heifers and calves. It produces solid manure. The AFC feeding option was used for the calculations. The farm has 135 dairy cows, but it didn't split the lactating cows and dry cows, so they were calculated together. There were no other problems with other animal groups.

The farm could only provide feed analysis data for the silage. For other feed the farm had no data and a handbook with analysis results for various feeds was used for them (*Lopbarības analīzu rezultātu apkopojums*, 2013). The handbook doesn't have any data for potassium content, so for some of the feed it was left blank. The dry matter digestibility was calculated according to the handbook.

The largest problem with input data was technological water – the farm did not have such data.

The results of the calculation tool match well with both national regulations and analyses (Figures 6.7.1 and 6.7.2). The biggest differences are for potassium results. But the conclusion is that with sufficiently detailed input data the calculation tool gives credible results.

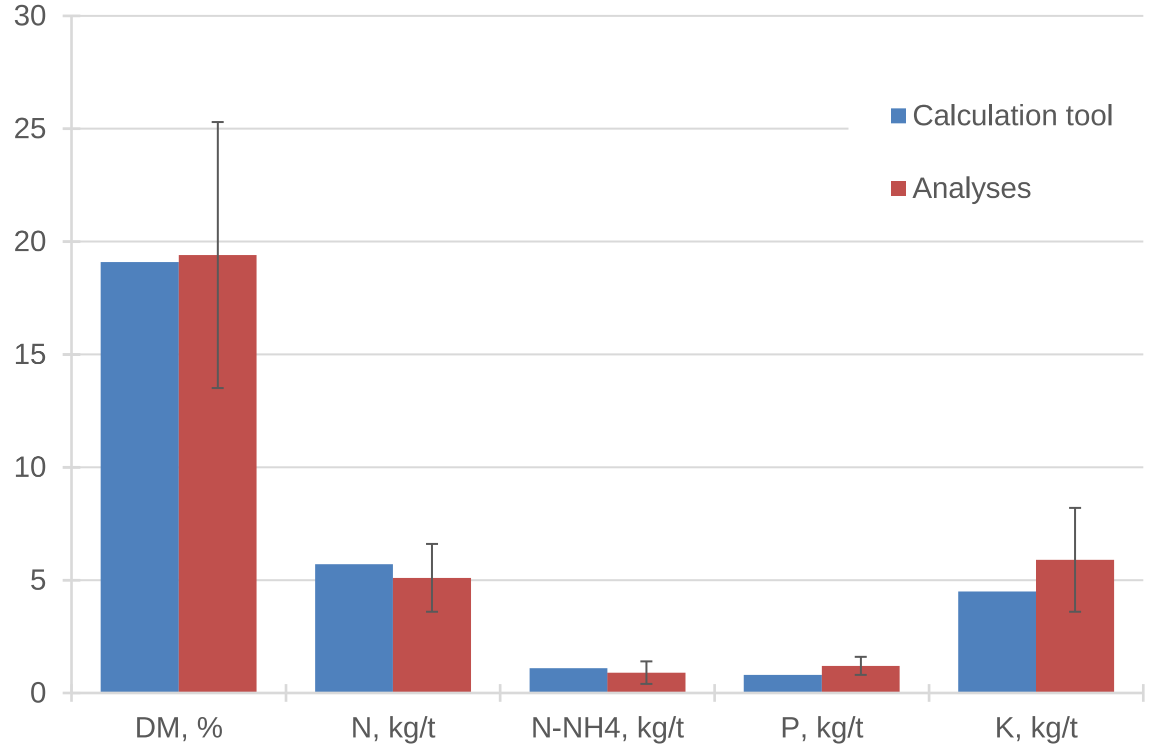

Figure 6.7.1. *Ex housing* results of the calculation tool and analyzed samples for farm LV2. Error bars show confidence interval at 95% confidence level.

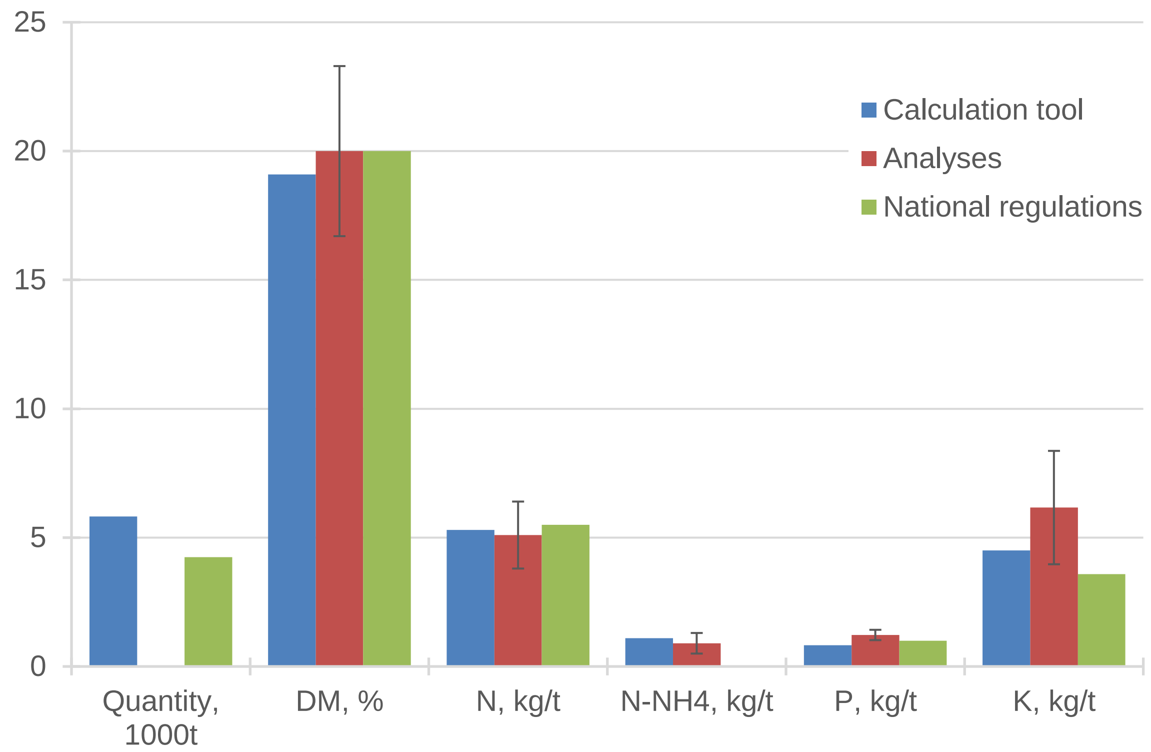

Figure 6.7.2. *Ex storage* results of the calculation tool, the analyzed samples and national regulations for farm LV2. Error bars show confidence interval at 95% confidence level.

Farm LV5

The farm is another dairy cow farm that produces solid manure. They are smaller than Farm LV2 and have very low milk yields – on average only 5 t per year. The feeding is very simple – mostly hay and silage, with some additional mineral feed and salt, so AFC method was used.

The farm did not have any feed laboratory analyses, so handbook with analysis results for various feeds was used. There was no problem with other input data except for technological water, but due to the dry matter results and how they compared with analyses and national regulations, no water was added.

The largest difference is for dry matter, phosphorus and manure quantity (Figures 6.7.3 and 6.7.4). The hardest difference to explain is dry matter – the farm, as mentioned, is simple and could provide most data precisely, including bedding materials. The manure quantity is closely related with dry matter, with higher DM, the quantity would be lower. The phosphorus difference can be explained with feed content – a general handbook was used, not the analyses of the specific feed they use.

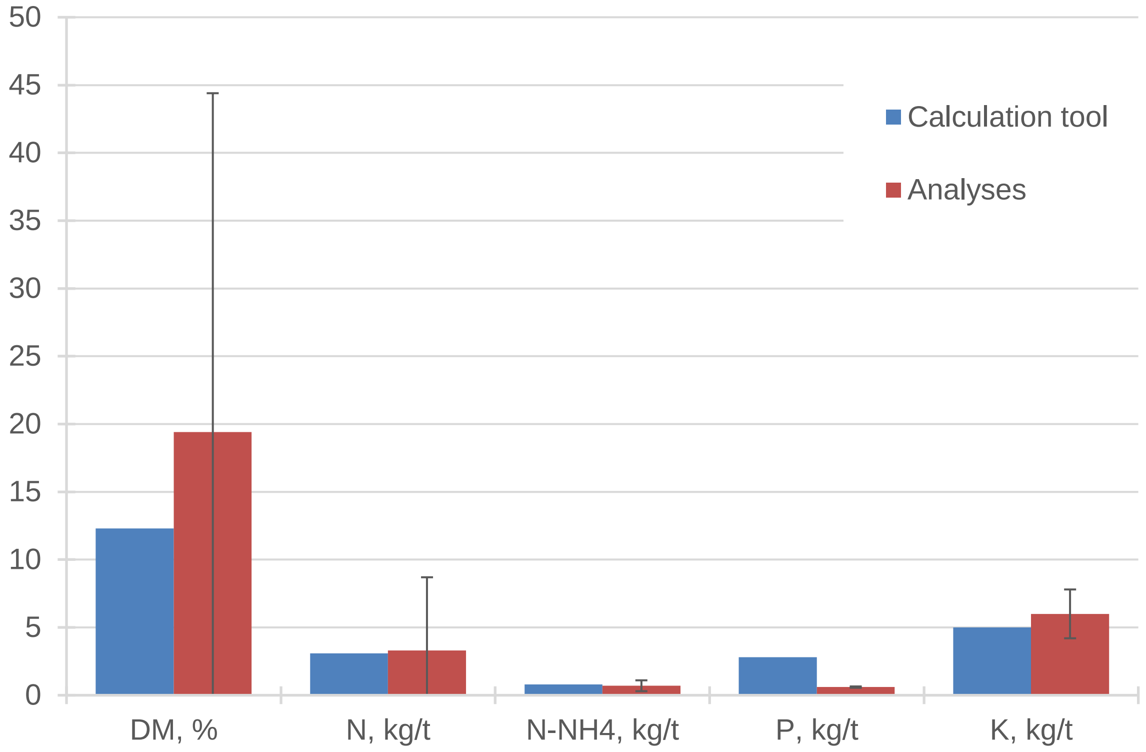

Figure 6.7.3. *Ex housing* results of the calculation tool, the analyzed samples and national regulations for farm LV5. Error bars show confidence interval at 95% confidence level.

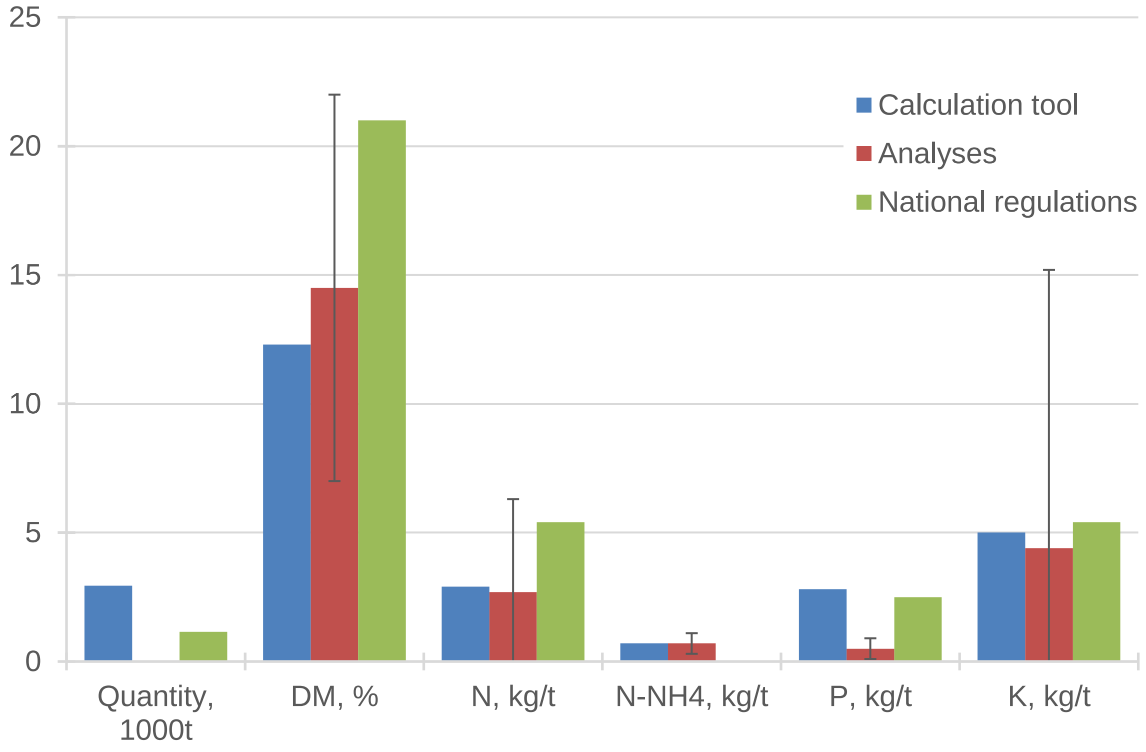

Figure 6.7.4. *Ex storage* results of the calculation tool, the analyzed samples and national regulations for farm LV4. Error bars show confidence interval at 95% confidence level.

6.8 Estonia

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The information availability needed for farm level calculation tool depending mainly from the size of the farm (company) and also from the production intensity. In the large-scale farms (for example dairy farms with more than 400 dairy cows + corresponding number of young stock and age groups are usually all year indoor), feed rations as well chemical composition of feeds and also technological nuances (bedding quantity etc.) are known. The main background information problems in the smaller farms especially if animals are grazed are connected with estimation of feed quantity and chemical composition of feeds consumed.

