

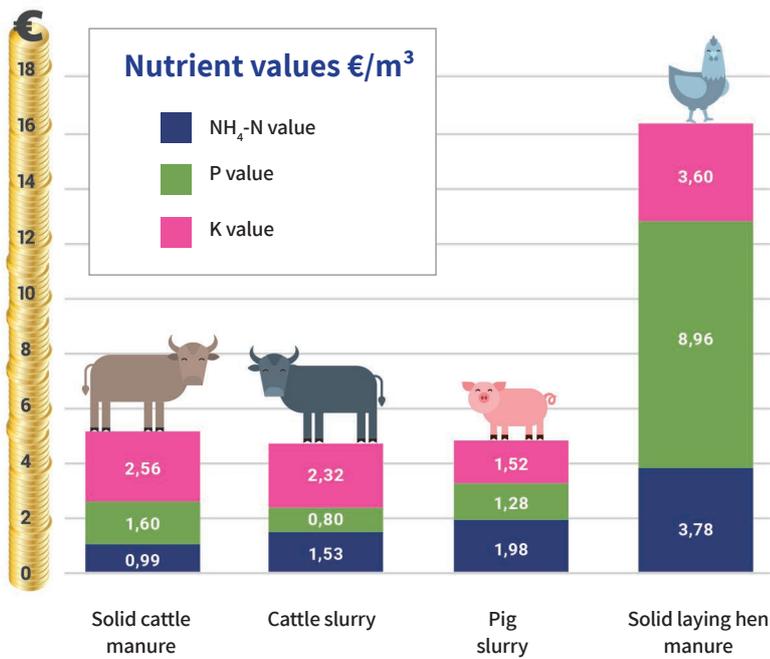


HOW TO MAKE THE MOST OF MANURE?

Handbook on good manure management practices

Manure as a valuable source of nutrients and organic matter

Manure is a valuable resource that should be managed efficiently to make use of its valuable nutrients and to minimize losses. Besides nutrients, manure is also a source of organic matter that is vital for good soil quality. When increasing the organic matter content in the soil, its microbial activity, structure, nitrogen (N) delivery and water holding capacity are improved.



Manure is valuable

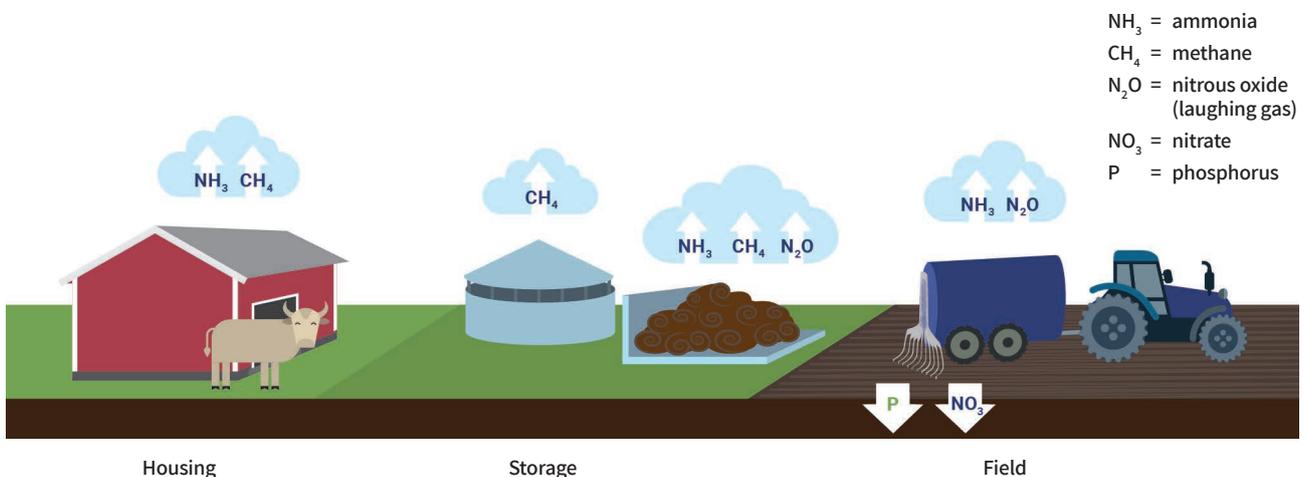
It includes nutrients which are essential to plant growth. The value of manure can be calculated by comparing the manure nutrients to the mineral fertilizer prices.

In this picture, only the readily crop-available ammonia nitrogen (NH₄-N) content is used when counting the value of N in manure. In addition to this, all manure types include essential amounts of organically bound N, which is slowly released to be used by crops.

In the figure, manure nutrient content is taken from Finnish table values and the reference prices for mineral fertilizers from average prices in the Baltic Sea countries in spring 2019.

