MANURE STANDARDS PUBLICATION

Economic Impacts of Using Manure Tools

Kalvi Tamm & Raivo Vettik

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Summary

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The change from current manure data to the data provided by the new manure tools may hold positive and negative impacts on farm economy. Manure application rate per hectare and subsequent manure handling cost depend on the value of manure quality (nutrient content) provided by the new manure tools. Potentially achievable more precise manure nutrient dosing would affect the demand for mineral fertilizers and their expenses.

Annual manure quantity affects the appropriate manure storage capacity and the performance of manure handling equipment. Potential change in their investment costs depend on the manure quantity calculated by new manure tools.

The calculation method is composed and data are collected from Manure Standards project pilot-farms to evaluate economic impact of change of knowledge about manure amount and properties in manure storages of farms. The calculation tool in Excel is built to analyse the economic impact of change of knowledges. Analysed were at least one pilot-farm from every country (except Denmark) around Baltic Sea, 15 farms in total.

The report contains overview about calculation results for every analysed pilot-farm. The change of knowledges about manure amount and properties had positive and negative economic impacts. Farm costs decreased in 5 farms, in range 491 - 18,262 € yr^{-1}. Costs increased in 10 farms, in range 775 - 21,556 € yr^{-1}.

The conclusions and recommendation were composed by calculation results. Main recommendation is that the national manure standards should be maintained periodically to check - are the data and calculation methods reflecting correctly current real manure amounts and properties by different production and climatic conditions.

Keywords: manure standard, handling cost, storage cost, mineral fertiliser cost, economic impact

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Symbols and abbreviations

a, b – calculation factors depending on storage construction;

a_1, b_1, a_2, b_2 – calculations factors to calculate values for calculation factors a_o and b_o;

$A_{m,e}$ – existing annual manure amount, t yr^{-1};

$A_{m,i}$ – improved annual manure amount, t yr^{-1};

a_o, b_o – calculation factors for spreading cost by own transporter;

a_s, b_s – calculation factors for spreading cost by separate transporter;

c – basic cost by separate transporter, € t^{-1};

c_a – cost addition by separate transporter, € t^{-1} km^{-1};

c_K – K element content in manure, kg t^{-1};

$C_{\min}$ – minimum storage capacity, months;

c_{NH4} – NH_4-N content in manure, kg t^{-1};

c_{Ntot} – total nitrogen content in manure, kg t^{-1};

c_P – P element content in manure, kg t^{-1};

$C_{st,e}$ – existing storage volume, t;

$C_{st,i}$ – improved storage volume, t;

e – unabated ammonia emission from manure, % from total ammonium nitrogen (TAN) ;

f_K – K amount planned to apply with fertilisers to the field, kg ha^{-1};

f_N – N amount planned to apply with fertilisers to the field, kg ha^{-1};

f_P – P amount planned to apply with fertilisers to the field, kg ha^{-1};

$f_{p,max}$ – maximum limit value of P, what is allowed to apply to the field by national legislation, kg ha^{-1};

h_m – manure amount by NH_4-N or P, t ha^{-1};

H_m – total amount of manure per field, t yr^{-1};

$h_{m,NH4}$ – manure amount by NH_4-N, t ha^{-1};

$h_{m,P}$ – manure amount by P, t ha^{-1};

I_f – total economic impact for each field, € yr^{-1};

I_s – total economic impact for each storage, € yr^{-1};

K_c – K content in mineral fertiliser, %;

M_K – additional amounts mineral K fertilisers, kg;

$M_{K,e}$ – additional amounts mineral K fertilisers by old data, kg;

$M_{K,i}$ – additional amounts mineral K fertilisers by new data, kg;

M_N – additional amounts mineral N fertilisers, kg;

$M_{N,e}$ – additional amounts mineral N fertilisers by old data, kg;

$M_{N,i}$ – additional amounts mineral N fertilisers by new data, kg;

M_P – additional amounts mineral P fertilisers, kg;

$M_{P,e}$ – additional amounts mineral P fertilisers by old data, kg;

$M_{P,i}$ – additional amounts mineral P fertilisers by new data, kg;

N_c – N content in mineral fertiliser, %;

P_c – P content in mineral fertiliser, %;

p_K – K element price in mineral fertiliser, € kg^{-1};

P_m – manure price, € t^{-1};

$P_{m,e}$ – manure price by old data, € t^{-1};

$P_{m,i}$ – manure price by new data, € t^{-1};

p_N – N element price in mineral fertiliser, € kg^{-1};

p_P – P element price in mineral fertiliser, € kg^{-1};

r – ammonia emission abatement factor, % from unabated emissioon;

S – field area, ha;

$Z_{m,e}$ – is total amount of manure applied to the fields by old data, t yr^{-1};

$Z_{m,i}$ – is total amount of manure applied to the fields by new data, t yr^{-1};

x – capacity of storage, m^3;

y_e – calculated cost of existing storage, € t^{-1};