Farm EE1 (good example) - dairy cattle, liquid manure

The number of animals was 591 year cows. Loose housing had a liquid manure system without bedding. Average milk yield was 11 256 kg per cow per year. Cows are divided into feeding groups (TMR feeding): Negative energy balance period 1 (0-30 days of lactation), negative energy balance period 2 (31-120 days of lactation), zero energy balance period (120-210 days of lactation), positive energy balance period (from the 210 day of lactation to the end of lactation), dry period 1 (at least 14 first days of dry period) and dry period 2 (at least 14 days before expected calving). All roughages (silage of different moving, hay, straw), cereals and concentrates are chemically analyzed. Purchased feeds (for example minerals) are accompanied by a certificate of chemical composition. During the routine chemical analysis in the feeds are determined (only parameters required in the calculator are mentioned): dry matter, crude ash, crude protein and phosphorus content also organic matter digestibility. Rations are prepared according to the feeding normative of each lactation phase (the main criteria's are milk yield and duration of lactation period). The protein feeding is based on the Scandinavian AAT/PBV system. In the Table 6.8.1 and Figure 6.8.1 the results of chemical analysis and calculated values of ex storage manure have been compared. Also added average table values (kg/t) from the current Estonian regulation.

Table 6.8.1. Dairy cows - liquid manure (good example).

	Calculated	Chemical analysis, spring	Chemical analysis, autumn	Default table values
Quantity, t	17639			14598
DM, %	9.7	7.6	7.6	5.9
N tot, kg/t	3.8	4.1	4.0	4.7
NH_4 - N, kg/t	2.3	2.3	2.1	1.2
P, kg/t	0.6	0.6	0.6	1.2
K, kg/t	2.8	2.1	2.1	4.1

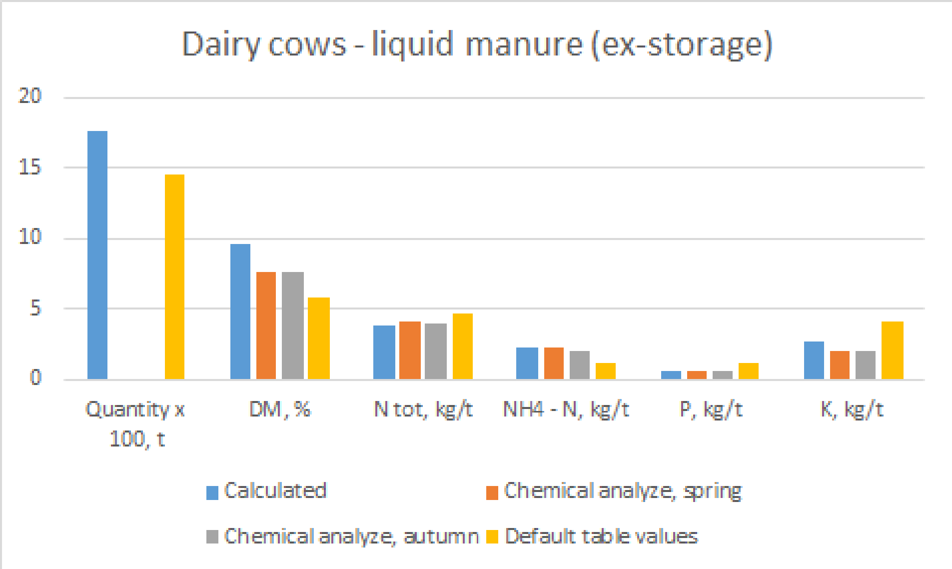

Figure 6.8.1. Results of chemical analysis, calculated and current table values of liquid dairy cattle manure at ex-storage level.

The main reason of higher calculated dry matter content of liquid manure can be connected with indirect estimation of technological water quantity added to the manure at ex housing level. Water used for cleaning and washing of milking parlor and waiting area was not measured. The amount of potassium is not standardized in the preparation of feed rations. Potassium is usually sufficient in feed and excess potassium does not cause any health problems to the animals. Therefore, potassium levels are usually not determined in feed analysis and the table values are used in the calculations. The values in the table appear to have been overestimated. This can be the reason of higher calculated potassium concentration in the liquid manure. Current table (default) values of manure properties are old (from year 2014) and improving needed.

Farm EE3 (bad example) - beef cattle, deep litter manure

The number of animals was 21 suckler year cows, 18 heifers, 12 young bulls, 10 calves and 1 breeding bull. The farm had loose housing and grazing (24/7) in the vegetation period without any extra feeding. The length of the grazing period (2018) was from 15 May until 15 October. The size of grazing area was 28 ha, of which 12 ha are natural and 18 ha are cultural pastures (50% legumes). In the winter period, feeding was with silage, hay and minerals (concentrates are not used) on the outside feeding area covered with straw bedding. For resting an open shelter with deep litter (straw) was available. Indirect calculation of consumption of grass in the grazing period is based on the size of grazed area and average consumption per animal per day (all animal categories separately). Feed consumption in the winter period is calculated also indirectly. Known were total number of silage and hay balls fed, average weight of balls and quantity and chemical composition of mineral feeds. Feed consumption per animal age groups wasn't measured. There was also no chemical analysis of the feeds. In the calculations used only table values describing chemical composition of feeds. Known was number and average weight of straw balls used as bedding. In the Table 6.8.2 and Figure 6.8.2, the results of chemical analysis and calculated values of ex storage manure have been compared. Also added average table values (kg/t) from the current Estonian regulation.

Table 6.8.2. Beef cattle - deep litter manure (bad example).

	Calculated	Chemical analysis, spring	Chemical analysis, autumn	Default table values
Quantity, t	182.8			
DM, %	25.9	27.3		38.3
N tot, kg/t	4.5	5.7		7.0
NH_4 - N, kg/t	0.9	1.1		0.1
P, kg/t	0.8	0.7		0.9
K, kg/t	8.6	5.7		9.5

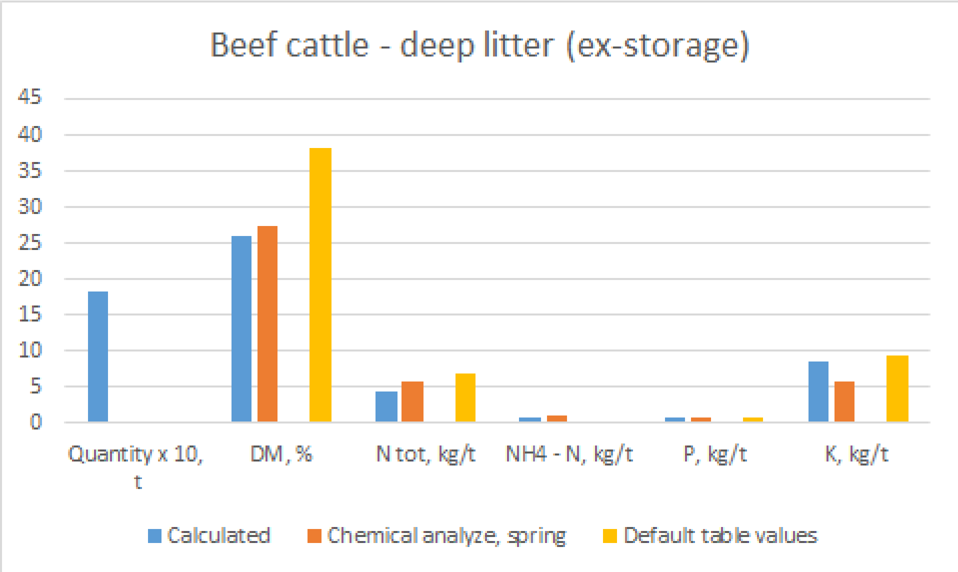

Figure 6.8.2. Results of chemical analysis, calculated and current table values of deep litter beef cattle manure at ex-storage level.

The main problem here is connected with indirect estimation of feed consumption on the grazing period. Accurate measurement is often impossible in practice.

6.9 Russia

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Farm RU2 (good example) - dairy cattle
The farm was situated in Leningrad Region. Breed – black-and-white Holstein. Milk yield – 7000 kg/cow/year. Housing system (dairy cows) – indoor tied housing, zero grazing. Housing system (other animal categories) – indoor loose housing. Manure removal system – mechanical, without water. Bedding – sawdust. Technology for manure processing into organic fertilizer – passive composting; the period of compost maturing after the temperature has reached 60°C in all parts of the clamp is at least 2 months in the warm season (May-October) and at least 3 months in the cold season (November-April).

Dairy cows, early lactation (1 to 90 days) – 214 head; dairy cows, mid lactation (91 to 210 days) – 186 head; dairy cows, late lactation (211 to 300 days) – 52 head; dairy cows, dry period (301 to 365 days) – 359 head; cow calves (age 0-6 months) – 203 head; heifers (age 6 months to calving) – 235 head.

The animals were fed with TMR composed of complete feed, rolled and preserved barley, clover and timothy hay, vetch and oats silage and beet pulp.

The initial feeding data received from the farm first was not sufficient to meet the calculation tool's requirements. The feeding rations were sent later. However, the accurate data on the amount of feed for each animal were never provided. All the feeding calculations needed the expert evaluation in animal nutrition and feeds. Converting the feeding data available to be suitable for the input into the farm-level tool appeared to be too difficult for the agricultural producer, especially as far as the dimensions of the input values were concerned. The feeding data should be delivered to the agricultural producer in the correct form to enable his/her independent use of the tool.

Manure samples were taken by a professional following the recommendations developed in the project.

The experience in manure calculation using the farm data and the developed calculation tool:

1. The farm applies different cow housing and manure removal systems for cows with different lactation phases. It is not possible to take into account this aspect in the calculation tool at one time. The user would need to calculate the different housing systems for different lactation phases separately.
2. According to the manure processing technology used on the farm, the moisture-absorbing material is added to *ex-housing* manure. It is not possible to calculate this since the moisture-absorbing material is included in the calculation as additional bedding material when calculating *ex-housing* manure.
3. The tool calculates the mass of commercial mixed feed according to the animal's age and milk yield. However, the mass of feed consumed by animals is not directly taken into account.
4. Concerning the feed produced by the farms, there is no data on distribution of these feeds among different animal categories (only the total mass of feed per farm per year is available)
5. The mass of water consumed by animals is not taken into account.
6. Questionnaires return numbers for livestock population for the time being.
7. Using vitamin additives and premixes affects the animal feed digestion is not considered though it would be needed in the Russian context.

On this Russian dairy farm (farm RU2), different animal categories were housed in one livestock building with different housing practices and manure removal systems. Therefore, the calculated and analyzed values of mixed manure samples were compared (Figure 6.9.1)

Dry matter content was lower in the calculated results in comparison to the laboratory analysis data. Total nitrogen and phosphorus *ex housing* were lower in the calculated results than in the analysis.

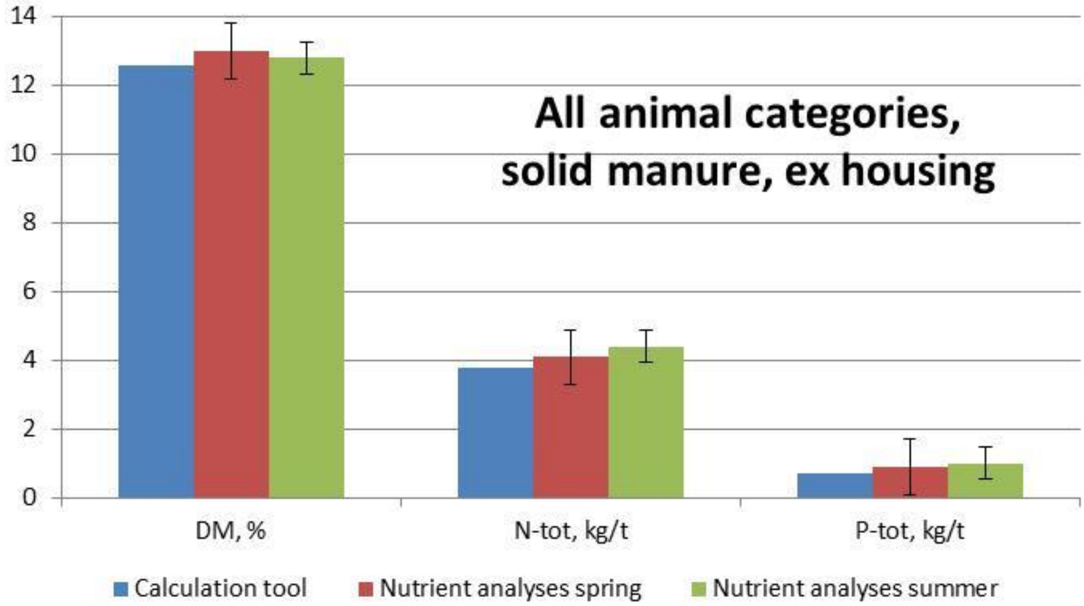

Figure 6.9.1. Results of solid manure *ex housing* from the calculation tool and from the analyzed samples in all animal categories of the Russian dairy farm (**farm RU2**). The standard deviation bars for the analyzed samples represent the deviation between three replications of the same samples taken on the farm in spring and summer of 2018.

The differences between calculated and analyzed data are from 3 to 7% for *ex-housing* N content and from 1 to 4% for *ex-housing* P content.

On the farm, passive composting was used to process manure into organic fertilizer requires adding a moisture absorber in order to achieve DM=25% and C/N=20:1. Additional mass of moisture-absorbing material was added in “bedding” column. Figure 6.9.2 shows the comparison results of calculated and analyzed data.

Dry matter content was lower in the calculated results in comparison to the analyzed data.