Avoiding losses from manure on the farm

Losses can occur in all steps of the manure handling chain; in housing, storage or field. This handbook highlights good practices to prevent or minimize the losses.

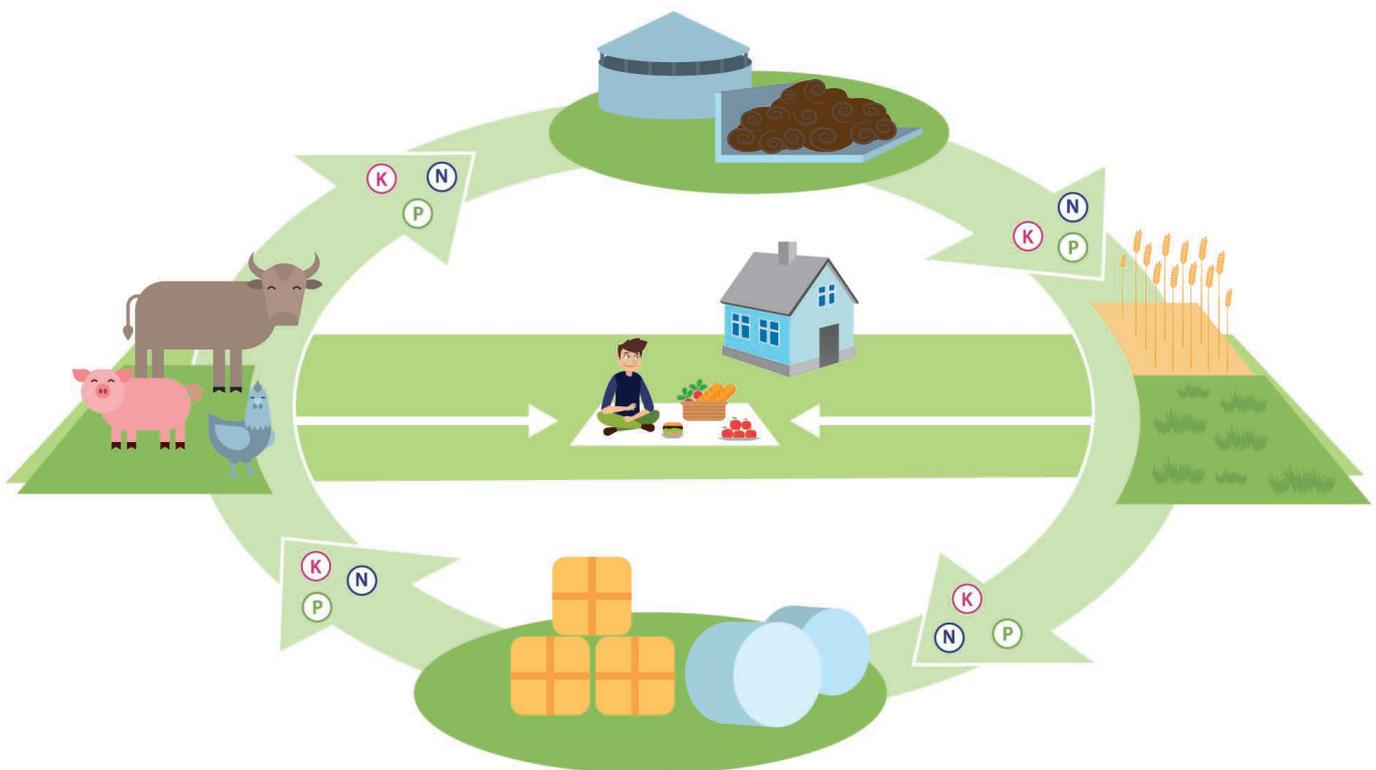


Closing the nutrient loops and minimizing losses to the environment

Phosphorus (P) is a non-renewable resource with finite mineral reserves. As it is essential to feed the world's growing population, there is a need to start recycling phosphorus properly. Nitrogen fertilizers, on the other hand, are produced with energy-intensive methods. They cause high greenhouse gas emissions despite improvements in the production technologies.

Nutrient recycling aims at optimal reuse of nutrients already cycling in the food system. Manure is the most abundant nutrient resource in the Baltic Sea region. Thus, efficient manure management is the key to successful nutrient recycling, preserving phosphorus resources for future generations as well as reducing nutrient losses to surface and ground waters and to the atmosphere as greenhouse gases and ammonia.

Treating manure as a resource instead of a waste requires taking manure nutrients fully into account when fertilizing the crops. That is why it is important to know the manure nutrient content and manure quantity produced as precisely as possible.



The importance of knowing manure nutrient content

Manure nutrient content varies from farm to farm - even between farms with the same animal production. Manure nutrient content can also vary within the farm at different times. The differences stem from e.g. feed recipes and quality, production yields (e.g. milk yield), housing technology including the amount of bedding materials and water added, and storage technology. Therefore, it is essential to know the farm-specific quality of the manure. There are two methods for this: manure sampling for chemical analysis or using a farm level calculation tool.