Y_{ex} – cost of manure export if excess manure is taken over by some other company, € t^{-1};

y_f – cost of mineral fertiliser storage, loading and spreading, € t^{-1};

y_{ft} – cost of mineral fertiliser transportation, € t^{-1} km^{-1};

y_i – calculated cost of improved storage, € t^{-1};

y_l – liquid manure storage cost, € m^{-3} yr^{-1};

y_{ms} – manure transportation and spreading cost, € yr^{-1};

$y_{ms,e}$ – manure transportation and spreading cost by old data, € yr^{-1};

$y_{ms,i}$ – manure transportation and spreading cost by new data, € yr^{-1};

y_s – solid manure storage cost, € t^{-1} yr^{-1};

Δ_{Em} – increase of cost for exported manure, € yr^{-1};

Δ_{fs} – increase of mineral elements handling and transportation costs, € yr^{-1};

Δ_K – difference of K amounts, kg;

Δ_N – difference of N amounts, kg;

Δ_{NPK} – increase of mineral NPK fertilisers cost, € yr^{-1};

Δ_P – difference of P amounts, kg;

Δ_{Pm} – increase of manure price, € t^{-1};

Δ_{Sm} – increase of income for selling of manure, € yr^{-1};

Δ_y – increase of storage cost, € yr^{-1};

Δ_{yms} – increase of manure spreading and transportation costs, € yr^{-1};

ρ – bulk density of solid manure, t m^{-3};

1. Introduction

The change from current manure data to the data provided by the new manure tools may hold positive and negative impacts on farm economy. Manure application rate per hectare and subsequent manure handling cost depend on the value of manure quality (nutrient content) provided by the new manure tools. Potentially achievable more precise manure nutrient dosing would affect the demand for mineral fertilizers and their expenses.

Annual manure quantity affects the appropriate manure storage capacity and the performance of manure handling equipment. Potential change in their investments costs depend on the manure quantity calculated by new manure tools. Similarly, the cost of buildings and other manure machinery will be calculated in case of using the new manure tools and compared to current situation.

The cost of manure as a valuable farm resource depends also on the quantity and quality of manure utilised and thus on the manure data used. The change in costs between potential difference in using sampled/analyzed data (WP2) and calculated data (WP3) for the pilot farms will be determined and also compared to using current manure data.

Such farm-scale impacts will be discussed and subjected to feedback with the target groups in farming and advisory to ensure valid background information taking into account national differences in practices and costs. In cooperation with the policymakers, regulation for the required manure storage capacity and required field area for manure application will be tested and discussed. The resulting costs and cost savings will be calculated.

Some chosen pilot farms will serve as examples to study potential economic changes on farm-scale. Special attention will be given to potential changes in fertilization regime (in cooperation with A4.1).

The output will be an Excel-based tool and written guidelines for assessing the economic impact of using the new manure tools as the basis for manure application and storage. The guidelines will also contain a few examples for calculation. The tool will be free to be modified and updated by the user. The BSR countries will also be free to make their own official versions of it, outside the project.

A4.3 will also produce a report on the economic consequences of implementing the new manure tools on farm and national level. This output will be used as input to A4.4.

2. Methods and materials

2.1. The overview about calculations

The economic impact calculator calculates cost difference if there is new knowledge about:

- Total nitrogen N_{tot} content in manure, kg t^{-1};
- Ammonium nitrogen NH^{+}_{4}–N content in manure, kg t^{-1};
- P content in manure, kg t^{-1};
- K content in manure, kg t^{-1} and
- annual manure amount in a storage, t.

The calculation of economic impact on farm is divided to impact on:

- manure storage costs, € yr^{-1};
- manure monetary value, € t^{-1};
- manure transportation and spreading costs to the fields, € yr^{-1};
- mineral fertiliser cost € yr^{-1} and
- mineral fertiliser handling costs € yr^{-1}.

An Excel tool is composed to make the calculations. The tool calculates for every manure storage:

- increase of storage cost, € yr^{-1};
- increase of manure price, € t^{-1};
- increase of cost for exported manure, € yr^{-1};
- increase of income for selling of manure, € yr^{-1};
- total economic impact on all storages, € yr^{-1}

The Excel tool calculates for every field the difference between existing and new:

- manure transportation and handling cost, € yr^{-1};
- mineral N, P and K cost, €;
- mineral N, P and K transportation and handling, € yr^{-1};

and then

- increase of manure transportation and spreading cost (new-existing), € yr^{-1};
- increase of mineral element cost, €;
- increase of mineral element handling + transportation costs, € yr^{-1};
- total economic impact on all fields, € yr^{-1}.

The totals on all storages and on all fields are summed up to calculate total impact on farm.

2.2. Calculations related to stored manure

2.2.1. Increase of storage cost

The storage costs are calculated in the case of old data and new data both for every storage separately. The calculation tool in Excel allows to enter data for up to five storages per farm.