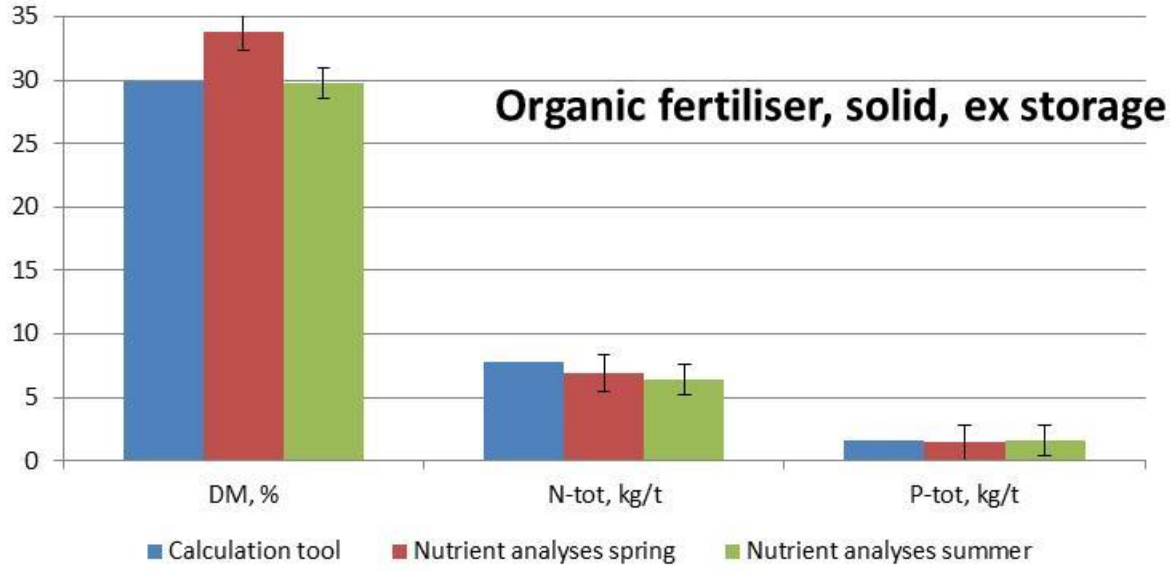

Figure 6.9.2. Results of solid organic fertilizer *ex storage* from the calculation tool and from the analyzed samples in the organic fertilizer of the Russian dairy farm (**farm RU2**). The standard deviation bars for the analyzed samples represent the deviation between three replications of the same samples taken on the farm in spring and summer of 2018.

The differences between calculated and experimental data for *ex-storage* N content are from 7 to 10% in the calculation tool. The nutrient content in the organic fertilizer is higher than in *ex housing* manure due to the addition of the moisture-absorbing material when processing manure into organic fertilizer.

The conclusion is that the calculation tool appears to work well for dairy cows in Russia, provided the feeding data is received in the accurate and sufficiently detailed form. Overall, considering the *ex housing* results, the calculated values match the analyzed values very well.

Farm RU12 (bad example) - pig-breeding complex

The farm was situated in Pskov Region. Breed – Pietrain and Duroc. Housing system – bedding-free housing on partially slatted floors. Slurry removal – the gravity flow pipe-and-pit system with periodic slurry removal. Slurry processing into organic fertilizer – long-term storage (maturing). The maturing period is 12 months. The storage capacity is calculated with due account for slurry produced and the amount of the average precipitation value for the previous year.

One-time animal housing on the farm is as follows: sows – 6042 head; weaned piglets (26 - 60 days old) – 12534 head; weaned piglets (61 - 106 days old) – 19592 head; replacement stock – 2531 head; fattening pigs (under 70 kg) – 21191 head; fattening pigs (above 70 kg) – 6869 head; boars – 116 head.

Animals are fed with purchased feed. The protein content in the diet is from 15.0% to 16.6%, depending on the animal category; the dry matter content of the diet is from 89.3% to 89.8%. Feed is diluted with water until a homogeneous liquid suspension is obtained.

The slurry samples were taken by a farm employee, not a professional. It is not known whether the sampler strictly followed the recommendations developed in the project or not. The templates were filled in by the farm employees as well.

The experience in manure calculation using the farm data and the developed calculation tool:

1. There are different rations for slaughter pigs (under 70 kg and above 70 kg) in Russia than assumed in the calculation tool.
2. The lack of control systems over manure production and processing leads to inaccurate source data. In order to obtain more reliable data, one would need to fill in the questionnaires together with the specialists from agricultural enterprises.

The results of the calculations were compared to the analyzed results (Figures 6.9.3-6.9.4).

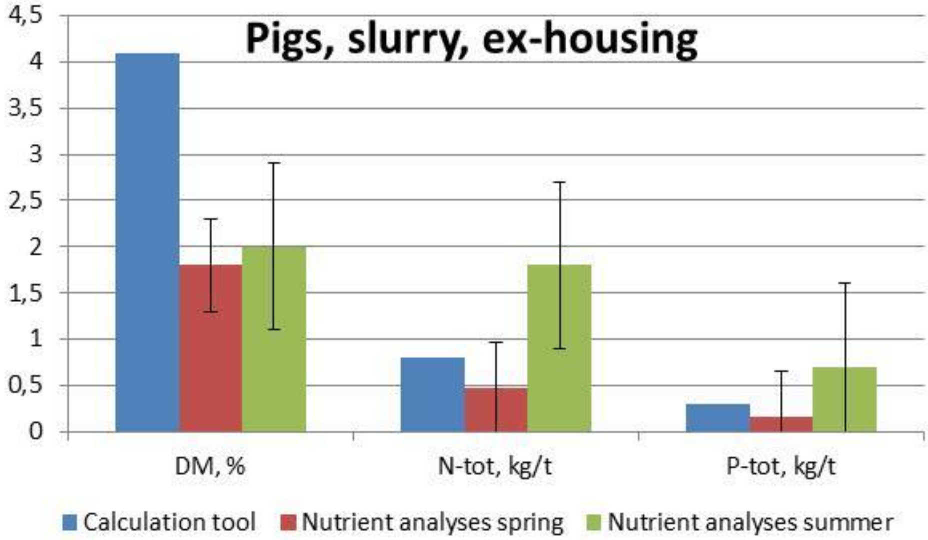

Figure 6.9.3. Results of slurry *ex housing* from the calculation tool and from the analyzed samples of the Russian pig farm (**farm RU12**). The standard deviation bars for the analyzed samples represent the deviation between three replications of the same samples taken on the farm in spring and summer of 2018.

Comparison of the calculated and analyzed data on *ex-housing* slurry showed that the difference in dry matter content was 56%, the difference in total nitrogen content was 41%, and the difference in total phosphorus content was 50%. These significant differences may be explained by potentially incorrect manure sampling. Maybe the raw manure was not mixed thoroughly before sampling with the consequence that the sample of the (upper) clarified part only was taken to the laboratory.

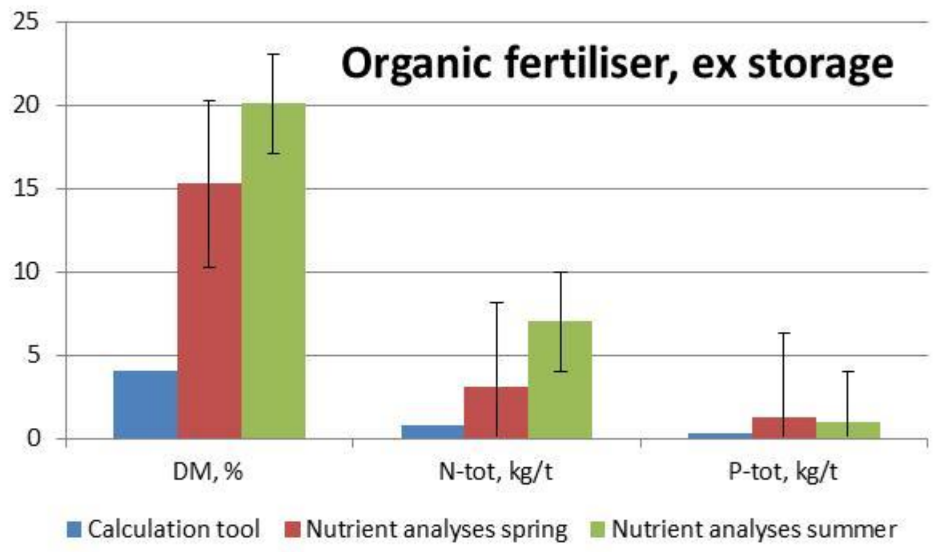

Figure 6.9.4. Results of organic fertilizer *ex storage* from the calculation tool and from the analyzed samples in the Russian pig farm (**farm RU12**). The standard deviation bars for the analyzed samples represent the deviation between three replications of the same samples taken on the farm in spring and summer of 2018.

The actual data on all indicators (dry matter, total nitrogen and phosphorus content) exceed the calculated data by above 70%. Maybe the employees of the pig-breeding complex filled in the template inaccurately regarding the technology of slurry processing into the organic fertilizer. If the farm uses passive composting rather than long-term storage (maturing) (as specified in the template), then taking into account the added moisture-absorbing material, the calculated data for total nitrogen, phosphorus and dry matter content will be close to the actual ones.

7. Water consumption measurements

In Baltic Manure project, it was noticed that the manure quality and quantity changed a lot through dilution from identified and diffuse water sources. E.g. dry matter content in a swine farm slurry was higher according to analysis compared to mass balance calculations Based on this, water flow measurements were carried out at the five Swedish pilot farms. All water ending up in the manure storage was included. The measurement took note of the following (Table 7.1):

- Drinking (indoor, outdoor)
- Milkroom (dishing etc)
- Washing (stable, milking room, field equipment)
- Feeding
- Staff areas
- Total consumption

7.1 Water consumption observations

Measured water amounts were divided into two different water categories, drinking water (including also wet fodder) and other water. The drinking water is assumed to go through the animal and end up as urine and dung and the other water is assumed to go directly to the storage (Table 7.1.).

The water amount from the different water categories differ between the animal categories, where dairy cows used in total 20-30 m^3 per animal and year and the fatteners and sows around 10 m^3 per animal and year (Table 7.1). Out of the total water to the dairy cows, around 75% of the water was drinking water and the rest other technological water (e.g. cleaning of milk room, milking pit and dishes). For pigs, the ratio was higher for drinking water (over 95% of water consumption to drinking water). Here, the largest section of water was from wet foddering making up 75% of the drinking water. Normally a dairy cow drink 10 times as much as a fattener or a pregnant sow, 80-120 liters per day compared to 4-10 and 10 liters per day respectively, which partly explain the difference. Water through water cups per dairy cow amounted to 17-23 m^3 per year depending on if drinking water on pasture was included or not. This gives a daily consumption of 70-115 liters per animal and day which is in line with the literature.

7.2 Adjustment of technological water in the calculation tool

When calculating in the Manure Standard calculation tool, water data was adjusted so that the DM content of the manure *ex storage* was close to the DM content analyzed at the manure storages of the Swedish pilot farms (Table 7.2, assessment 2). The water in the tool was then compared to the measured water amounts. There are two parameters for water in the tool, one for precipitation and one for technological water. When using the measured amount of technical water in the model (Table 7.2, assessment 3) it resulted in 13 % lower DM content compared to manure analysis for the dairy slurry (SE1) while 13 % higher for the sow deep litter (SE4) while correlation was good for the swine slurry (SE 3). If set with the measured amounts of water, the model would then need to generate a manure with higher DM before technical water is added for the dairy farm, and correspondingly with lower DM for the swine farm, to generate a DM correlating with the sample analysis.

So, one possible reason for differences can be connected with ex-animal calculation. The amount of urine and faeces excreted is calculated on the basis of the dry matter of the feed consumed. It is also assumed as default value that the dry matter content of dairy cows, for example, is 10.5% at the ex-animal level (all coefficients and constants used to calculate faeces and urine volume and dry matter content are adjustable in the calculator database as needed). If the calculated dry matter content of the manure differs from the actual level already at the ex-animal level, the addition of the exact amount of technological water does not guarantee the correct result at the ex-storage level.

Comparisons were complicated by the fact that manure analysis were affected by water addition during the period early autumn 2017 to late spring 2018, while water flow measurements took place from September 2018 to August 2019. Hence values are not directly comparable.The possible effect from low precipitation and high evaporation during the hot summer of 2018 was tested. However, adjusting the precipitation in the mass balance calculations did not have any significant effect on the results.

A concluding remark was that neither technical water nor a variability in precipitation did have any major effect on the DM content in slurry ex-storage. Instead the water supply from faeces and urine was what determined the DM content. Additional water flow measurements on farms would provide data that van be used for generating default values for calculation tools.

Table 7.2. Manure dry matter (DM) content and amount of technical water (TW, m^3) used in mass balance calculations for the Swedish pilot farms SE 1, 3 and 4. Assessment by 1) manure sampling and analysing, 2) the Manure Standards (MS) farm calculation tool with water volumes adjusted to correlate with analysed DM and 3) the MS farm calculation tool with measured water volumes. Numbers in i*talic*=measured values.

	SE1 DM (%)	TW m^3	SE3 DM (%)	TW m^3	SE4 DM (%)	TW m^3
1) Analysed samples	*7,3-7,7*	-	*4,2-8,05**	-	*21,3-21,6*	-
2) MS Calculation tool **	7,6	240	7,2	610	22,2	91,8
3) MS Calculation tool, measured	6,6	*450*	7,3	*528*	25,1	*10*
Difference (%)	-13%		+1,3%		+ 13%	

* Large difference between laboratories.

** Input of technological water to the model was adjusted so that DM content correlated with DM in analysed manure samples as there are no default values for technical water in the model.

Table 7.1. Water usage at the Swedish pilot farms from water flow measurements.

Animal	Farm	Usage of water	Amount ($m^3\ yr^{-1}$)	% of total	Per animal ($m^3\ yr^{-1}$)	Per animal ($l\ day^{-1}$)	Placement	Amount ($m^3\ yr^{-1}$)	% of total
Dairy cow	SE 1 (55 dairy cows)	Tot. water in	2353	100	35.7	99	Tot. water in	2353	100
		Drinking water	1815	77	27.5	76.4	Water cups	1808	77
							Sick box	7	0.3
		Other water	538	23	8.2	22.6	Milk room	196	8
							Cleaning water (animal house)	342	15
	SE 2 (190 cows)	Tot. water in	5875	100	30.9	85.9	Tot. water in	5875	100
		Drinking water	4415	75	23.2	64.4	Water cups (heifers &calves)	392	7
							Water cups (pasturage)	941	16
							Loose housing and pumping pit	3082	52
		Other water	1460	25	7.7	21.3	Staff room and dishes	211	4
							Milking pit	110	2
							Dishes	452	8
							Cleaning water (milk stable)	687	12
Pig	SE 3 (3050 fatteners)	Tot. water in	9878	100	3.2	10.8	Tot. water in	9878	100
		Drinking water	9482	96	3.1	10.3	Water cup	2228	23
							Wet fodder	7254	73
		Other water	528	5	0.2	0.5	Cleaning water	498	5
							Staff room and dishes	30	0.3
	SE 4 (300 sows)	Tot. water in	924	100	3.1	8.6	Tot. Water in	924	100
		Drinking water	914	99	3.0	8.5	Water cup	196	21
							Wet fodder	718	78
		Other water	10	1	0.03	0.1	Cleaning water	10	1
Poultry	SE 5 (180 000 broilers)	Total in	9528	100	0.05		Water cups	9528	100

8. Conclusions

The project partners in the nine Baltic Sea countries cooperated in creating joint instructions for manure sampling and analysis and for manure mass balance calculation. Sampling and analysis were tested at a total of 94 pilot farms complemented with mass balance calculations on some of them. The results, from sampling and calculation, respectively, were compared. Furthermore, data on analysis methods used in the different national laboratories were also collected.