Manure sampling

Manure is a heterogeneous material and an appropriate sampling technique is important to get a representative sample for manure analysis. In order to have as accurate results as possible, the sampling should occur as close to the removal of manure from the storage basin or spreading the manure as possible.

Manure sample can alternatively be collected as subsamples from several loads during spreading with subsequent mixing of the subsamples to form the actual sample to be analyzed. This 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.

Solid or semi-solid manure (non-pumpable/ dry matter >15%)



Suitable instruments for solid manure sampling include e.g. a pitchfork or a solid manure auger. If sampling is done with an auger, a suitable sampling depth is approximately 1 meter.



8–10 subsamples from different locations of the manure pile in the housing unit or storage should be taken and mixed together to achieve a representative sample of approximately 1 litre for analysis. Subsamples should be taken at different places and depth, not only from the outer layer of the manure pile.



Slurry or urine (pumpable / dry matter <15%)



Slurry and urine should be thoroughly mixed before sampling. To ensure a representative sample, especially in case of difficulties with mixing, the subsamples should preferably be taken at different levels: top, middle and bottom layer.



5–10 subsamples should be taken and mixed together, and a sample of about 1 litre should be taken from the mixture for analysis.



The sample should be sealed immediately and placed in a cooler to ensure a temperature between 1 and 5 Celsius degrees until quick delivery to the laboratory for analysis. The sample may also be frozen.

Farm-level calculation tool for manure amount and nutrient content

Manure nutrient content and manure quantity produced can be calculated as a mass balance. Many countries have national standard values for this, but farm-specific values may give more useful information via consideration of differences between farms. To make an accurate calculation, it is important that the data on farm practices, animals, feedstuff etc. are as precise as possible.

The Manure Standards project has developed a farm-level calculation tool that is free and available online.

THE CALCULATION TOOL

requires accurate input data to produce accurate results. It should only be used, if the required input data is available. The information needed include:

- Precise feed quantity and composition per animal category on the farm
- Information of the produced yield of animal products (milk, meat, eggs)
- Number of animals per animal category on the farm
- Grazing
- Housing technology, including bedding materials and different waters directed to manure
- Storage technology (open or different covers)
- Average precipitation

Understanding the manure analysis report

Results per wet weight or per dry matter content

Manure analysis results (nutrient content) can be reported in different ways, for example based on the sample wet weight or dry matter content. If the results are expressed on dry matter basis (kg/kg DM) the data could be converted to wet weight by:

Result in wet weight = Result per dry matter content x (% dry matter/100)

The wet weight value is then in kg/kg w.w.

If multiplied with 1000, it will be kg/ton slurry.

Total nitrogen (N)

Consists of organically bound N + soluble N (mainly ammonium-N = $\text{NH}_4\text{-N}$). In solid manure, a higher proportion of N is in bound to organic matter than in slurry. It is slowly released due to mineralization and hence crops with a longer growth period (e.g. grasses, cereals with undersown ley or catch crop, maize or sugar beet) can make better use of the released N than e.g. cereals with a shorter growth period.

Soluble N or ammonium N ($\text{NH}_4\text{-N}$) content

Soluble N in manure is directly available for crops.

Total phosphorus (P) may be expressed as P or P_2O_5 where $\text{P} = 0.436 \times \text{P}_2\text{O}_5$

Total potassium (K) may be expressed as K or K_2O where $\text{K} = 0.830 \times \text{K}_2\text{O}$