The old value for annual manure amount base on volume of existing storage. The presumption is that the volume of existing storage bases on old knowledge about manure production. The old value for annual manure amount flowing through the storage is calculated by storage volume and minimum number of months required by national legislation.

Formula to calculate annual manure amount is

$$A_{m,e} = 12\frac{C_{st,e}}{C_{\min}} , \tag{1}$$

where $A_{m,e}$ is existing annual manure amount, t yr^{-1}; $C_{st,e}$ is existing storage volume, t; $C_{\min}$ is minimum storage capacity, months.

The new value for annual manure amount is estimated by farmer experiences about actual annual slurry amount or slurry flow through the storage. Or it is estimated by new manure standards tool composed in WP3 of Manure Standards project.

The new value for required storage volume is calculated by formula

$$C_{st,i} = \frac{A_{m,i}C_{\min}}{12} , \tag{2}$$

where $C_{st,i}$ is improved storage volume, t; $A_{m,i}$ is improved annual manure amount, t yr^{-1}; $C_{\min}$ is minimum storage capacity, months.

Storage cost is increasing if existing storage is too big. It means, there has been overinvestment and this increases cost of storing of manure.

Formula to calculate increase of storage cost is

$$\Delta_y = \left|y_e C_{st,e} - y_i C_{st,i}\right| , \tag{3}$$

where Δ_y is increase of storage cost, € yr^{-1}; y_e is calculated cost of existing storage, € t^{-1}; $C_{st,e}$ is existing storage volume, t; y_i is calculated cost of improved storage, € t^{-1} $C_{st,i}$ is improved storage volume, t.

Manure storage cost calculation factors base on data published in KTBL 18/19, page 152.

The cost of liquid manure storage is calculated by storage capacity and construction with formula

$$y_l = ax^b , \tag{4}$$

where y_l is liquid manure storage cost per m^3 of storage capacity and year; x is capacity of storage, m^3; a, b are calculation factors depending on storage construction (table 2.1).

The cost of solid manure storage is calculated by storage capacity and construction with formula

$$y_s = 9.33x\rho \ , \tag{5}$$

where y_s is solid manure storage cost per tonne of storage capacity and year; x is capacity of storage, m^3; ρ is bulk density of solid manure, t m^{-3} (table 2.1).

The price of slurry storage per unit of amount of manure and per year is multiplied with required storage capacity to calculate need for investment per year.

Table 2.1. Slurry storage cost calculation factors (KTBL 18/19, page 152)

Description of manure storage		
Liquid manure storage	**a**	**b**
Slurry storage from concrete, cast in place, on the ground	267.63	-0.582
Slurry storage from concrete elements, 1 m in the ground, leakage indicator	407.9	-0.608
Slurry storage from steel elements, on the ground	227.55	-0.535
Slurry storage, lagoon, PE bottom, leakage indicator, fenced	93.43	-0.436
Solid manure storage	**Unit**	**Value**
Solid manure storage, concrete plate, pile height 1.5 m	€ m^{-3} yr^{-1}	9.33
Bulk density of solid manure	t m^{-3}	0.8

2.2.2. Increase of manure price

The formula to calculate manure price is

$$P_m = p_N c_{N_{tot}} + p_P c_P + p_K c_K \ , \tag{6}$$

where P_m is manure price € t^{-1}; c_{Ntot} is total nitrogen content in manure, kg t^{-1}; p_N is N element price in mineral fertiliser, € kg^{-1}; c_P is P element content in manure, kg t^{-1}; p_P is P element price in mineral fertiliser, € kg^{-1}; c_K is K element content in manure, kg t^{-1}; p_K is K element price in mineral fertiliser, € kg^{-1}.

The price of manure calculated by both, old and new data about NPK content in manure.

Formula to calculate increase of manure price is

$$\Delta_{Pm} = P_{m,i} - P_{m,e} \ , \tag{7}$$

where Δ_{Pm} is increase of manure price, € t^{-1}; $P_{m,i}$ is manure price by new data, € t^{-1}; $P_{m,e}$ is manure price by old data, € t^{-1}.

2.2.3. Increase of cost for exported manure

The model should calculate the cost change for exported manure, exported out from farm. This is in the case if farm has more manure than allowed to apply to the fields and part of manure should be transported out and the manure producer must pay to somebody who is taking the manure. This cost changes if knowledge about manure amount is changing.
The formula to calculate increase of cost for exported manure is

$$\Delta_{Em} = (A_{m,i} - Z_{m,i})y_{ex} - (A_{m,e} - Z_{m,e})y_{ex} \ , \qquad (8)$$

where Δ_{Em} is increase of cost for exported manure, € yr^{-1}; $A_{m,i}$ is improved annual manure amount, t yr^{-1}; $Z_{m,i}$ is total amount of manure applied to the fields by new data, t yr^{-1}; $A_{m,e}$ is existing annual manure amount, t yr^{-1}; $Z_{m,e}$ is total amount of manure applied to the fields by old data, t yr^{-1}; y_{ex} is cost of manure export if excess manure is taken over by some other company, € t^{-1}.