The results confirmed that manure nutrient content varies greatly between farms, also between those with the same production type. Hence, farm-specificity should be taken into account for achieving more precise fertilization planning and thus improved use of the manure. However, the two possible methods for manure data generation, sampling and analysis and mass balance calculation, both have their limitations (Table 8.1).

Getting representative manure samples can be very laborious, especially from solid manure storages. Furthermore, slurry tanks and lagoons are seldom sufficiently mixed. Farmers are also often reluctant to mix the slurry tank an extra time for sampling in time to receive analysis values before spreading. Failing to take the time for proper mixing and sampling, the analyzed values (esp. dry matter and phosphorous) may end up being underestimated (esp. slurry) or overestimated (esp. solid manure) as compared to mass balance calculation.

Also, the analysis methods in the laboratories may affect the results. There were differences between laboratories especially in analysis of nitrogen (N). The most important recommendations from the project are both total-N and ammonium-N should be included in the analyses, and ammonium-N analysed from fresh samples (not dried). Also, attention should be paid to diluting (solid) manure samples during sample preparation as this can cause significant error in the results.

For accurate mass balance calculation, the quality of the input data needed is essential. The pilot farms of the project seldom had sufficient data, especially on feeding, and farm-specific use of mass balance calculation would need improvement in data availability and/or expert advising.

To generate accurate data on manure quantity and composition, a combination of the methods of sampling and analysis and of mass balance calculation could often provide the best results for different uses.

The information and instructions collected by the project Manure Standards can form a uniform baseline on which different countries can build their national methods for manure data generation.

Table 8.1. Advantages and drawbacks with manure analysis and mass balance calculations.

Analysis	Mass balance calculations
(+) Usable on all farms, also those with complex nutrient flows and manure processing.	(+) Data available in time for direct spreading.
(+) Independent of the manure storage period.	(+) An easy and fast way to calculate the amount and composition of manure if input data is available.
(-) Data may not be available in time for direct spreading.	(+) Suitable especially for large-scale and intensive production farms.
(-) Difficulties in getting representative samples.	(+) The structure of the calculation tool is flexible, all databases (coefficients, constants) can be modified according to regional specificities.
	(-) Less suitable for extensive farms, especially for grazing animals.
	(-) Sufficient input farm data not always available.

Appendix 1. Descriptions of the pilot farms

Finland

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In Finland, seven farms were chosen as pilot farms, representing dairy and beef production, pig production, broiler production and fur animal production (Table 1). Of these, the cattle, pig and broiler farms are described in this report. The fur farm represents such a different production unconnected to crop production on fields that its results are left out.

Table 1. The production line, animal categories and numbers, and manure types on the Finnish pilot farms.

Farm number	Production	Animal categories	Number of animals	Manure type
1	Dairy cattle	Dairy cows Heifers Calves	130 20 130	Slurry (deep litter with dry cows)
2	Dairy cattle	Dairy cows Heifers Calves	50 12 10	Solid manure Urine
3	Beef cattle	Bulls Heifers Young bulls	52 66 48	Slurry
4	Beef cattle	Suckler cows Bulls Heifers Calves	135 10 80 170	Deep litter
5	Pigs	Fattening pigs Weaned pigs	1300 880	Slurry
6	Poultry	Broilers	195000	Deep litter

Farm FI1 - dairy cattle and slurry

Farm 1 represents Finnish dairy production and a slurry-based housing system. The farm is situated in South-West Finland where animal production is otherwise more concentrating on pigs and poultry. During 2017-2018, there were 130 dairy cows on the farm. Only heifers (20) were grazing for 60 days during the grazing period (usually between May and September), while all other animals were kept in loose housing at all times. Lactating cows produced 9880 kg of milk per year on average. Average lactation period was 300 d and dry period 60 d. The farm had an automated milking system with two milking robots.

The dairy cows are fed with a mixed feed ration composed of grass silage, cereals, protein supplement and minerals. Only one mix is used for all dairy cows with an extra compound concentrate given during the visit in the milking robot. The amount given was determined according to the cow-specific milk yield to fulfill the nutrient requirements.

The animals are kept in three different buildings with loose housing. Dairy cows have a slurry system with peat as the bedding material (peat consumption 220 m^3/a). Average water consumption is 350 liters per day. Pregnant heifers have a similar housing unit and a manure system as the dairy cows. Dry cows and calves are kept in a separate barn with deep litter (bedding material: 180 round bales of straw/a, bale diameter 1.5 m).

The slurry from dairy cows is collected via pumping pit to two storage tanks (2700+1000 m^3). The slurry from heifers is collected to a separate storage tank (1200 m^3) by gravity. An additional storage tank (1100 m^3) is located 20 km away from the farm center to assist with spreading on fields adjacent to it. The storages in the farm center are not covered, but form a natural crust, while the remote storage is covered with a tarpaulin roof. The deep litter of calves and dry cows (500 m^3/a) is removed every 50 days and stored or directly handed over to another farm (50:50).

All slurry is used as a fertilizer on the farm (or partly the neighbouring farm for deep litter). Of the slurry, 60% is spread during the growing season and 40% is stored over winter. The total field area for manure spreading is 207 ha. A contractor spreads the slurry by injection, also an umbilical system is applied on the closest fields to the farm center. Slurry is spread for spring and autumn cereals, grass and also for sugar beet.

Farm FI2 - dairy cattle and solid manure, urine separately

Farm 2 is also a dairy farm, but with separate collection of solid manure and urine. It is situated in the Western Finland on a region with intense animal production (cattle, pigs, poultry). During 2017-2018, there were 50 dairy cows on the farm, with on average 10 month lactation period and 2 month dry period. Lactating cows produced milk on average 10 000 kg/a and milked on average 2.6 times per day. All other cattle were grazing for 4 months during the grazing period (usually from May to September), while the calves were kept in the loose housing at all times.

Feeding plans for dairy cows and heifers are made by a feeding advisor of the feed manufacturer. Dry cows are fed according to the plan for dairy cows but without concentrates. The farm produces only grass silage and buys the cereals needed for concentrates from a neighbour.

The dairy cows are kept in an old tie stall barn in which solid manure and urine are separately collected. Dry cows, heifers, bulls and calves older than 2 months are in loose housing with bedding. The bedding consumption is 500 m^3/a of peat for dairy cows and 70 round bales/a for the other animals. Average water consumption for cleaning the milking system is 300 m^3/a.

Urine from dairy cows is collected to two storage tanks with a total volume of 550 m^3. Also the wastewater from cleaning the milking system, totally about 300 m^3/a, is stored in these tanks. One of the tanks is covered by a tin roof, the other is uncovered. Solid manure from dairy cows is collected to an uncovered concrete pad (volume 745 m^3) by hydraulic machinery twice a day. Part of the manure from heifers, calves, young bulls and one bull is collected to the same storage as the solid manure every five days by the same machinery.

The field area for manure fertilization is 80 ha and 20% of the manure is given to the neighbouring farm. The farm cultivates only grass for silage. Solid manure is spread by a broadcaster and incorporated by ploughing in the spring for renewed grass only. Urine is spread by a broadcaster on grass after the first and second cut for silage.

Farm FI3 - beef cattle and slurry

Farm 3 is focused on beef cattle with mixed bull and heifer production. The housing system produces slurry as is usual for larger bull rearing units in Finland. The farm is located in Western Finland. In 2017-2018, 52 bulls, 48 young bulls and 66 heifers were kept on the farm for beef production. All animals were kept in a loose housing all the time. Average production time is 15 months and carcass weight 380-440 kg. Animals are bought to the farm.

The farm's feeding plans are made by a primary production advisor of the meat-processing company. One mixture is used for all animals.

The loose housing has a slurry system with a gravity removal. The animals are kept in separate pens for different ages and gender. The floor of the pens is fully slatted. On the slats there were only rubber mats, no bedding was used. Water consumption is 0.1 m^3 for cleaning the drinking system every other day.

The slurry from all animals is collected to a storage tank of 2100 m^3 volume. The tank is covered by a natural crust.

The total field area for manure spreading is 104.5 ha. Of the manure, 625 tons are exported off-farm and spread on the fields (25 ha) of the neighbouring farm from where grass is harvested for the bulls. The slurry is spread with a broadcaster on grass and cereals in spring, summer and autumn.

Farm FI4 - beef cattle and deep litter

Farm 4 produces beef cattle as suckler cows. Their manure type is deep litter. The farm is located in the South-West of Finland. During 2017-2018, the farm had 170 nursing cows, 80 heifers, 35 pregnant heifers, 16 young bulls and 10 bulls. All animals were kept in several different loose housing units with deep litter (straw bedding) except for an average 4-5 month grazing period. Young bulls were not grazing. Average carcass weight is 400 kg (daily growth 900 g).

The animals were fed according to a feeding plan made by an advisor of the meat-processing company.

Animals were kept in a five different loose housings with one side open. Straw consumption was 7480 m^3 and peat consumption 300 m^3 per year. Deep litter was removed twice a year, except for suckler cows calving in autumn once a year. Peat bedding was removed twice a week from the front of feeding table by machinery.

Two concrete pads of 810 m^3 and 910 m^3 for deep litter storage were located in the farm center and a remote storage of 1150 m^3 by a 1.5 km distance. All storages were covered by roof and divided into different sections by walls. During 2018-2018 the farm also had one field heap of 600 m^3 manure for short-term storage between removal from housing and spreading to the field.

The total field area of the farm is 376 ha where manure is used as a fertilizer for grass and cereals, usually on the fields close to the farm center. Manure is spread in spring, summer and autumn. 600 m^3 of manure was exported off-farm in 2017-2018.

Farm FI5

Farm 5 produces fattening pigs and also rears weaned pigs. The manure type produced in slurry. The farm is located in southwestern Finland. The farm reared 1300 pigs in 2017-2018. Every five weeks, 440 weaned pigs are brought to the farm. After reaching 26-27 kg in seven weeks, the pigs are transferred to the fattening pig section. Delivery weight for the fattening pigs is 88-90 kg which they reach in 85 days.

Feeding was planned with an advisor of the meat-processing company.

All the pigs are kept in pens with partially slatted floor. The slurry is removed from manure channels by suction into pumping pit (fattening pigs) or by gravity (weaned pigs). Peat is used for bedding 60 m^3/a. Water consumption for washing the pens is 200 m^3/a.

The slurry is stored in a 2000 m^3 tank covered with a floating styrox cover.

The field area for manure spreading is 135 ha and manure is applied by injection for spring cereals. 900 m^3 of slurry is exported to the neighbouring farms where slurry is spread on an area of 70 ha.

Farm FI6

Farm 6 was an example of the Finnish poultry production with broilers and deep litter manure. The farm is located in the southwestern Finland. The farm rears 195 000 broilers in six batches yearly. The number of days from starter to delivery is 33.5 and the delivery weight of broilers is 1.6 kg.

The broilers are fed according to a feeding plan provided by expert advisors.

The broiler hall, with an area of 10 430 m^2, provides deep litter with peat bedding. The peat consumption is 1800 m^3/a. Between the batches deep litter is removed.

The manure storage of 2780 m^3 is situated 8 kilometers from the farm center. All manure is stored except for 840 ton which is exported off-farm. One sixth of the manure is spread directly after emptying the hall during the spring spread.

The total field area for manure spreading is 158 ha. The manure is spread by a broadcaster and incorporated for spring cereals.

Sweden

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Five Swedish pilot farms were included in the study. They represented milk production (n=2), pig production (n=2) and broiler production (n=1) (Table 2). All were situated in Central Sweden.

Table 2. The production line, animal categories and numbers, and manure types on the Swedish pilot farms.

Farm number	Production	Animal categories	Number of animals/places	Manure type
1	Dairy cattle	Dairy cows Heifers Calves Bulls	55 32 22 1	Slurry* (55 dairy, 11 heifers, 1 bull). Deep litter (19 heifers, 24 calves)
2	Dairy cattle	Dairy cows Heifers* Calves	170 35 55	Slurry* (170 dairy, 20 heifers) Deep litter (15 heifers, 55 calves)
3	Pigs	Fattening pigs	3050	Slurry*
4	Pigs	Sows Gilt Fattening pigs Farrowing sows Weaned pigs	240 80 1600 96 960	Deep litter* (240 sows, 80 gilts) Slurry (fattening pigs 1600, farrowing sows 96, Weaned pigs 960)
5	Poultry	Broilers	180000	Deep litter* Slurry for cleaning water

*Used for manure sampling and modelling of mass balances

Farm S1 - dairy cattle and slurry

Farm 1 represents Swedish dairy production and a slurry-based housing system. During 2017-2018, average milk production per cow was 9.259 kg (10.125 kg ECM). The farm had 55 dairy cows with recruitment and one bull. Lactating cows (50 cows) were kept together with dry cows (5 cows) in the dairy cow barn where the manure was handled as slurry. Pregnant heifers were also moved to this barn one month before calving. Heifers and calves were kept in the recruitment barn with solid manure and urine. Bull calves are sold at an age of 2-4 weeks. Dairy cows, pregnant heifers and bulls were grazing from May to September.

All cows were fed with grass-silage, barley, corn and minerals.

The animals were kept in two different loose housing buildings with a slurry manure handling system in the larger house (dairy cows, pregnant heifers and a bull) and a deep litter system with a straw consumption of 16250 kg/year in the smaller house (calves and young heifers) (Table 2.2.1). Water consumption during 2018/2019 (12 months) in the dairy cow building was 2355 m^3, of which 2193 m^3 for drinking.

Slurry from dairy cows was collected via a pumping pit to a container (1560 m^3 with a surface area of 380 m^2). The storage had a natural solid crust which was 15-20 cm thick in the spring. Deep litter of calves and heifers amounted to approximately 600 m^3 per year and was stored on a concrete pad.