Dry matter usually expressed as %, the rest being water

Volume weight

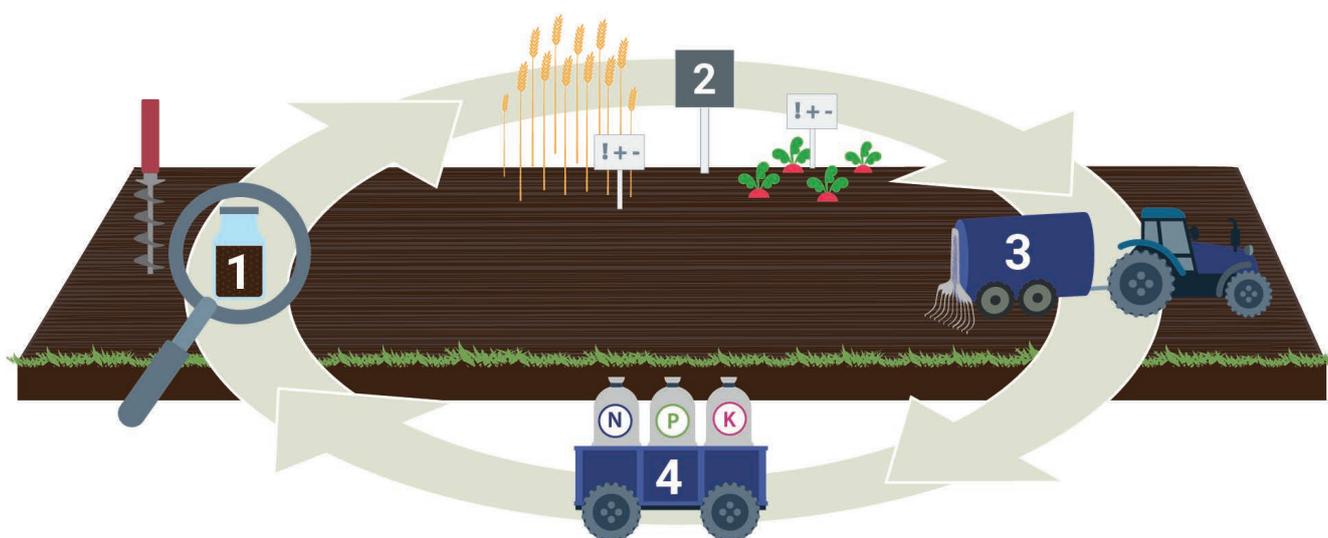
Slurry and urine are in most cases considered to have the volume weight of one tonne per m^3 . The volume weight of solid, semi-solid and deep litter manure varies a lot depending e.g. on the type and amount of bedding material used. Semi-solid manure usually has a volume weight of ca 900 kg/m^3 , solid manure $700\text{--}800 \text{ kg/m}^3$ and deep litter around $350\text{--}600 \text{ kg/m}^3$.

Other nutrients

Analyzing also the contents of other macronutrients (Ca and Mg) and micronutrients (Cu, Mn, Zn and Na) gives important knowledge on their quantity applied in manure.

Planning fertilization according to crops' need and soil fertility

Nutrients are essential for crop growth. Fertilization should therefore be planned well, field by field, to make sure that all the essential nutrients are available for growth. Furthermore, overfertilization should be avoided, as it leads to wasting farm resources and a lower nutrient use efficiency. It also causes negative effects on the environment.



The process of the planning: 1. Soil analysis ► 2. Plant nutrient need ► 3. Starting with manure ► 4. Complementing if necessary

1. Starting with soil analysis

The nutrient content of the soil is the starting point for fertilization planning. The results of the soil fertility analysis give information on the need of many macronutrients, such as P, K, Mg, Ca, S as well as micronutrients (Fe, Cu, Mn, Zn, B, Mo, Cl).

MORE INFORMATION

Look for the national instructions or see the instructions of farm advisory organizations, on how to interpret the soil sample analysis.

2. Defining the crop nutrient need

The next step in fertilization planning is to estimate the amount of nutrients that the crops need. This depends on e.g. crop species, variety, realistic yield potential and the purpose of yield use.

For planning nitrogen fertilization, the starting point is usually the standard nitrogen recommendations based on expected crop yields. The yield potential for each field is based on soil productivity, but weather conditions during the growing season also have a large effect on the final yield. Nutrient balances from previous years are a helpful tool in estimating the suitable nutrient amounts needed.

NOTE

When planning the N fertilization rates, it is also important to include the pre-crop effect, i.e. how much nitrogen is left from the previous crop. Long-term use of manure will also increase the content of soil organic matter and the annual nitrogen delivery from the soil. This must therefore be taken into consideration when planning fertilization.

MORE INFORMATION

Look for the national recommendations for (nitrogen) fertilization for different plants in your country.

3. Choosing the fertilizers starting with manure, taking into account N and P limits

When the amount of nutrients needed has been calculated, suitable fertilizers need to be chosen. On animal farms, the planning starts with how to best utilize the manure nutrients.

The manure nutrients available on farm can be calculated from national standard values or using analysis results. It is important to note that manure nutrients may not be directly available for crop. Depending on manure type, the share on organically bound and thus slowly released nutrients may be higher or lower and their mineralization should be considered. For instance, only part of N is available to the crop during the first year after application.

A good starting point for choosing the fields receiving manure could be to allocate manure to the fields with the lowest P status and dose the manure according to manure P content and crop need, without exceeding maximum N fertilization rates.

NOTE

The manure nutrient content is rarely optimal for crops.

There is usually too much P and K in relation to N which means that there is often a need to complement N with other fertilizers. This depends on the manure type; e.g. cattle manure usually contains more K and less P than pig manure.

The overall fertilization should be a combination of crop nutrient requirement, manure nutrient content and soil nutrient content.

4. Complementing the nutrient need, if necessary

There are several options for complementary fertilizers, if needed, after using the farm's own manure. Fertilizers with one or several nutrients are available. There are both mineral fertilizers as well as fertilizer products of organic origin. N-fixation of leguminous plants can also be used for N complementation.