2.2.4. Increase of income for selling of manure

If farm sells manure and selling price depends on NPK content in manure, then the income from selling of manure is recalculated if the knowledge about manure NPK content changes.
The formula to calculate increase of income if price of manure is changing, is

$$\Delta_{Sm} = (A_{m,i} - Z_{m,i})P_{m,i} - (A_{m,e} - Z_{m,e})P_{m,e} \ , \qquad (9)$$

where Δ_{Sm} is increase of income for selling of manure, € yr^{-1}; $A_{m,i}$ is improved annual manure amount, t yr^{-1}; $Z_{m,i}$ is total amount of manure applied to the fields by new data, t yr^{-1}; $P_{m,i}$ is manure price by new data, € t^{-1}; $A_{m,e}$ is existing annual manure amount, t yr^{-1}; $Z_{m,e}$ is total amount of manure applied to the fields by old data, t yr^{-1}; $P_{m,e}$ is manure price by old data, € t^{-1}.

2.2.5. Total economic impact on all storages

The formula to calculate total economic impact for each storage is

$$I_s = \Delta_y + \Delta_{Em} - \Delta_{Sm} \ , \qquad (10)$$

where I_s is total economic impact for each storage, € yr^{-1}; Δ_y is increase of storage cost, € yr^{-1}; Δ_{Em} is increase of cost for exported manure, € yr^{-1}; Δ_{Sm} is increase of income for selling of manure, € yr^{-1}.

2.3. Calculations related to the fields

2.3.1. Calculations of increase of manure transportation and spreading cost

By the calculation of difference in manure transportation costs is presumed that:

1. Farmer has defined for every field the N, P and K amount applied with fertilisers.
2. Farmer aims to handle manure with least costs.
3. Transportation costs are kept on minimum.
4. The manure is transported to the closest fields (suitable for manure application) around storages with maximum application amount. Selection of suitable fields for manure application starts from closest to storage and every next field is further.
5. The maximum manure amount is chosen so that N and P defined for field are not exceeded
6. In the list of fields are only fields that are suitable for manure application on observed year.

Calculations

For every field in the list are calculated:

1) amounts of manure per hectare by N and by P. Smaller manure amount is chosen for next calculations. Manure NH_4-N amount is used to calculate manure amount. The maximum manure amount is limited also by 170 kg total nitrogen (N_{tot}) amount per hectare and year. Or, if maximum P per hectare and year is defined then the maximum amount by N_{tot} and P both is calculated;
2) total amounts of manure per field,
3) sums of applied manure amounts starting from closest to farthest field (the sum includes amounts from previous fields plus this field);
4) the last field - this is the field where sum of applied amounts exceeds the annual amount of manure in the storage;
5) hectare amount for this field by dividing residual amount left to this field with the field area,
6) transportation and spreading costs for every field by hectare amount, field area and cost of manure transport per tonne and km;
7) sum of transportation and spreading costs as total of all fields.

The calculation formulas are next.

1. Amounts of manure per hectare by N and by P

Maximum hectare amount of manure, by manure NH_4-N content, is calculated with formula

$$h_{m,NH4} = \frac{f_N}{c_{NH4}\left[1-\frac{e}{100}\left(1-\frac{r}{100}\right)\right]}, \quad (11)$$

where $h_{m,NH4}$ is manure amount by NH_4-N, t ha^{-1}; f_N is N amount planned to apply with fertilisers to the field, kg ha^{-1}; c_{NH4} is NH_4-N content in manure, kg t^{-1}; e is unabated ammonia emission from manure, % from total ammonium nitrogen (TAN) (Table 2.2); r is ammonia emission abatement factor, % from unabated emission (Tables 2.3 and 2.4).

Table 2.2. Unabated ammonia emission factors by different manure types (Grönroos et al 2017)

Manure type [2)]	Emission of TAN, unabated, % from TAN	Solid or liquid manure
Cattle slurry	55%	Liquid manure
Cattle deep litter	79%	Solid manure
Cattle manure with urine	79%	Solid manure
Cattle urine	30%	Liquid manure
Cattle dung	79%	Solid manure
Fur animals manure with urine	80%	Solid manure
Horse, pony deep litter	90%	Solid manure
Horse or pony manure with urine	90%	Solid manure
Lamb, goat deep litter	90%	Solid manure
Lamb or goat manure with urine	90%	Solid manure
Pigs slurry	35%	Liquid manure
Pigs deep litter	81%	Solid manure
Pigs solid manure with urine	81%	Solid manure
Pigs urine	30%	Liquid manure
Pigs dung	81%	Solid manure
Poultry slurry	69%	Liquid manure

Poultry deep litter	60%	Solid manure
Poultry solid manure with urine	69%	Solid manure