Total field area for manure spreading was 137 ha. All slurry manure was used as a fertilizer within the farm. Half of the deep litter manure was spread within the farm and half was given away. The slurry was band spread, with hanging hoses/trailing shoe, by a contractor. Slurry was spread to spring and autumn cereals as well as in lay. The deep litter manure was broad casted mainly in autumn before establishment of winter wheat.

Farm SE2 - dairy cattle and slurry

Farm 2 also represents Swedish dairy production and a slurry-based housing system. During 2017-2018, average milk production per cow and year was 9.700 kg (9500 kg ECM). Average dry period was 7 weeks. Dairy cows and heifers for recruitment were grazing for 5 months, from May to September. Calves and remaining heifers were grazing for some months, depending on circumstances.

The cows were fed with grass-silage, peas-silage and corn-silage as well as mixes containing barley, molasses, field beans, oats and oil seed rape.

The animals were kept in two different loose housing buildings with a slurry manure handling system with peat as bedding material in the larger house (dairy cows, heifers for recruitment) and a deep litter system with straw in the smaller house (calves and heifers) (Table 2.2.1). Water consumption during 2018/2019 (12 months) in the dairy cow building was 3300 m^3. Some of this water was led to the pumping pit for diluting the slurry when pumping to the storage basin twice a day.

Slurry from dairy cows was collected via a pumping pit to a lagoon (5000 m^3). The storage had a natural solid crust in the spring. Deep litter of calves and heifers was stored on a concrete pad.

All slurry manure was used as a fertilizer within the farm. Approximately 400 tons of deep litter manure were spread within the farm and 300 tons were given away. Total field area for manure spreading was 164 ha. The slurry was band spread by a contractor, with trailing shoe or injector, to corn and ley and establishment of pasture and ley. The deep litter manure was broad casted on fields with pasture and ley.

Farm S3 – pigs and slurry

Farm 3 is a finishing farm where pigs were held in a building with a slurry-based housing system. The farm had 3050 places and a production of approximately 9100 pigs or three rounds per year. From a starting weight of 30 kg the pigs reached a delivery weight of 129 kg in 110 days.

The pigs were fed a wet feed mix of wheat, barley, corn, soya, peas and a small additive of a premix.

Pigs are kept in pens with partially slatted floor. Slurry is removed from manure channels once a day. Saw dust was used as bedding at an amount of 300 m^3 per year.

Slurry was collected via a pumping pit to a manure storage pit of 2350 m^3 with a surface area of 380 m^2). The storage has a natural crust. In addition, there were two satellite storage tanks of 1500 and 1000 m^3 respectively 1.5 km away.

The farm has no crop production and hence lack field are for manure spreading. Hence, all of the manure is sold to a close by crop rotation farm.

Farm S4 – pigs and deep litter

Farm S4 is a pig farm with integrated production. The farm had 336 sows that weaned 7500 piglets. The number of fattening pig places were 1600. Fatteners, farrowing sows and weaned pigs were held in a slurry manure handling system while mating sows, gestating sows and gilts were kept on deep litter (Table 2.2.1).

A wet feed system with premixes was used.

Only the deep litter manure was considered in the project work. Straw, 250 ton per year, was used as its bedding material. All slurry was transported to a biogas plant before returning as digestate for further storage in the slurry pits.

The deep litter manure from the sows and gilts was kept on a concrete pad with ribs for hindering leaching of liquid. The deep litter beds were mocked out after each animal rotation. Part of the deep litter manure was stored in a field heap.

The total area of arable land for spreading of manure was 320 ha. The farm had a cereal based crop rotation with field beans and ley as break crops. All crops were fertilized with manure.

Farm SE5 – poultry and deep litter

Farm SE5 represents Swedish broiler production. In 2017/2018 the number of animal places was 180000 divided into four housing units. The number of days from starter to delivery was 30 and delivery weight 1.6 kg.

The farm used a conventional Swedish full-feed product (0.08213 kg per day and animal as averaged over the production period).

Total broiler hall area was 8200 m^2. Bedding consisted of a two cm saw dust layer. Yearly consumption of sawdust was 18900 kg.

Manure from all four animal houses was stored in two concrete pads, one with and one without a roof and with a volume of 1200 m^3 and 1500 m^3 respectively. Sampling was made from the larger of the two, which was the one not covered (34m*18m*2m(h)). All manure was stored.

Total field area for manure spreading was 818 ha. All manure was used as fertilizer on the farm. Manure was broadcasted mainly to winter cereals in the spring.

Denmark

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In Denmark, eleven pilot farms were used, representing sows, slaughter pigs, dairy cows, poultry and mink production (Table 3). Major focus was given to sampling slurry from fattening pig barns, which were represented by seven farms, and five of these are described in further details below. Two of the farmers also owned sows and piglets, which were at other sites. All samples studied were taken during April 2018. In Table 2.3.1 are given the total numbers of piglets and fattening pigs produced as well as the number of year sows and cows in the period of August 2017 – August 2018. Furthermore, the number of animals produced in the sampled barn is given for the period of April 2017 – April 2018. This is the number of animals, which produced the slurry to the sampled slurry tank from it was emptied in the spring of 2017 until it was sampled in the spring of 2018. The date of sampling is known for all farms.

The date of emptying the tanks in 2017 and the amount taken out of the tanks between the emptying in 2017 and the sampling time in spring 2018 were given by the farmers. The date of emptying in 2017 was known rather precisely by all farmers, whereas for some farmers the amount taken out after spring 2017, and the amount left in the spring of 2017 was less precise. The amount of slurry in the tanks at the day of sampling was calculated from the diameter of the tank and the depth from the surface of the slurry to the bottom of the tank.

Table 3. The production line, animal categories and numbers, and manure types at the Danish pilot farms.

Farm number	Production	Animal categories	Total number of animals per farm	Number of animals at the sampled barn during the manure production period	Manure type
1	Pigs	Sows Weaning pigs Slaughter pigs	520 18000 14400	0 0 6670	Slurry
2	Pigs	Slaughter pigs	8750	8483	Slurry
3	Pigs	Slaughter pigs	5974	5974	Slurry
4	Pigs	Sows Weaning pigs Slaughter pigs	563 20000 8200	0 0 2665	Slurry
5	Pigs	Slaughter pigs	7000	6693	Slurry
6	Pigs	Slaughter pigs	26000	3405	Slurry
7	Pigs	Slaughter pigs	33600	5853	Slurry
8	Dairy cattle	Dairy cows Heifers	209 257	209 257	Slurry
9	Pigs	Sows Weaning pigs Slaughter pigs	2200 62000 1500	2061 0 0	Slurry
10	Fur	Adult mink	7200	7200	Slurry
11	Broilers	Broilers	800000	800000	Solid

Farm DK1

The farm had 520 sows that weaned 18000 piglets and 14400 of these were fed up to slaughter weight. The manure type produced was slurry. Only slurry from 6670 slaughter pigs was stored in the tank which was sampled. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered the composition of both home-grown feed and the feed bought from commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels once per week. Straw was used for bedding with 5 tons per year.

Slurry was stored in a 4 m high 2500 m^3 tank covered with natural crust and added deep litter.

Farm DK2

The farm produced 8483 pigs to slaughter weight. The manure type produced was slurry. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels once every six weeks. No bedding material was used.

Slurry was stored in a 5 m high 5500 m^3 tank covered with natural crust.

Farm DK3

The farm produced 5974 pigs to slaughter weight. The manure type produced was slurry. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels every second week. 11 tons of straw was used as bedding material per year.

Slurry was stored in a 4 m high 2000 m^3 tank covered with natural crust.

Farm DK4

The farm had 563 sows that weaned 20000 piglets and 8200 of these were fed up to slaughter weight. The manure type produced was slurry. Only slurry from 2665 slaughter pigs was stored in the tank, which was sampled. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels once per month. No bedding material was used.

Slurry was stored in a 4 m high 2500 m^3 tank covered with natural crust and 3 tons of straw per year.

Farm DK5

The farm produced 6693 pigs to slaughter weight. The manure type produced was slurry. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels once every second week. 11 tons of straw was used for bedding per year.

Slurry was stored in a 4.5 m high 5.000 m^3 tank covered with natural crust and 7 tons of straw per year.

Farm DK6

The farm produced 26000 pigs to slaughter weight. The manure type produced was slurry. Only slurry from 3405 slaughter pigs was stored in the tank, which was sampled. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels once every second week. No bedding was used.

Slurry was stored in a 4 m high 2.000 m^3 tank covered with natural crust and ‘LECA’ nuts.

Farm DK7

The farm produced 33600 pigs to slaughter weight. The manure type produced was slurry. Only slurry from 5853 slaughter pigs was stored in the tank, which was sampled. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected. Live weight at slaughter was calculated as 1.31 * slaughter weight.

Pigs were kept in pens with partially slatted floor (2/3) and partially drained floor (1/3). Slurry was removed from manure channels once per week. No bedding was used.

Slurry was stored in a 3.5 m high 1.800 m^3 tank covered with natural crust and 2.500 tons straw.

Farm DK8

The farm had 209 dairy cows and 257 heifers and calves of heavy breed. The manure type produced was slurry. The farm is located in Eastern Jutland.

Feed and production data were collected by the local cattle advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed for each animal category was registered only a few times during the year. The annual feed intake was extrapolated from these data in the Danish DMS (Dairy Management System) software, which stores data in a central database at Seges. Furthermore, production data such as milk yield and milk composition were collected in DMS.

All cows were kept in a loose housing system with cubicles. There was slatted floor for all cows, despite in the calving boxes with deep litter, where cows were kept for 4-5 days before calving. Cows were kept indoors during the whole year.

Calves and heifers were kept in door all year. Calves until 6 months were housed on deep litter and thereafter on slatted floor and cubicles. Some pregnant heifers were kept on another farm.

Under the slatted floor there was a ring channel system where slurry was flushed frequently.

Straw was used for bedding in the deep litter and saw dust was used in the cubicles.

Slurry was stored in a 4 m high 4.000 m^3 tank covered with natural crust. Also under the slatted floor there was room for a significant amount of slurry.

Farm DK9

The farm had 2200 sows that weaned 62000 piglets and 1500 of these were fed up to slaughter weight. The manure type produced was slurry. Only slurry from 2061 sows was stored in the tank, which was sampled. The farm is located in Eastern Jutland.

Feed and production data were collected by the local pig production advisor, who gathered composition of both home-grown feed and the feed bought at commercial suppliers. The amount of feed was also registered. Furthermore, production data such as daily gain and slaughter weight were collected.

Sows were kept in pens with partially slatted floor (approx. 40%) and partially solid floor (approx. 60%). Slurry was removed from manure channels once per month in the barn for pregnant sows and once per day in the barn with lactating sows. Straw was used for bedding with 150 tons per year.

Slurry was stored in a 5 m high 3.000 m^3 tank covered with natural crust. The farmer did not know how much slurry was removed to other tanks during the year, so it was not possible to compare nutrient production based on the measured N, P and K analyses to the mass balance calculated by the farm-level Calculation Tool.

Germany

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In Germany, five farms were chosen as pilot farms, representing pig, broiler, dairy and beef production (Table 4). Of these, the cattle and pig production are described in this report.

Table 4. The production line, animal categories and numbers, and manure types on the German pilot farms.

Farm number	Production	Animal categories	Number of animals	Manure type
DE1	Dairy cattle, Pigs Sheep Poultry	Dairy cows Heifers Calves Fattening pigs Sows Weaning pigs Sheep Hens	77 9 21 147 49 153 250 1300	Solid manure/ Slurry
DE2	Dairy cattle	Dairy cows Heifers Calves		Slurry
DE3	Dairy cattle, Beef cattle	Dairy cows Heifers Calves Bulls Young bulls	115 90 40 50 65	Slurry
DE4	Pigs	Fattening pigs	1280	Slurry
DE5	Dairy cattle, Pigs	Dairy cows Heifers Calves Fattening pigs	unknown 3100	Slurry

Farm DE1 – cattle and pig manure

Farm DE1 is a research station to investigate species- and behaviour-appropriate husbandry of farm animals. The farm has several animal categories (cattle, pigs, sheep, hen) and production branches. Only cattle and pigs are considered in this report. The farm is situated in the North of Germany where animal production is otherwise more concentrating on cattle and pigs.

During 2017-2018 the farm had 55 dairy cows. Lactating cows produced milk 8600 kg/a on average. Average lactation period was 300 d and dry period 56 d.

The pig production of the farm includes sows, fattening pigs and rears weaned pigs. The production of fattening and weaned pigs is not considered in this project, because only data about sows are available. During 2017-2018 the farm had 49 sows.

The dairy cows were fed with self-produced grass and corn silage, as well as purchased concentrates Milk 335 (rape, soy) MLF 318 G. Non-lactating cows were feed with grass silage and MLF 318 G. The feed ration for the heifers consists only of grass silage. The calves get grass silage, minerals and from the age of 6 weeks for the first 1 year muesli.

The sows were fed with purchased fodder. The daily ration varies between 2.5 kg/sow and day (pregnant sows) and 4.5- 8.5 kg/sow and day (suckling sows).

The animals are kept in loose housing buildings. Dairy cows have a slurry system with straw and sawdust as bedding material (consumption 1kg/animal/day). Heifers, dry cows and calves have bedding with straw (rye, wheat, barley). The amount of straw used is between one round bale (300 kg) for 20 calves up to three round bales for 20 heifers/dry cows per week. The average water consumption is 800 liters per day.

Heifers (52) and non-lactating cows were grazing for the whole day during the grazing period from April to October, while the dairy cows and calves are kept in the barn all times.

The floor of the sow-barn is not slatted. For bedding, one round bale per week (300 kg rye straw) is used.

One part of the slurry is collected in three pumping pits (30 – 40 m^3) with a removal frequency of four times per year. The other part is collected in three further storages (1000 m^3, 1000 m^3, 800 m^3), where the manure of cattle and pigs are stored together. By a clearly reduction of the livestock, the storage capacity is much higher than needed. Usually the storages are not covered, but a formation of a natural crust is possible.

The solid manure is stored on a concreted pad with a floor area of 670 m^2 without a cover. The removal frequency in the barn of heifers is four times per day and one time per week from the barn (capacity 10 m^3) to the storage. In the barn of the dairy cows is an automatically removal system (frequency: 2 times/day). The removal frequency from the barn (capacity 650 m^3) to the storage is normally four times per year.