A variety of recycled fertilizers of organic origin available

- digestate from biogas plants as such or separated into a liquid and a solid fraction
- compost of different organic origin
- meat and bone meal of rendered slaughtering by-products
- dried and pelleted organic fertilizers of different organic origin
- vinasse
- ash-products
- ammonium sulphate from ammonia stripping
- nutrient concentrates from e.g. membrane technologies
- struvite

How to minimize nutrient losses during housing

Optimize feeding

Farm animals can be fed diets with higher than recommended nutrient content as a safeguard against production loss arising from a deficit of these nutrients. In practice, however, the animal cannot utilize the surplus nutrients, but excretes them into manure. The additional feed is thus wasted and more manure is produced.

Livestock at different stage of growth and reproductive cycle have different nutritional requirements. Avoiding excess N and P in the diet by more precise division and grouping or individual feeding of livestock can thus reduce the amount of N and P excreted.

Housing techniques

Factors affecting ammonia volatilization from manure include temperature, the size of the emitting surface area and pH. Addressing these conditions can mitigate ammonia emissions in animal housing. One suitable measure is reducing manure surfaces, using regular and frequent removal of manure.

Since ammonia volatilization is lower in cooler temperatures, lowering the indoor temperature and optimizing ventilation, taking into account animal welfare, can reduce ammonia emissions. There are also techniques to cool or acidify the manure to reduce emissions.

Also, the exhaust air can be treated by acid scrubbers or bio-filters to reduce ammonia and odor emissions.

Feeding recommendations and tools to reduce the excretion of phosphorus and nitrogen

- Reduce the import of crude protein by domestic protein sources or by replacing soybean meal by industrially produced amino acids for pigs and poultry.
- Reduce the import of mined phosphates by replacing feed phosphates by microbial phytase for pigs and poultry.
- Use protein and energy optimised diets for dairy cattle.
- Use multiphase feeding as a tool to supply the animals with the nutrients required for optimal health and production.
- Use liquid feeding as a powerful tool to improve the utilisation of phosphorus and protein in animals.

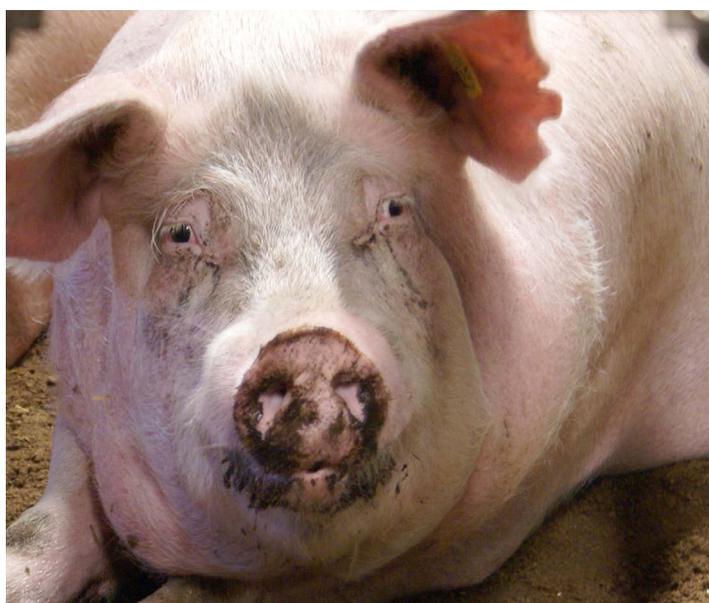


Photo: Airi Kulmala

Ammonia emissions can be reduced

- by regularly cleaning the corridors and slats in animal housing
- by removing urine effectively
- by regularly cleaning slatted floors
- by reducing the air conditioning in the manure corridor
- by lowering the temperature
- by using plenty of bedding material

How to minimize nutrient losses in storage

Safe storage facilities

Solid manure should be stored in dung yards with waterproof floor and side walls. Slurry should be stored in containers that are made of strong material impermeable to moisture and resistant to impacts of manure handling operations. Covering the manure storage reduces ammonia and methane losses. A tight lid, roof or tent are the most effective in preventing losses through volatilization. Covering both slurry and solid manure storages also prevents rain water from entering the manure, reducing the storage capacity needed and the application cost related to increased manure quantity.

Adequate storage capacity

Adequate manure storage capacity provides the possibility to choose when to apply manure on fields. With sufficient storage capacity there will be few occasions when the farmer is forced to spread manure at unsuitable times. Manure should be spread at times when there is an actively growing crop to maximize the nutrient uptake of plants from the manure. Hence spring and summer are generally better times for manure spreading than autumn.