Table 2.3. Ammonia emission abatement factors by different liquid manure application methods (Grönroos et al 2017)

Liquid manure spreading and incorporation method [1)]	**Emission abatement factor, %**
Broadcast spreading, no incorporation	0%
Band spreading on bare land, no incorporation	30%
Band spreading on covered land, no incorporation,	35%
Surface spreading on bare land, ploughing < 4 h	70%
Surface spreading on covered land, ploughing < 4 h	75%
Surface spreading, ploughing 4-12 h	45%
Surface spreading, ploughing > 12 h	20%
Surface spreading, harrowing < 4 h	60%
Surface spreading, harrowing 4-12 h	35%
Surface spreading, harrowing > 12 h	15%
Band spreading + SyreN, no incorporation	75%
Injection	78%

Table 2.4. Ammonia emission abatement factors by different solid manure application methods (Grönroos et al 2017)

Solid manure spreading and Incorporation method	**Emission abatement factor, %**
Broadcast, no incorporation	0%
Broadcast on bare land, ploughing < 4 h	70%
Broadcast on covered land, ploughing < 4 h	75%
Broadcast, ploughing 4-12 h	50%
Broadcast, ploughing > 12 h	20%
Broadcast on bare land, harrowing < 4 h	50%
Broadcast on covered land, harrowing < 4 h	60%
Broadcast on bare land, harrowing 4-12 h	25%
Broadcast on covered land, harrowing 4-12 h	35%
Broadcast, harrowing > 12 h	15%

Maximum hectare amount of manure, by manure P content, is calculated with formula

$$h_{mP} = \frac{f_P}{c_P}\,, \tag{12}$$

where $h_{m,P}$ is manure amount by P, t ha^{-1}; f_P is P amount planned to apply with fertilisers to the field, kg ha^{-1}; c_P is P content in manure, kg t^{-1}.

Smaller or equal manure amount is chosen for next calculations.

If $h_{m,NH4} <= h_{m,P}$ then $h_m = h_{m,NH4}$,

else $h_m = h_{m,P}$,

where h_m is manure amount per hectare, t ha^{-1}.

The N_{tot} amount applied with manure amount h_m should not exceed limit value 170 kg ha^{-1}.

If $c_{Ntot}h_m > 170$ then $h_m = \frac{170}{c_{Ntot}}$,

else $h_m = h_m$,

where c_{Ntot} is total nitrogen N_{tot} content in manure, kg t^{-1}.

And next, if maximum limit P amount per hectare and year is defined by national legislation, then the P amount applied with manure amount h_m should not exceed P limit value.

If $c_P h_m > f_{p,max}$ then $h_m = \frac{fp{,}max}{c_P}$,

else $h_m = h_m$,

where $f_{p,max}$ is maximum limit value of P what is allowed to apply to the field by national legislation, kg ha^{-1}.

2. The total amount of manure per field is calculated with formula

$$H_m = h_m S \ , \qquad (13)$$

where H_m is total amount of manure per field, t yr^{-1}; S is field area, ha.

3. - 5. and 7. No need to express calculation formulas.

6. Calculation of transportation and spreading costs for every field by hectare amount, field area and cost of manure transport per tonne and km;

If the driving distance from storage to the field is greater than the limit distance (table 2.2) then manure transportation and spreading costs for every field calculated by formula

$$y_{ms} = H_m(dc_a + c) + H_m\left(a_s {h_m}^{b_s}\right) \ , \qquad (14)$$

where y_{ms} is manure transportation and spreading cost, € yr^{-1}; H_m is total amount of manure per field, t yr^{-1}; d is driving distance to the storage, km; c_a is cost addition per kilometre of distance, by separate transporter, € t^{-1} km^{-1}; c is basic cost by separate transporter, € t^{-1}; a_s, b_s are calculations factors for spreading cost by separate transporter.

If the driving distance to the storage is less than the limit distance or equal, then manure transportation and spreading costs for every field is calculated by formula

$$y_{ms} = H_m\left(a_o {h_m}^{b_o}\right) \ , \qquad (15)$$

where y_{ms} is manure transportation and spreading cost, € yr^{-1}; H_m is total amount of manure per field, t yr^{-1}; a_o is calculation factor for spreading cost by own transporter (calculated by formula 16); b_o is calculation factor for spreading cost by own transporter (calculated by formula 17).

$$a_o = b_1 + a_1 d \ , \qquad (16)$$

$$b_o = b_2 + a_2 d \ , \tag{17}$$

where a_1; b_1; a_2 and b_2 are calculations factors to calculate values for calculation factors a_o and b_o.

The calculation factors a_s, b_s, a_1, b_1, a_2 and b_2 are calculated for every farm separately.