All slurry and solid manure is used as a fertilizer in the farm. The total field area for manure spreading is 420 ha. The slurry is spread by trailing shoes on arable land and grassland. For the application of solid manure, the broadcaster is applied.

Farm DE2 – dairy cattle slurry

The farmer was unable to answer the survey.

Farm DE3 – dairy and beef cattle slurry

Farm DE3 represents German dairy and beef production. The farm is situated in North-West Germany.

During 2017-2018, the farm had 115 dairy cows. Lactating cows produced milk 9565 kg on average. Additionally, the farm had 90 heifers, 40 calves, 65 young bulls and 50 bulls. The breed is 100% Holstein-Frisian.

The dairy cows were fed with total mixed ration (TMR) composed of grass silage, corn silage, rapeseed coarse meal, rye-corn-mix, straw and minerals. Due to other nutrient requirements, non-lactating cows were fed with a different mix ratio of TMR and without rye-corn mix. The feed ration for heifers consisted of grass silage and minerals. Calves get milk and ad libitum hay and muesli. For bulls and young bulls, the TMR is grass silage, corn silage and cereals in different composition.

Dairy cows were grazing 6h per day for minimum 120 days during the grazing period in summer time, while non-lactating cows, heifers and calves older than 5 months grazed all day in the summer time. Calves less 5 months, bulls and young bulls were not grazing.

The animals are kept in different loose housing. Dairy cows have a slurry system with straw as the bedding material (0.3 kg/animal/ day). Average water consumption is 3500 liters per day. Dry cows, calves and young bulls have straw bedding. Heifers and bulls have a similar housing and manure system than the dairy cows.

Slurry from dairy cows is emptied every 4 weeks to the lagoon (2700 m^3). The slurry of heifers as well as the slurry of the bulls is stored in tanks (800m^3, 1000m^3). All stored slurry have a natural crust. Solid manure of dry cows, young bulls (removal frequency: every 4 weeks) and calves (removal frequency: weekly) is emptied to a container with a storage volume of 400 m^3.

The total field area for manure spreading is 170 ha. 200 tonnes of solid fraction from slurry separation is used in a biogas plant and the resulting digestate is used as a fertilizer. Slurry is spread by a bandspreader on arable land and by a broadcaster on grassland. For the application of the solid manure, a broadcoaster is used.

Farm DE4 – pig slurry

Farm DE4 produces fattening pigs. The farm is situated in the North of Germany and the manure type produced is slurry. The farm produced 1280 pigs in 2017-2018.

The fattening pigs were fed with purchased ATR SM VM 104 and ATR SM MM 204. The daily ration is 2.48 kg/animal and day. The fattening period of 103 days ends with a delivery weight of 124.9 kg.

Pigs are kept in bays (28 pigs/bay) with slatted floor. Slurry is removed from manure channels via pumping. No bedding material is used and the water consumption for washing is 105.85l/animal/year.

The slurry is emptied automatically every 6 weeks and is stored in a 1500 m^3 tank with a perlite cover.

All slurry manure is used as a fertilizer in the farm. The field area for manure spreading is 73.25 ha where manure is applied by band spreaders with drag hoses.

Farm DE5 – pig slurry

Farm DE5 is situated in North-West Germany and produces fattening pigs and milk. Here only the pig production system is described because the farmer was not able to answer the survey concerning dairy cattle. The farm fattened 3100 pigs in 2017-2018.

Feeding

The fattening pigs were fed with self-produced as well as purchased feed. The self-produced feed contains crop seeds (wheat, triticale, rye), barley and pea. The daily ration is 2.27 kg/day and animal. The fattening period of 112 days ends with a delivery weight of 120 kg.

All pigs are kept in a barn with 3600 m^2 and 100% slatted floor. Water for washing is used once per week, but the amount of the consumed is not given.

Slurry is removed from manure and cross channels to a 5900 m^3 tank with a crust (no further description). The frequency of emptying was according to the demand of a biogas plant. More details about the solid manure are not available.

All slurry manure is used as a fertilizer on the farm. The field area for manure spreading is 1200.48 ha. More details about the application technique and the use of solid manure are not available.

Poland

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In Poland, sampling was done on five pilot farms representing various branches of production: dairy and beef cattle, sheep, pigs and poultry (broilers) (Table 5). After acknowledging that during the project meeting sheep production is of marginal importance (PL3), another pig farm (PL6) and a dairy farm (PL7) were selected. Due to the involvement in another Interreg Baltic Slurry Acidification project, samples were also taken from two farms (PL8 and PL9) where the slurry was acidified with sulfuric acid and used for fertilization.

Table 5. The production line, animal categories and numbers, and manure types at the Polish pilot farms.

No.	Production	Animal categories	No. of animals	Manure type	Farm area [ha]
PL1	Pigs	Fattening pigs	650	solid manure, urine	165
PL2	Chicken broilers	Chicken broilers	70,000	solid manure	78
PL3	Sheep	Ewes Lambs Rams	50 55 2	deep litter	28
PL4	Dairy cows	Dairy cows Heifers Young bulls	90 30 40	solid manure, urine	75
PL5	Beef cattle	Young bulls	60	deep litter	65
PL6	Pigs integrated	Sows Fattening pigs Weaning pigs	65 1,700 1,800	slurry	83
PL7	Dairy cows	Dairy cows Heifers Young bulls	70 30 20	solid manure, urine	130
PL8	Dairy cows	Cows Heifers Young bulls	350 100 150	solid manure, slurry	220
PL9	Pigs integrated	Sows Weaning pigs Fattening pigs	100 2,800 2,500	slurry	120

Farm PL1

Farm PL1 produces fattening pigs. Their manure type is solid manure. The farm is situated in the Wielkopolska Region – Central Western part of Poland. The farm produces on average 1400 pigs a year. Weaning pigs weighing 30 kg (400 reared pieces) are purchased from specialized breeding (Danish landrace x Duroc / Pietrain) and fattened to 115-120 kg. The fattening cycle lasts 95 days plus 5 days between batches, it means 3.5 cycle a year, which after deducting losses gives 1400 units sold.

Weaned pigs had fixed doses by an advisor from a feed company which contained: 12% of protein starter composition, 12% of maize and 12% rye F1, and 32% of spring barley and 32% winter wheat. The dose for fatteners was protein finisher composition - 30%, 10% maize and 10% winter wheat, and 25% of spring barley and 25% rye F1.

Both weaned and fattening pigs were kept in shallow litter barn with pens. 10 to 30 animals were placed in pens the size of which differed from 16 to 25 m^2. Manure was removed out once a day. Fatteners were kept on shallow litter too in big pens 20-40 pigs, and manure was removed once a day. Between littering, surfaces were flushed to the handheld tank. Straw consumption was 1500 big bales per year (350 tons).

Manure was stored in an open manure plate with an area of 350 m^2 (875 m^3) located 500 meters from piggery. Manure on the heap was stored up to a height of 3-3.5 m. The urine from piggeries was stored in two tanks. First tank (60 m^3) was located next to the piggery and the urine was transported to the second tank every two months. Second tank (150 m^3) was located under manure plate and it was used as the main urine container and for collecting leachate from the plate.

Manure was used for fertilization on maize fields (spring, 40 t/ha) and winter cereal fields (autumn, 10 t/ha). Manure was applied on stubble before rye and spread by horizontal spreader and urine was spread by band spreader.

Farm PL2

Farm PL2 produces chicken broilers. The housing system provides deep litter. The farm is situated in the Wielkopolska Region – Central Western part of Poland. The farm is specialized in poultry production with broilers and deep litter manure. Production is 240000 broilers a year in six batches (39500 broilers per batch). The number of days from start breeding to delivery is 49 days and delivery weight is 2.2 kg.

Feeding was divided into five stages (from starter to the finisher). Based on own cereals (mainly winter wheat, and corn – both 30%) with soybean meal 30% and feed additives: rape meal, fish meal plus adequate to stage premix.

Broiler halls had a total area of 4150 m^2, provided deep litter with straw (partly) and lastly peat bedding. Deep litter was removed between batches.

At the farm, there were maneuvering plates for removed manure. Manure was stored on the plate 2000 m^2. Field heaps were also established in the fields intended for fertilization.

The farm has 78 ha - most manure was used on its own farm. Manure was occasionally sold. Manure was used every second year for winter crops (wheat, rape, barley), and corn. For winter crops were applied mostly in autumn (7 t/ha), before sowing. For maize (10 t/ha) was used in spring, in April. The manure was spread by a muck spreader and immediately incorporated.

Farm PL4

Farm PL4 is a dairy farm with solid manure and deep litter system, but with a separate collection of solid manure and urine. The farm is situated in the Southern Mazovia, Central part of Poland. The farm is focused on dairy cows (cross between Holstein Frisian 80-90% and Polish Black and White), but the farmer keeps some young bulls and heifers for sale. There were 90 dairy cows on the farm, with on average 10 month lactation period and 2 month dry period. Lactating cows produced milk 9500 kg. The cows are milked on average twice a day. The farmer is currently building a modern building with 120 automated milking bays.

The cows received TMR composed of corn silage, grass silage, cereals, protein supplement and minerals.

The dairy cows were kept in an old tie stall barn 600 m^2, with shallow bedding, removed daily. The second building was 250 m^2 for heifers, calves and young bulls in loose housing with deep litter bedding. The solid manure and urine were separately collected from milking cows. Bedding consumption was 300 round bales per year.

In the loose range building (young cattle), the manure was removed twice a year - in spring and early autumn. The manure was transported directly to the fields where it was spread. The manure from the milking cows' building was removed every day by a tractor with a front loader to the manure plate (60 m^2). Excess of manure was transported to fields where field piles are located. Urine is moved through the underbuilding channels to the 80 m^3 tank.

Manure was transported to fields - in autumn for winter crops and for grass. The manure was spread by a muck spreader.

Farm PL5

The farm is focused on rearing beef cattle (Limousine, Hereford, Charolais). The manure type produced is deep litter. The farm is situated in the Southern Mazovia, Central part of Poland. The farmer buys a calf - bulls weighing 50-70 kg and raised to a weight of 500-600 kg. Sometimes farmer buys heifers that he breeds, inseminates them and sells the calves.

The bulls were divided into age groups up to one year and above. The fodder was a mixture of grass and clover in the form of silage with a complementary feed - cereals. The older animal group received increased doses of cereals.

The older bulls were kept in a 180 m^2 building, while the youngest in 80 m^2. Bulls were maintained in loose housing with deep litter bedding.

The manure was stored in the buildings and was removed twice a year - in spring and early autumn. The manure was transported directly to the fields where it was spread.

The manure was transported to fields - in autumn for winter crops and for grass. The manure was spread by a muck spreader.

Farm PL7

Farm PL7 is also a dairy farm, with a separate collection of solid manure and urine too. The farm is situated in the Southern Mazovia, Central-Eastern part of Poland. The farm belongs to the Institute of Soil Science and Plant Cultivation. In addition to the experimental and scientific part of the 3500 plot of land, commercial agricultural production is carried out, with a focus on dairy farming. The farm has an average of 125 cattle units. Calves with the exception of breeding heifers are sold. There are feed stations and computerized feeding systems on the farm. The farm consists of 100% of HF Holstein Frisians. There were 60 dairy cows on the farm, with an average of 10.5 month lactation period and 2 month dry period. Lactating cows produced 8000 kg of milk and it is still rising. They were milked on average twice per day. The farm manager intends to increase the herd to 100 dairy cows with a capacity of 10000 kg of milk per year and move young cattle to other buildings.

During the winter period, the cows received TMR composed of 50% corn silage, 34% grass and lucerne silage, 10% brewers grains 8% cereals and proteins, minerals. During the summer period, the cows received TMR composed of 25% corn silage, 17% grass and lucerne silage, 33% grass grazing, 7% brewers grains, 8% cereals and proteins, and minerals.

The dairy cows and young animals were kept in the new tie stall barn (1000 m^2), with shallow bedding and concrete floor, cleaned by tractor daily. Solid manure and urine were separately collected. Bedding consumption was 1350 m^3 of straw per year.

In the loose range building, the manure was removed twice a day by the tractor with front loader and it pushed the manure directly onto a manure plate behind the building. The plate is 480 square meters with the possibility of storing 1200 m^3 of manure. Under the plate, there is a tank for urine and leachate from the plate with a capacity of 360 m^3. The manure was transported directly to the fields where it was spread.

The manure was spread each year to about 45% of the farm's area (for corn, barley and spring cereals), the rest was sold to local farmers. The urine was entirely used on grassland.

Lithuania

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In Lithuania, eleven farms were chosen as pilot farms, representing dairy, beef, sheep, goat, horse and broiler production (Table 6). Of these, the cattle, beef and horse farms are described in this report. Other farms are lacking mostly crop production data or as in case with broiler farms are unconnected to crop production on fields.

Table 6. The production line, animal categories and numbers, and manure types on the Lithuanian pilot farms.

Farm number	Production	Animal categories	Number of animals	Manure type
1	Dairy cattle	Dairy cows Heifers Calves	123 66 47	Slurry
2	Dairy cattle	Dairy cows Heifers Calves Bulls	39 15 22 12	Solid manure
3	Dairy cattle	Dairy cows Heifers Calves	127 151 19	Slurry
4	Dairy cattle	Dairy cows Heifers Young bulls	73 67 77	Solid manure
5	Beef cattle	Suckler cows Bulls Heifers Calves	60 41 24 60	Deep litter compost

Farm LT1 - dairy cattle and slurry

Farm LT1 represents Lithuanian dairy production and a slurry-based housing system. The farm is situated in Central Lithuania.

During 2017-2018, there were 123 dairy cows on the farm. Only dry cows and pregnant heifers (10) were grazing for around 6 months during the grazing period (usually from April-May to September-October in Lithuania), while all other animals were kept in the loose housing at all times. Lactating cows produced milk 9421 kg on average. Average lactation period was 300 d and dry period 60 d. The farm had milking parlour system.

The cows were fed with mixed ration composed of grass and corn silage, cereals, protein supplement and minerals. Three slightly different mixtures were used for lactating, dry cows and heifers respectively.