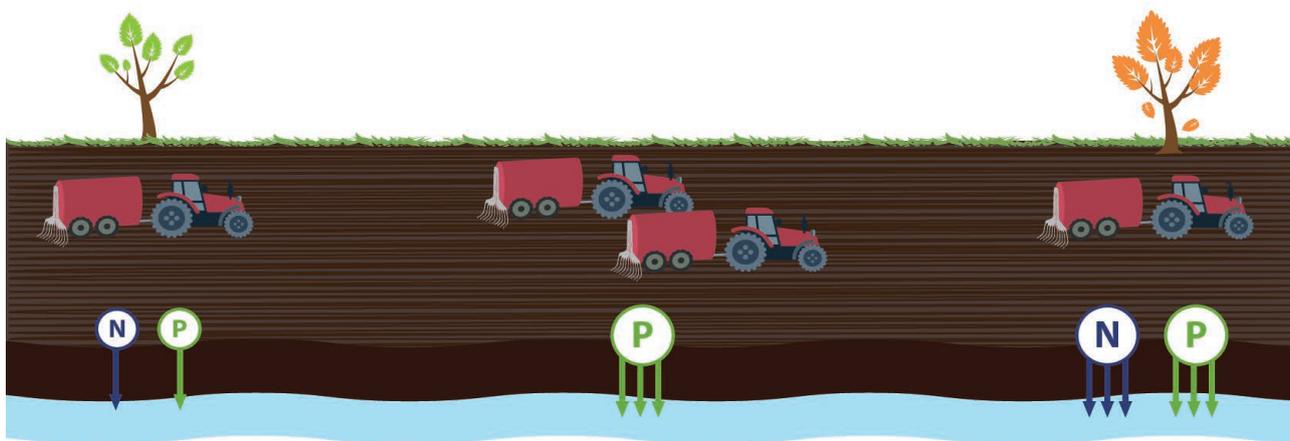
Photo: Torkild Birkmose, SEGES

Spreading manure and other fertilizers

The right timing and method of application are as important as applying the correct nutrient amounts. By avoiding well-known risk times in spreading, harmful environmental effects can be decreased. Also, the crop yield and quality benefit from the right timing of spreading. The selection of application technique depends on e.g. crop and fertilizer type as well as application time.

The timing of manure application is important

Crop nutrient demand varies throughout the growing season but is the greatest in the early growth stages.



Spring application

is the time with the lowest risk for nutrient leakage. The weather is still a risk as heavy rains may cause nutrient losses. Also, if the soil is still too moist, there is a risk of soil compaction.

Repeated soil surface application

increases the risk for P surface runoff since it results in P accumulating in the upper layer of the soil. As for the timing, application close to the sowing time is the most efficient.

Autumn application

causes a risk for nutrient loss both as surface runoff and leaching. There is also a higher risk for nutrient loss through erosion if there is no plant cover.

Recommendations

- Place focus on the timing, dosage and spreading evenness of manure application in the field
- Incorporate solid manure as soon as possible after spreading
- Incorporate slurry as soon as possible after spreading if not injected, acidified or spread to vegetation
- For more accurate spreading, use precision agriculture technology that utilizes spatial field and biomass data

Using a contractor

- Consider using a contractor in order to save time and get access to modern, efficient and environmentally friendly spreading technologies.
- Using a contractor is often more economical than investing in the farm's own equipment and it also saves the farmer's time for other farm work.

Manure spreading techniques

Slurry spreading



Photo: Sakari Alasuutari



Photo: Sakari Alasuutari



Photo: Kaisa Riiko

Broadcast spreading

- + low cost
- + good spreading width
- uneven spreading
- high risk for ammonia and odor emissions
- hygiene risk
- not recommended due to high nutrient losses
- not allowed in some countries
- ! incorporation needed

Trailing hose spreading

- + easy to operate
- + good spreading width
- + even distribution
- comparatively high risk for ammonia and odor emissions (ammonia emissions can be reduced with slurry acidification)
- ! incorporation needed (when application on bare soil)

Injection spreading

- + small risk for ammonia and odor emissions
- + good working hygiene in silage production
- + different injection depths can be used
- + even distribution
- relatively small working width
- heavy machinery, risk for soil compaction

Umbilical hose spreading

- + light, minimum soil compaction
- + can be connected to both trailing hose or injection unit
- Extra work caused by moving the pipelines, unpractical for small fields



Photo: Kaisa Riiko

Solid manure spreading

Different solid manure spreader types

Horizontal beater spreader

- uneven nutrient distribution
- small working width

Vertical screw beater spreader

- + more even nutrient distribution
- + wider working width

Spreading disc and horizontal beaters

- + extra wide spreading
- + good spreading accuracy with small volumes

Tight box and rear gate make the spreading of semi-solid manure possible

Calculating nutrient balances

Nutrient balance is a tool to keep track of the nutrient flows on the farm. Calculation of nutrient balances provides important information for improved fertilization planning and farm economy. Nutrient balances inform the farmer about the farm-specific nutrient use efficiency and help to identify the risks for nutrient loss on the farm.