The principle of calculating of the factors is next

1) calculation of the manure spreading and transportation costs for transportation distances 1, 2, 3, 4 and 5 km and for spreading amounts 10, 15 ,20 ,25 ,30, 35 and 40 t ha^{-1}. The spreader parameters are chosen by pilot-farm spreader work width and box or tank volume;
2) for every distance is constructed a separate graph where on abscissa is manure amount , t ha^{-1} and on ordinate is manure handling cost, € ha^{-1};
3) by the correlation lines on the graphs are constructed trendlines by power function,
4) the values of x- factor and power-factor of functions are ordered by values of the distance,
5) for each factor are constructed separate graphs where abscissa is field distance from storage (km) and ordinate is value of factor;
6) by the correlation lines on the graphs are constructed trendlines with linear function,
7) the function factors of trend line of x-factor are b_1 and a_1
8) the function factors of trend line of power-factor are b_2 and a_2.

This calculation is made for both

1) old manure data about properties and amounts and
2) new manure data about properties and amounts.

By the difference of costs calculated by old and new is calculated increase of manure spreading of transportation costs:

$$\Delta_{yms} = y_{ms,i} - y_{ms,e} \ , \tag{18}$$

where Δ_{yms} is increase of manure spreading and transportation costs, € yr^{-1}; $y_{ms,i}$ is manure transportation and spreading cost by new data, € yr^{-1}; $y_{ms,e}$ is manure transportation and spreading cost by old data, € yr^{-1}.

2.3.2. Calculations of increase of mineral element cost

The increase of mineral element cost calculation consists the calculation of the

1) need for additional mineral N, P and K amount if previously calculated organic manure amount h_m does not cover the planned N, P and K amount to the field; the additional amounts of mineral N,P and K are calculated for old and new data both;
2) differences of N, P and K amounts if old and new data for manure are used.

The calculation formulas are next.

1. The need for additional mineral N amount to the whole field is calculated with formula:

$$M_N = (f_N - h_m c_{NH4})S \ , \tag{19}$$

where M_N is need for additional mineral N amount, kg; f_N is N amount planned to apply with fertilisers to the field, kg ha^{-1}; c_{NH4} is NH_4-N content in manure, kg t^{-1}; S is field area, ha.

2. The need for additional mineral P amount to the whole field is calculated with formula:

$$M_P = (f_P - h_m c_P)S \ , \tag{20}$$

where M_P is need for additional mineral P amount, kg; f_P is P amount planned to apply with fertilisers to the field, kg ha^{-1}; c_P is P content in manure, kg t^{-1}.

3. The need for additional mineral K amount to the whole field is calculated with formula:

$$M_K = (f_K - h_m c_K)S, \tag{21}$$

where M_K is need for additional mineral P amount, kg; f_K is K amount planned to apply with fertilisers to the field, kg ha^{-1}; c_K is K content in manure, kg t^{-1}.

The calculations are made for both

a) old data about manure properties and amounts and
b) new data about manure properties and amount.

4. The increase of need for mineral N in the case of new manure data is calculated by formula

$$\Delta_N = M_{N,i} - M_{N,e} \ , \tag{22}$$

where Δ_N is difference of N amounts, kg; $M_{N,i}$ is additional mineral N amount by new data, kg; $M_{N,e}$ is additional mineral N amount by old data, kg.

5. The increase of need for mineral P in the case of new manure data is calculated by formula

$$\Delta_P = M_{P,i} - M_{P,e} \ , \tag{23}$$

where Δ_P is difference of P amounts, kg; $M_{P,i}$ is additional mineral P amount by new data, kg; $M_{P,e}$ is additional mineral P amount by old data, kg.

6. The increase of need for mineral K in the case of new manure data is calculated by formula

$$\Delta_K = M_{K,i} - M_{K,e} \ , \tag{24}$$

where Δ_K is difference of K amounts, kg; $M_{K,i}$ is additional mineral K amount by new data, kg; $M_{K,e}$ is additional mineral K amount by old data, kg.

Increase of mineral NPK fertilisers cost is calculated by formula

$$\Delta_{NPK} = \Delta_N p_N + \Delta_P p_P + \Delta_K p_K, \tag{25}$$

where Δ_{NPK} is increase of mineral NPK fertilisers cost, € yr^{-1}; Δ_N is difference of N amounts, kg; p_N is price of N element in mineral fertiliser, € kg^{-1}; Δ_P is difference of P amounts, kg; p_P is price of P element in mineral fertiliser, € kg^{-1}; Δ_K is difference of K amounts, kg; p_K is price of K element in mineral fertiliser, € kg^{-1}.

2.3.3. Calculations of increase of handling and transportation costs of mineral elements

If the need for mineral N, P and K changes in the case of new data, compared to old data, then the cost of handling of mineral fertilisers is also changing. In present model N, P and K fertiliser are calculated as mono-fertilisers not complex fertilisers. So, the handling costs are in calculation taken into account separately for every element.