Dairy cows and heifers are kept in one loose house building with slurry manure system without bedding material (on rubber mattresses in the cubicles). Average water consumption is around 800 litters per day. Calves are kept in separate building and have a deep litter bedding with straw.

Slurry from dairy cows is collected via pumping pit to the above-ground container (2400 m^3). Storage near housing has a natural crust. Deep litter of calves is emptied every 50 days and is given away.

All slurry manure is used as a fertilizer in the farm. Of the slurry, 50% is spread during the growing season and 50% is stored over winter. Of the deep litter, 100% is given away right after emptying the house. Total field area for manure spreading is 208 ha. Farm spreads the slurry manure by hose applicator. Slurry is spread mostly for cereals and legumes.

Farm LT2 - dairy cattle and solid manure

Farm LT2 is also a dairy farm, but with solid manure system. It is situated in Central Lithuania on a region with intense animal production (cattle, pigs and poultry).

During 2017-2018, there were 39 dairy cows on the farm, with on average 258 days lactation period and 2 months dry period. Lactating cows produced milk 6373 kg. All animals were grazing for 6 months during the grazing period (usually from April-May to September-October in Lithuania). The farm had line milking system.

Feeding plans for milking cows and heifers are made by an advisor from Lithuanian Agricultural Advisory Service. Cows are fed according to the plan for milking cows and total mixed ration is composed of grass silage, cereals, protein supplement and minerals.

The dairy cows were kept in an old tie stall barn. Solid manure is collected with help of tractor loader at least once per week. Heifers and calves older than 2 months were in a loose housing with deep litter bedding. Bedding consumption was around 60 t/year of straw.

Solid manure is collected to field heap of total size 400 m^3 by trailer once a week. This storage is uncovered.

Field area for manure fertilization is 40 ha. 31 ha are dedicated to grass for silage and remaining 9 ha are used for cultivating of cereals. Solid manure is spread by a broadcaster and incorporated by ploughing.

Farm LT3 - dairy cattle and slurry

Farm LT3 is situated in Central-West Lithuania on a region with intense animal production (cattle, pigs and poultry).

During 2017-2018 there were 127 dairy cows on the farm. Dairy cows were grazing for 6 months during the grazing period (usually from April-May to September-October in Lithuania), while all other animals were kept in the loose housing on litter at all times.

Lactating cows produced milk 6517 kg on average. Average lactation period was 283 d. The farm had line milking system.

The cows were fed with mixed ration composed of grass silage, cereals, protein supplement and minerals.

The animals are kept in three different buildings. The dairy cows were kept in an old tie stall barn without bedding material (on rubber mattresses in the standing places). Heifers, dry cows and calves have a litter bedding with straw.

Slurry from dairy cows is collected via pumping pit to the container (2700 m^3). Solid manure is collected in field heap 2 km away where some of the fields are situated. The storages near the animal house have a natural crust and the remote storage is not covered. Solid manure of heifers, calves and dry cows is emptied every 10 days to the storage.

All slurry and solid manure is used as a fertilizer in the farm. Total field area for manure spreading is 314 ha. Manure is used for fertilizing of spring, autumn cereals and grass. Solid manure is spread by a broadcaster and incorporated by ploughing.

Farm LT4 - dairy cattle and solid manure

Farm LT4 is a dairy farm with collection of solid manure. It is situated in the North-Western Lithuania on a region with intense animal production (cattle, pigs and poultry).

During 2017-2018, there were 73 dairy cows on the farm, with on average 262 days lactation period. Lactating cows produced milk 6217 kg. They were milked 2 times per day in milking parlour. All animals were grazing for 6 months during the grazing period, while calves were kept in the loose housing at all times.

Feeding plans for milking cows and heifers are made by an advisor from Lithuanian Agricultural Advisory Service. Mixed ration composed of grass silage, cereals, protein supplement and minerals. Dry cows are fed according to the plan for milking cows but without concentrated feed.

Dairy cows and heifers are kept in one loose house building with straw as bedding material (in pathways and in the cubicles). Calves and bulls are kept in separate building and have a litter bedding with straw.

Solid manure is collected to open storage with concrete pad with capacity over 1200 t per year. Solid manure is transported from barn to storage by bulldozer once a week. Liquid manure and other effluents from solid manure storage are collected via pumping pit to the aboveground container (800 m^3). Both storages are uncovered. Solid manure from calves and bulls and bull is collected to the same storage every 10 days by machinery.

Field area for manure fertilization is 95 ha. Manure is used for fertilizing of cereals and grass. Solid manure is spread by a broadcaster and incorporated by ploughing.

Farm LT5 - beef cattle and deep litter compost

Farm 5 produces organic beef cattle. Their manure type is deep litter. The farm is located in the Central-East of Lithuania.

During 2017-2018, the farm had 60 nursing cows, 24 heifers, 60 calves and 41 bulls. All animals were kept in a loose housing with a deep litter (straw bedding) except for 6 month grazing period. Average body weight at the end of fattening is 750 kg.

Beef cattle are fed mostly with own grown and prepared cereal ration mixtures.

Animals were kept in a loose housing with one side open. Straw consumption was 150 t per year. Deep litter was removed once a year.

Four field heaps of 175 m^3 each for manure were located by a 0.5 km distance from the farm. All storages were covered by straw or natural sward. Manure stays in heaps for around one year and aerobic compost is produced. After 1-4 months the heaps are first time mixed with front loader for purpose of aeration and the total mixing frequency is four times. The core temperature is monitored and not allowed to reach more than 70 ^oC.

Total field area is 100 ha where manure is used as a fertilizer for cereals. Produced compost is spread by a broadcaster and incorporated by ploughing.

Latvia

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In Latvia 26 farms (Table 7) were chosen initially as pilot farms, but during the sampling and surveying only 22 remained. Farms were chosen to match the animal categories from 23 December 2014 Cabinet Regulation No. 834 and distributed evenly throughout the country.

Table 7. The production lines and manure types of the Latvian pilot farms.

Animal category	Number of production lines	
	Solid manure	*Slurry*
Dairy cattle (< 6000 kg milk yield)	1	1
Dairy cattle (6000-8000 kg milk yield)	2	2
Dairy cattle (8000-10000 kg milk yield)	3	5
Dairy cattle (> 10000 kg milk yield)	2	7
Suckler cow	2	0
Heifer (< 6 months)	4	0
Heifer (≥ 6 months)	3	0
Fattening young cattle (≥ 6 months)	1	2
Sheep	2	0
Fattening pigs (> 30 kg)	0	3
Sow with piglets	0	3

Out of 22 pilot farms 8 could not provide almost any of the required data for various project activities and only few of the farms with the most complete data were used in the project activities (Table 8).

Table 8. The production line, animal categories and numbers, and manure types of the Latvian pilot farms.

Farm number	Production	Animal categories	Number of animals	Manure type
1	Dairy cows	Dairy cows Heifers Calves	637 563 148	Slurry and solid manure
2	Dairy cows	Dairy cows Heifers Calves	135 154 62	Solid manure
3	Dairy cows Beef cattle	Dairy cows Bulls Heifers Calves	640 256 314 307	Slurry
4	Pigs	Fattening pigs Weaned pigs Sows	1362 735 291	Slurry
5	Dairy cows	Dairy cows Bulls Calves Suckler cows	57 1 3 35	Solid manure
6	Dairy cows	Dairy cows Heifers	450 335	Slurry

Farm LV1

Farm LV1 is a large dairy cow farm with an average of 10.6 t/a milk yield. The manure produced is slurry. The farm is located in Vidzeme state planning region.

During 2017-2018 the farm had 637 dairy cows, 563 heifers and 148 calves. The animals were kept in loose housing all year round. The dairy cows had 358 day lactation period and 61 day dry period, on average the dairy cows produced 10375 kg milk.

Each animal group has different feed mixture. The main component in mixtures is grass-silage produced by the farm itself.

The manure is removed by continuous scraper system to 60 m^3 pumping pit. The slurry is moved from pumping pit to storage twice per day. Calves have rubber mat, for other animal groups 900 m^3 straws are used as litter yearly. The farm could not provide amounts of water used.

Slurry from cows is collected in 8000 m^3 lagoon. It is covered by a natural crust.

Total field area for manure spreading is 1015 ha. All produced manure is spread by the farm itself on their fields.

Farm LV2

Farm LV2 is an average sized dairy cow farm with 11.9 t/a milk yield. The housing system is unusual for such a large farm and provides solid manure. The farm is located in Riga state planning region.

In the years 2017-2018 the farm had 135 dairy cows, 154 heifers and 62 calves. On average the dairy cows had 400 day lactation period and 64 day dry period and produced 11900 kg of milk. The farm had loose housing for all animals and without grazing.

Each animal group has different feed mixture.

584 t or 7300 m^3 of winter wheat straw were used as bedding per year. The manure is removed once per day. The farm uses 110 L of water per day.

The farm has four small concrete storages for 500 t of solid manure. After one to two weeks manure is removed to five heaps on the field.

Total field area for manure spreading is 163 ha. All produced manure is spread by the farm itself on their fields.

Farm LV3

Farm 3 is a large farm. It has dairy cows farm with 12.5 t yields and beef cattle. The manure type produced slurry. The farm is in Zemgale state planning region.

The farm had 640 dairy cows, 256 bulls, 314 heifers and 307 calves in 2017-2018. The dairy cows produce 12564 kg of milk and has lactation period of 368 days and dry period of 63 days. For the beef cattle the final weight is 750 kg. The animals are kept in loose housing and are not let out to graze.

Total mixed ratio is used, each animal group has a different feed mixture.

3000 m^3 of winter crop straws and the same amount of spring crop straw are used as litter each year. The calves up to 3 months are kept on straws on solid floor and produce solid. The slurry is collected with scraper once per day and pumped to storage once per day. From all the water the farm consumes approximately 2000 L of water per day is directed to slurry storages.

The farm has three slurry storages. Two of them are lagoons for 6000 m^3 and 7000 m^3 manure, the third is tank with volume of 6000 m^3. The storages are covered with natural crust.

The manure is spread on fields with total area of 391 ha. The spreading partly is done by themselves and partly as a service.

Farm LV4

Farm LV4 is a large pig farm that produces slurry. The farm is in Kurzeme state planning region.

In the period of 2017-2018 they had 1362 fattening pigs, 291 sows and 735 weaned pigs.

The farm use prepared mixtures for each animal group. The feed is mixed on the farm using mostly own products. The farm knows the recipes of all the mixtures, total amount of feed used and amount of each component in the mixture. Additionally, the feed is provided as necessary, which makes it hard to calculate how much feed each animal group consumes.

No bedding material is used except for gestating sows, which are kept on glass fiber mat. The animals are kept on slated floor. The slurry is removed by gravity. 200 L of washing water is used per week.

The farm has concrete storage with 700 m^3 volume that is covered by natural crust.

The manure is spread on fields with total area of 316 ha using only their own equipment.

Farm LV5

Farm LV5 is a small dairy cow farm with a 5 t/a milk yield. The manure type is solid manure. The farm is located in Riga state planning region.

In year 2017-2018 the farm had 57 dairy cows, 1 bull, 3 calves and 35 suckler cows. For the dairy cows average lactation period is 319 days and the dry period is 46 days. The dairy cows produce 5000 kg of milk annually. The animals are kept in loose housing system. The animals graze five to six months from the late spring to early autumn and grazing time is about 10 hours each day. The suckler cows have free access to outdoors.

During grazing period, the animals mostly consume grass, during winter they are given silage.

The manure is collected with scrapper system two times per day in summer or three times per day in winter. Throughout the year 300 m^3 hay is used as bedding material.

The manure has storage with area of 392 m^2 the volume of storage depends on heap size but is estimated to be 1417 m^3. Urine is collected separately in a tank with volume of 45 m^3.

The manure is spread on field with area of 35 ha.

Farm LV6

Farm LV6 is a dairy cow farm that produces slurry from Kurzeme state planning region. The average milk yield is 13 t per year.

In year 2017-2018 the farm had 450 dairy cows and 335 heifers. For the dairy cows average lactation period is 310 days and the dry period is 55 days. Both the dairy cows and heifers are kept in loose system and indoors all year. The dairy cows produce 13000 kg milk per year.

The dairy cows have different feed depending on group, but main components are corn and grass silage.

The manure is removed with scrapper system once per hour. 2500 m^3 of hay, 2100 m^3 of sawdust and lime is used as bedding material. About 4365 m^3 washing water is added to slurry per year.

The farm has an old slurry storage for 4100 m^3 manure or only 4 months of manure. The storage is covered by a natural crust.

The manure is spread on field with area of 603 ha. The crops grown are corn, grass or spring wheat.

Estonia

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In Estonia, there were six pilot farms, five of which are described here (Table 9).

Table 9. The production line, animal categories and numbers, and manure types on the Estonian pilot farms.

Farm number	Production	Animal categories	Number of animals	Manure type
1	Dairy cattle	Dairy cows	591	Slurry
2	Dairy cattle	Dairy cows Heifers Calves Young bulls	134 75 37 10	Slurry
3	Beef cattle	Suckler cows Hefers Young bulls Calves Breeding bulls	21 18 12 10 1	Deep litter
5	Poultry	Broilers	27 500	Deep litter
6	Poultry	Laying hens	27 840	Solid

Farm EE1 – dairy cattle (only milking cows) and slurry

Farm EE1 representing large scale Estonian loose housing dairy farm with liquid manure system. Animals are kept all year inside without grazing.

During 2017-2018, there were 591 Estonian Holstein cows, (average dry period 62 days). Average milk yield was 11356 kg per cow per year.

Milking cows were fed with four different total mixed ration (TMR) composed of grass and corn silage, hay, barley straw, cereals, rapeseed cake and minerals. Dry cows are fed with two different TMR (first and pre-calving period). The company produces silage and cereals. Protein, energy and mineral feeds are purchased.

Cows are kept in a loose housing uninsulated cowshed without bedding material (rubber mats). Manure is removed by scraper 12 times per day (summer period) or 24 times per day (winter period). Manure from cross-channel is removed twice a day to the 20 m^3 pumping pit, which is emptied daily. Average water consumption for washing/rinsing is approximately 300 l/day.

Manure is stored in one 8900 m^3 slurry tank, covered with natural crust.

Field area for manure fertilization is 695 ha. All the manure is used (spread out) to own fields, twice a year. Manure is applied mainly by injecting to the soil.