The nutrient balances can be calculated on different levels; for the whole farm, for a field or for animal production. Balances can also be calculated for larger regions or countries. The balances are most often calculated for N, P and K.

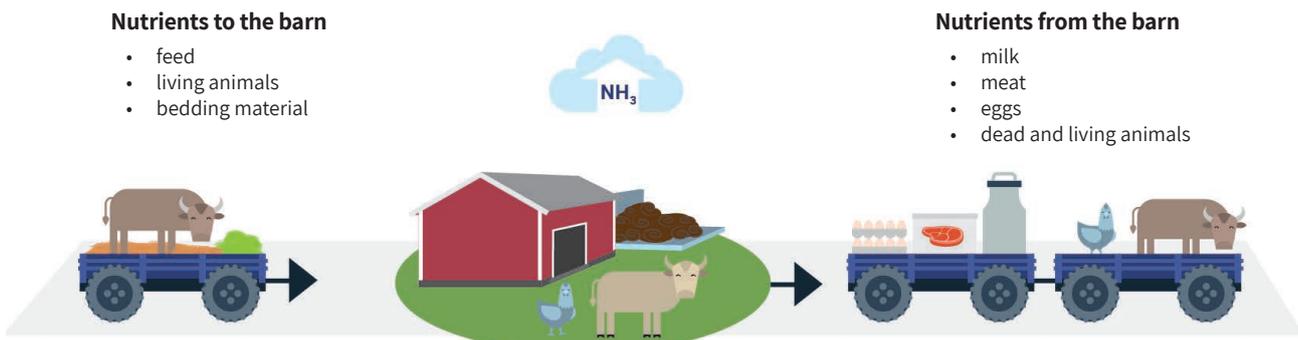
The farm balance

The farm balance (also known as the farm gate balance) is calculated as nutrients imported to the farm minus nutrients exported from the farm. Nutrients may come to the farm via fertilizers, feed, new animals and seeds. Nutrients may leave the farm in the form of animal products, grain, oilseed, vegetables e.g., manure (if it is sold or given away) and sold animals. The farm balance gives an overview of the nutrient efficiency on the farm.



The barn balance

The barn balance is a nutrient balance for the animal production. It tells how efficient the animal production is and how much N, P and K ends up into manure. Incoming products may be feed, living animals and bedding material, while products coming out may be milk, meat, eggs, dead animals and living animals. Some N is always lost as ammonia (NH_3), which reduces the N content of the manure.



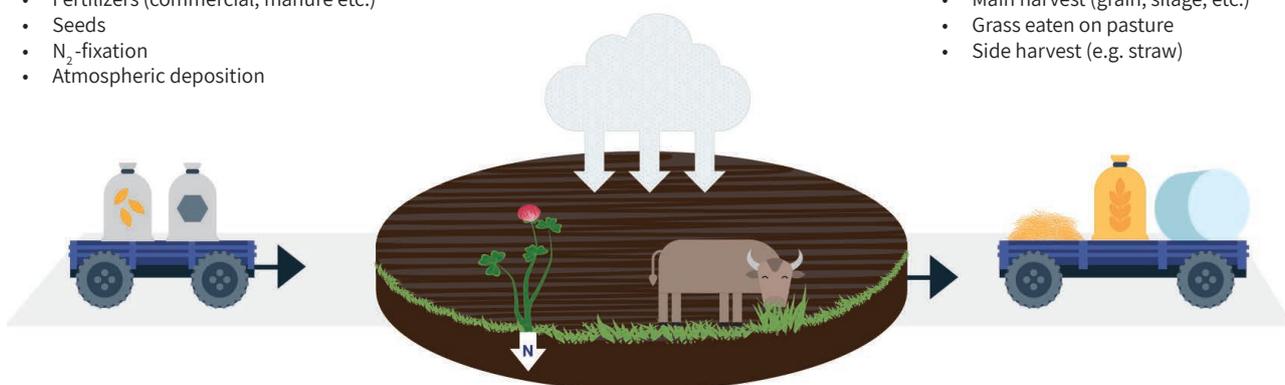
The soil surface or field balance

The soil surface or field balance is calculated as the difference between nutrient inputs to the field and nutrients removed with the harvest. If crop residues, like straw, are collected, they should also be taken into account in the calculations as nutrients removed.

For P and K the soil surface balance gives information on how nutrient inputs relate to outputs and may be used together with soil mapping to avoid depletion or deficit in the long run. For N it gives information mainly about the N use efficiency. The idea of the soil surface balance is also to give information on the fields where the nutrient efficiency is low. On these fields, the risk of nutrient leaching or accumulation in the soil is considerable and appropriate measures to tackle the problem should be targeted there.