Increase of handling and transportation costs of mineral N, P and K is calculated by formula

$$\Delta_{fs} = \left(\frac{\Delta_N}{10N_c} + \frac{\Delta_P}{10P_c} + \frac{\Delta_K}{10K_c}\right)\left(y_f + y_{ft}d\right) , \quad (26)$$

where Δ_{fs} is increase of handling and transportation costs of mineral N, P and K, € yr^{-1}; Δ_N is difference of N amounts, kg; N_c is N content in mineral fertiliser, %; Δ_P is difference of P amounts, kg; P_c is P content in mineral fertiliser, %; Δ_K is difference of K amounts, kg; K_c is K content in mineral fertiliser, %; y_f is cost of mineral fertiliser storage, loading and spreading, € t^{-1}; y_{ft} is cost of mineral fertiliser transportation, € t^{-1} km^{-1}; d is driving distance from storage to the field, km.

Presumed is that the distance between mineral fertiliser storage and field is approximately same as distance between manure storage and the field.

2.3.4. Calculations of total economic impact on all fields

For every field were calculated in previous paragraphs (2.3.1, 2.3.2 and 2.3.3.)

1) increase of manure transportation and spreading cost
2) increase of mineral element cost and
3) increase of cost of mineral NPK fertiliser handling and transportation costs.

The total economic impacts for every field is calculated by formula

$$I_f = \Delta_{yms} + \Delta_{NPK} + \Delta_{fs} \quad (27)$$

where I_f is total economic impact for each field, € yr^{-1}; Δ_{yms} is increase of manure spreading and transportation costs, € yr^{-1}; Δ_{NPK} is increase of mineral NPK fertilisers cost, € yr^{-1}; Δ_{fs} is increase of mineral elements handling and transportation costs, € yr^{-1}.

Economic impacts for every field are summed to calculate total impact on all fields.

2.4. Calculations of total impact on farm

The total impact of all fields and total impact of all storages are summed to calculate total impact on farm:

$$I = \sum_{i=1}^{n} I_{s,i} + \sum_{j=1}^{m} I_{f,j} \ , \qquad (28)$$

where *I is* total impact on farm, € yr^{-1}; *n* is number of storages; $I_{s,i}$ is total economic impact for *i*-th storage, € yr^{-1}; *m* is number of fields; $I_{f,i}$ is total economic impact for *j*-th field, € yr^{-1}.

3. Results

3.1. Estonia

3.1.1. General data for calculations made for Estonian farms

Table 3.1. General data for calculations made for Estonian farms

	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	25	
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.72	
N content in mineral fertiliser	%	34.4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	1.8	
P content in mineral fertiliser	%	20	Triple-Superphosphat (TSP), 46% P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.6	
K content in mineral fertiliser	%	50.6	Potassium Chloride
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	24	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.7	

3.1.2. Farm EE1

Storages

Manure amount

Farm EE1 is milk production farm. In Estonia is required minimum storage capacity for manure, which is produced during 8 months. Farm EE1 has a slurry storages with volume 8,900 m^3 and it corresponds to 13,350 t annual slurry production. Farm EE1 has dairy herd producing actually 17,639 t of slurry annually. It means that farm has storage capacity for 6.1 month.

Manure properties

Table 3.2. Manure properties in Farm EE1

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle slurry	4.74	1.23	1.22	4.09	8.06
New data	Cattle slurry	3,82	2.29	0.64	2.75	5.55

Old data are taken from EE manure standard. (Põllumajandusministri määrus nr 71. 2014.)
New data are calculated by Allan Kaasik (PP6), by WP3 calculation tool.

By old data the

maximum hectare amount of manure, by N_{tot} or P is 21 t ha^{-1} and
minimum area, fertilised with manure can be 652 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 39 t ha^{-1} and
minimum area, fertilised with manure can be 452 ha.

Manure price

The price of Farm EE1 manure decreases 2.5 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.2) is calculated by the data in tables 3.1 and 3.2, and formula 6. The manure contains by new data less P and K, therefor the new price is lower compared to the price calculated by old data.

Income from selling

Farm EE1 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm EE1 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage from concrete elements, 1 m in the ground.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 14,411 € yr^{-1} and by new data would be 16,075 € yr^{-1}. The storage cost by old data is calculated by actual storage size (8900 t). The storage cost by new data is calculated by storage size (11,759 t) which is required to store 8 month amount from 17,639 m^3 annual slurry production.

The farm requires 2,859 m^3 additional storage space to satisfy demand to have storage space for minimum 8 month manure production. The additional cost is 1,663 € yr^{-1}.

Fields

Farm EE1 fertilises 50 fields with manure, totally 1,013 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount vary for:

N: 77-310 kg ha^{-1}

P: 8-65 kg ha^{-1}

K: 27-116 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farms field book.

The distances between storage and fields vary from 0.7 to 8.5 km. The distances were measured with help of GIS tool (https://kls.pria.ee/kaart/) managed by Estonian Agricultural Registers and Information Board (PRIA).