Farm EE2 – dairy cattle and slurry

Farm EE2 representing medium size dairy farm in Estonia. Farm has a slurry-based manure system. Animals (all age groups) are kept all year inside without grazing

During 2017-2018, there were 132 (Estonian Holstein, Estonian Red and Estonian Native) cows (average dry period 68 days). Milk yield was 9736 kg per lactation.

Milking cows were fed with three different total mixed ration (TMR) composed of grass silage, cereals, rapeseed cake and minerals. Dry cows were fed with two different rations (first and pre-calving period). Heifers from the age of 8 months until pregnancy were fed with one ration composed of grass silage and minerals. Farm grows only grass for silage and hay, other feed components are bought.

Cows are kept in a one semi-insulated loose housing building, divided to two parts, with connected slurry system. Lactating cows have a little bedding material (rubber mats and peat + sawdust). In the other part young stock and dry cows (rubber mats) are kept and there is also a calving section. Calves' area is covered with bedding material (straw, sawdust and peat), which is removed daily. Otherwise, slurry is removed from manure channel by a scraper 12 times per day. Manure from the cross-channel is removed every two days to the 70 m^3 pumping pit, which is emptied twice a week. Average water consumption for washing/rinsing is 200 l/day. Water from cleaning the milking system is sent to the city wastewater system.

The slurry is stored in one 4500 m^3 slurry tank, covered with concrete roof.

Own field area for manure fertilization is 100 ha (grassland). 5500 m^3 manure is exported off-farm, to the local grain producer. Manure is applied by injecting to the soil.

Farm EE3 – beef cattle and deep litter

Farm EE3 is an example of an Estonian small-size beef cattle farm. All animals were kept in a loose housing system with deep litter (straw bedding in the shelter). Animals are grazed during the vegetation period. In the winter period, animals have free access outside to the walking and feeding area. During 2017-2018, there were 21 nursing cows.

All animals are fed with grass silage and hay (winter period) and only grass (summer period). Concentrates are not used.

For animals there is one uninsulated shelter with deep litter (especially for winter period). From the beginning of May to the end of September, all animal age groups are kept in grassland.

Manure is deep litter manure. It is collected only in the winter period from walking (feeding) area and from shelter. Manure from shelter is transported to a field heap, where it is stored until October. Manure from walking and feeding area is spread directly to the fields (usually in October).

All the manure is exported off-farm.

Farm EE5 – poultry (broilers) and deep litter

Farm EE5 is an example of Estonian broiler production with deep litter manure system.

During 2017-2018 the number of broilers produced was 27500. The average growing period was approximately 37-39 days, with a final weight of 2.3-2.5 kg.

Broilers were fed with four different rations, according to the age. The main components of all rations are wheat and minerals. For every age group, feed is added as a specific concentrate.

Broilers are kept in the floor on deep litter. Floor area is 1674 m^2, divided into eight sections. Manure is removed after every batch with telescope loader. Average depth of deep litter is 3 cm.

This unit has no manure storage. If a section is emptied then manure is loaded to trucks which transport the manure to a nearby (20 km) beef cattle farm where it is stored in field heaps.

Manure is exported off the farm and used for crop fertilization.

Farm EE6 – poultry (laying hens) and solid manure

Farm EE6 represents an Estonian egg producing company with solid manure system. The average number of laying hens per company is approximately 123600 per year. During 2017-2018 there were 27840 laying hens with average production of 276 egg/per bird and year.

The laying hens are fed with four different rations composed of cereals, soybean/sunflower meal, rapeseed oil, minerals etc. components.

The laying hens are kept in enriched cages. No bedding material is used, but the manure is removed by a manure belt and then by a screw-conveyor to the solid manure storage.

Manure is collected to the covered manure storage (floor area 192 m^2) next to the farm. The storage is emptied once every two months and loaded to the next manure storage (not covered) with floor area 1250 m^2 (emptied twice a year).

All the manure is exported off-farm.

Russia

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In Russia, twenty three farms were chosen as pilot farms, representing dairy, pig and farm poultry production, of which six farms are described in this report – 4 cattle farms, 1 pig farm and 1 poultry (egg) factory (Table 10).

Table 10. The production line, animal categories and numbers, and manure types on the Russian pilot farms.

Farm number	Production line	Animal category	Number of animals	Manure type	Number of housing buildings
1	Dairy cattle	Dairy cows Heifers (6 to 23 months) Calves Young bulls Dry (non-lactating) cows	612 543 271 176 86	Semi solid and solid	9
2	Dairy cattle	Dairy cows Heifers Calves Young bulls	1362 747 387 277	Semi solid and solid	15 on two production sites
3	Dairy cattle	Dairy cows Heifers (6 to16 months) Heifers (16 to 23 months) Calves (under 3 months) Calves (3 to 6 months) Dry (non-lactating) cows	833 80 60 450 113 100	Semi solid and solid	4
4	Dairy cattle	Dairy cows Heifers (16 to 23 months) Calves (under 3 months) Heifers (under 6 months) Heifers (12 to 18 months) Bulls (7 to 14 months)	15 2 1 12 5 5	Solid	1
5	Pigs	Sows Weaned piglets Replacement young animals Fattening pigs Boars	6042 32126 2531 28060 116	Slurry in a collector	2
6	Egg production	Layers Replacement young stock	1012735 367700	Solid	

Farm RU1 – dairy cattle and semisolid/solid manure.

Farm RU1 is a livestock complex specialising in dairy production and cattle breeding. The farm is situated in Leningrad Region.

As of the farm survey period (spring 2018), the total number of cattle was 1688 heads, of which 612 were dairy cows. No grazing was used throughout the year. Dairy cows were housed in four buildings. Two buildings had a tied housing system with the pipeline milking; manure was removed by scraper conveyors. The other two buildings for dairy cows had a loose housing system with a milking parlour; manure was removed by a delta scraper unit. Other animal categories were housed in the buildings with the loose housing system; manure was removed by mobile means. The average annual milk yield was 7000 kg per cow; the average lactation period was 302 days.

The rations were formulated according to the recommendations of the zoo-technician. The animals were fed with total mixed ration (TMR) composed of grass silage and complete feed. Different rations were used on different lactation phases.

The animals are housed in nine stand-alone buildings. The sawdust is used as bedding in all animal houses. The daily sawdust consumption on the farm is 2 tons. Calves are kept on litter bedding – 3 kg/head/day. The process water getting into manure on the whole farm is 3.8 tons.

Manure is transported by mobile means to an uncovered watertight pad. Here it is mixed with the moisture-absorbing material – straw (annual consumption – 4605.5 tons). The mix is processed by the passive composting to produce the organic fertiliser. Composting is arranged in clamps (a structured triangular heap) with a height of 2-3 meters, a width of 2.5 - 6 meters, and a random length. Technological passages at least 2.5-3.0 m wide are provided between the rows of compost clamps. The period of compost maturing after the temperature has reached 60 °C in all parts of the clamp is at least 2 months in the warm season (May-October) and at least 3 months in the cold season (November-April). To drain the rainwater away from the watertight pad, special facilities are provided, where both compost effluents and rainwater is accumulated. The minimum dimensions of the active composting pads are not set. The minimum mass of composted mixture in one clamp is set to be at least 100 tons. The farm has four uncovered watertight pads with a capacity of 3000 tons of manure each.

The resulting organic fertiliser is applied to the own agricultural land. The total agricultural land area is 1729 hectares: 400 ha under cereals, 10 ha under potatoes and 1319 ha under perennial grasses. Agricultural land is located at a distance of 15 km from the farm.

Farm RU2 – dairy cattle and semisolid/solid manure.

The main activity of the farm RU2 is milk production. The farm has two production sites; both are situated in Leningrad Region. As of the farm survey period (spring 2018), the total number of cattle was 2773 head: Site 1 - 1752 heads, including 830 dairy cows; Site 2 - 1021 heads, including 532 dairy cows. The average annual milk yield was 8000 kg per cow, with the average milk fat content being 3.6%. The cows were milked twice a day. No grazing was used.

At both production sites, the buildings for dairy cows had tied housing systems with the pipeline milking; manure was removed by scraper conveyors. Other animal categories were housed in the buildings with the loose housing system; manure was removed by mobile means.

The rations were formulated according to the recommendations of the zoo-technician. The animals were fed with total mixed ration (TMR) composed of grass silage and complete feed. Different rations were used on different lactation phases.

Site 1 had eight housing buildings; Site 2 had seven housing buildings. The sawdust was used as bedding in all animal houses. The daily sawdust consumption on Site 1 was 3 tons; the process water getting into manure was 5.8 tons. The daily sawdust consumption on Site 2 was 1.7 tons; the process water getting into manure was 3.9 tons. On both Sites, the pipeline wash water was discharged into the local sewerage system.

Each production site has its own uncovered watertight pad of 50x50 m. Bedding manure is transported by mobile means to these pads, where it is mixed with the moisture-absorbing material (straw) and processed by passive composting into an organic fertilizer. On Site 1 the straw consumption was 5125 t/yr, on Site 2 – 3050 t/yr.

Resulting solid organic fertiliser from both production sites is spread on the own agricultural land with the total area of 3397 ha: 1211 ha under cereals and 2186 ha under perennial grass. The fields are located at a distance of 20 km from the production sites.

Farm RU3 – dairy cattle and semisolid/solid manure.

The main activity of Farm RU3 was milk production. As of the farm survey period (spring 2018), the total number of cattle was 1636 head including 833 cows. The farm was situated in Leningrad Region. The farm had a loose housing system for dairy cows; manure was removed by a delta scraper unit. Other animal categories were housed in the buildings with the loose housing system; manure was removed by mobile means. No grazing was used. The cows were of Holstein breed producing 9032 kg milk per year with the average fat content of 3.6% and protein content 3.2%. The cows were milked three times a day in milking parlour. The average cow mass was 650-660 kg.

The rations were formulated according to the recommendations of the zoo-technician. The animals were fed with total mixed ration (TMR) composed of silage, hay of the own production and purchased complete feed.

Dairy cows were housed on solid floors without bedding. The process water consumption was 1.5 l/head/day. In the maternity barn, the process water consumption was 5 l/head/day and the bedding (sawdust) consumption was 4 kg/head/day. Other animal categories were housed on bedding (sawdust) – 0.5 kg/ head/day average; the amount of process water entering the manure was 1.5 l/head/day.

Semi-solid manure from dairy cows and the wastewater from washing the milking parlour was directed to the receiving tank of the separator by a pipeline. Solid manure from other animal categories was transported by mobile means to a watertight pad.

Semi-solid manure was separated into solid and liquid fractions on a screw separator. The liquid fraction was processed into a liquid organic fertilizer by a long-term storage (maturing) in two round iron uncovered storage facilities with a capacity of 5.5 tons each. The solid fraction of separated manure and solid manure was transported to a watertight pad of 20 x 400 meters, where it was mixed with the moisture-absorbing material (sawdust, 1080 t/yr) and processed into the solid organic fertilizer by passive composting.

The resulting solid and liquid organic fertilizers are applied to the own agricultural land. The total area of farmland is 2949 ha: 816 ha under winter wheat, 300 ha under barley, 1833 ha under fodder grass, of which 1059 ha are under perennial grass. The agricultural lands are located at a distance of 15 km from the livestock complex.

Farm RU4 – dairy cattle and solid manure

Farm RU4 is a small-scale private farm. The main activity is milk production and cattle breeding as well as eco-tourism. The farm is located in Leningrad Region. The farm has 15 dairy cows. The average annual milk yield is 7100 kg per cow with 5.6% fat content. The grazing of animals is provided.

The animals are fed according to the recommendations of the zoo-technician. The main components are complete feed and hay.

The animals are housed in one building. Loose housing on hay bedding is in place.

Solid manure is processed into an organic fertiliser by the long-term storage (maturing) in the storage facility with a capacity of 200 m^3.

The resulting solid organic fertiliser is spread on the own fields with the area of 32 ha.

Farm RU5 – pigs and slurry

Farm RU5 is a large-scale pig rearing enterprise producing pork and engaged in pig breeding. The farm is located in Pskov Region. As of the farm survey period (spring 2018), the farm had 68875 pigs including 6042 sows and 28,060 fattening pigs.

The animals are fed according to the recommendations of the zoo-technician. The main component is complete feed.

The animals are housed in two buildings in individual and group pens. The houses are equipped with the gravity flow pipe-and-pit system with periodic slurry removal (no flushing or scrapers are applied). Under the slatted floors in the houses, there are basins to accumulate the slurry, which flows by the canals to the central holding tank and is removed once in 14 days. No bedding material is used; the process water consumption is 4.5 l/head/day.

The slurry is processed into an organic fertiliser by the long-term storage (maturing) in an uncovered lagoon with the capacity of 3500 tons; uncovered reinforced-concrete collecting tank with the capacity of 1000 tons; uncovered reinforced-concrete collecting tank with the capacity of 3000 tons; two uncovered round reinforced-concrete collecting tanks with the capacity of 9000 tons each.

The resulting organic fertiliser is applied on 762 ha of the own agricultural land under perennial grasses.

Farm RU6 – poultry (eggs) and solid poultry manure

Farm RU6 is a large-scale poultry factory. Main business activity is egg production. Secondary production line is poultry meat and replacement young stock. The farm is located in Leningrad Region. As of the farm survey period (spring 2018), the total number of layers was 1012735 head, the number of young stock was 367700 head. The product yields were 329 eggs per head per year and 0.883 kg of poultry meat per head.

The poultry is fed according to the adopted technology. The complete feed Is purchased at the feed factory. The phase feeding is adopted depending upon the poultry development stage.

The poultry factory applies the cage housing system; the installed equipment is of Zucami Company (Spain). There are 5 poultry houses for replacement young stock and 19 houses for layers.

90% of the poultry manure is transported by mobile means to a watertight pad of 200x70 m, which is located at a distance of 200 m from the poultry complex, and processed into an organic fertilizer by passive composting.

10% of poultry manure are mixed with peat and processed into an organic fertilizer by biofermentation in the chamber fermenter.

The solid organic fertilizer after the passive composting is spread on the agricultural land with the total area of 2530 ha, of which 350 ha are rented by the poultry factory. The solid organic fertilizer after the biofermentation is packed and marketed.

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