Nutrients to the field

- Fertilizers (commercial, manure etc.)
- Seeds
- N₂-fixation
- Atmospheric deposition



Nutrients from the field

- Main harvest (grain, silage, etc.)
- Grass eaten on pasture
- Side harvest (e.g. straw)

Interpreting nutrient balance

Nutrient balance can be used as a measure of nutrient use efficiency on field level or on the farm level. Reference values have been calculated in many countries by e.g. advisory organizations. Reference values can be given for different crops and soil types.

Nutrient balances should be calculated over several years to get the right idea of the average nutrient flows as the annual balances are affected by yield variations caused by different weather conditions.

A significant surplus is economically and environmentally unprofitable. For example, positive soil surface balance with a surplus means that less nutrients have been taken out of the field with the harvest than have been put there e.g. in form of fertilizers. In contrast, if the balance is negative or in deficit, more nutrients have been taken from the field than have been put there. This may be preferred if the farm has a lot of fields with high P levels, but otherwise it is unsustainable in the long term.

Too much manure on the farm?

Manure is a valuable source of nutrients when it is used in the right time and form, and in the right place. Efficient use of manure nutrients reduces the need to purchase mineral fertilizers. However, big livestock farms or intensive livestock production areas often produce more manure nutrients than needed by the crops produced. Also, regulations may restrict the use of manure nutrients in order to avoid negative impacts on the environment.

What to do when there is too much manure?

- cooperate with farms which can replace purchased mineral fertilizers with manure
- avoid excessive nutrient import to farm by optimizing the feeding rations
- transport manure to nutrient-deficit areas

Co-operation

If there are farms close by that need to purchase mineral fertilizers, co-operation is a good solution. When replacing mineral fertilizers with manure nutrients, valuable organic material is also added to the soils. Crop farms can, in their turn, produce feed for the animal farms. Sometimes remote manure storages can facilitate co-operation.

Feeding strategy

Livestock feeding should be optimized to the nutritional requirements of the animals. Overfeeding is not beneficial for the animal, farm economy, or the environment, but results in excessive excretion to feces and urine. The feed efficiency can also be improved with feed additives such as phytase for swine and poultry to increase the utilization of P.

Transporting and processing

Occasionally, transporting manure further may be necessary. Slurry has low dry matter content and is thus uneconomical to transport far. Solid manure may be transported somewhat further.

On farms and regions with significant manure surplus, different manure processing techniques can be considered. The technology choice depends on e.g. the amount and type of surplus manure and how far the manure needs to be transported. Different technologies produce different types of end-products. In order to increase the use of manure or manure products on crop farms, contracting services should be developed.



Photo: Ylihuhtalan tila Oy

Manure processing

Possible motives to manure processing include:

- **Reducing the amount of manure to be stored and spread** (composting, slurry separation)
- **Enhancing the nutrient availability and utilization** (anaerobic digestion, separation)
- **Production of energy** (biogas or heat production)
- **Making manure spreading technically easier** (slurry separation)
- **Production of bedding material** (separation of cattle slurry)
- **Making manure transport easier and less expensive** (composting, slurry separation)

NOTE

Depending on the processing technology, the nutrients are still present after the processing.

Examples of manure processing technologies for farm scale



Photo: Kaisa Riiko

Mechanical separation

In mechanical separation, slurry (or digestate) is separated into solid and liquid fractions using a screw press, drum filter or centrifuge. Crop-available N mainly ends up in the liquid fraction, while the solid fraction contains more organic matter, organically bound N and P. Solid fraction typically contains more P than the untreated slurry, but the P ending up in the solid fraction depends on the separator type used and may be lower than expected.



Photo: Sari Luostarinen

Anaerobic digestion (biogas technology)

Anaerobic digestion is microbiological degradation of organic matter into biogas and digestate. Biogas can replace other energy sources and digestate – containing all nutrients in the original substrates - can be used directly as a fertilizer or as a substrate for more refined fertilizer products. Improved N availability for crops and (possible) pathogen reduction are examples of other advantages. The risk for ammonia loss during storage and spreading and methane losses during digestion storage must be minimized.



Photo: Kaisa Riiko

Composting

Composting is an aerobic microbiological decomposition process that transforms manure into a more stable, humus-like soil improver. Different techniques like drum, heap, tunnel, and tube composting are available. During composting, a lot of water is evaporated and organic matter is decomposed, which reduces the amount of manure and thus the need for transportation. As a result of reduced amount, P, K and micronutrients are concentrated. Also, the number of harmful microbes, pathogens and weed seeds can be reduced. However, a lot of N can be lost during composting via volatilization or leached water. Composting should thus be managed on a watertight plate or in composting plants with the possibility to recover the volatilized N.



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