Table 3.3. Manure loading, transporting and spreading cost (based on Farm EE1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)	Costs over distance limit, separate transporter

		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.1111	11.448	0.0463	-0.5545	11.151	-0.566	0.89	0.09

Results of calculations

By the old data are required 50 fields to spread all manure produced by farm. By new data are required only 36 fields although the amount of slurry is actually bigger than by old data. The reason is lower P content in manure by new data (see table 3.2). The limiting factor by calculating the maximum slurry amount per hectare is P content in slurry and the maximum amount of P (25 kg ha^{-1}) what is allowed to apply with organic fertilisers (Water Act, Estonian legislation).

Manure transportation and spreading cost, € in total over all field area is

by old data 54,066 € and

by new data 56,603 €.

The increase of this cost is 2,537 € if new data are used instead of old manure data.

The total cost increases because the farm has 4,289 m^3 more slurry by new data what should be transported and spread to the fields. The cost on manure transportation and spreading is 4.1 € m^{-3} by old data and 3.2 € m^{-3} by new data. The reason for cost decrease is lower P content by new data and thus, bigger manure amount per hectare – this means less field area >> less far fields >> maximum transportation distance decreases from 8.5 to 4.9 km >> decrease of transportation costs.

The total cost on mineral N is decreasing 10,615 € because manure NH_4-N content by new data is higher than by old data (see table 3.2) and the manure amounts per hectare are bigger than by old data (lower P content by new data allows use bigger manure amounts per hectare). Thus, there is less additional mineral N required to cover planned amounts of N to the fields. In same reason, the total handling cost of mineral N decreases 1,098 €.

The total cost on mineral P doesn't change on fields what get manure by both scenarios because the maximum amount of manure is calculated for all fields by P content in manure in the case of old and new data both. It means that additional mineral fertiliser amounts what can be used on fields, are same by new and old data. However, the cost on mineral P appears on fields, which are not fertilised with manure in the case of new data. The increase of costs for mineral P and handling of P-fertiliser are in total (if new data are used) 8,996 € and 725 € respectively.

There is little need (1-7 kg ha^{-1}) for mineral K by old data on most fields, some fields have bigger demand or not at all. By new data, the need for K is satisfied on most fields fertilised with manure although the content of K is lower in manure (Table 3.2). The reason, is that lower P content by new data allows use bigger manure amounts per hectare. However, by new data, less fields are fertilised with manure and number of fields, where K-demand should be covered by mineral K-fertilisers, increases. Therefore the total cost for mineral K- fertilisers and handling of that fertiliser rises 6,646 € and 659 € respectively in the case of new data.

The total cost on mineral fertilizers increases 5,312 € yr^{-1} in the case of new data.

The total cost on fields 7,849 € is sum of costs on manure handling (2,537€ yr^{-1}) and on mineral fertilisers (5,312 € yr^{-1}).

The total cost increase. In the Farm EE1, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (9,512 € yr^{-1}) is sum of additional storage cost (1,663 € yr^{-1}) and total cost on fields (7,849 € yr^{-1}).

3.2. Finland

3.2.1. General data for calculations made for Finnish farms

Table 3.4. General data for calculations made for Finnish farms

	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	30	
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.72	
N content in mineral fertiliser	%	34.4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	1.8	
P content in mineral fertiliser	%	20	Triple superphosphate (46%) P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.6	
K content in mineral fertiliser	%	50.8	Potassium Chloride
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	24	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.7	

3.2.2. Farm FI1

Storages

Manure amount

Farm FI1 is dairy cow farm. In farm FI1 is required minimum storage capacity for manure, which is produced during 12 months. The farm has two slurry storages (3,700 and 1,100 m^3) and it corresponds to maximum 4,800 t annual slurry production. This value is used in economic calculations as old data for manure amount. The new amount (3,100 t) was calculated by Janne Helin (PP1). It means that by new data farm has storage capacity for 18.6 month.

Manure properties

Table 3.5. Manure properties in Farm FI1

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle slurry	3.13	1.98	0.36	1.9	4.04

New data	Cattle slurry	4	2.4	0.45	2.6	5.25

Old data are from current Finnish manure standard.
New manure data are from manure samples collected during Manure Standards project.

By old data the

maximum hectare amount of manure, by N_{tot} or P is 54 t ha^{-1} and
minimum area, fertilised with manure can be 88 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 43 t ha^{-1} and
minimum area, fertilised with manure can be 73 ha.

Manure price

The price of Farm FI1 manure increases 1.21 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.5) is calculated by the data in tables 3.4 and 3.5, and formula 6. The manures contains by new data more NPK, therefore the new price is higher compared to the price calculated by old data.

Income from selling

Farm FI1 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm FI1 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storages are from concrete elements, 1 m in the ground.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storages by old data is 16,566 € yr^{-1} and by new data would be 14,377 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 12 month amount from 3,100 t annual slurry production.

The farm has 1,700 m^3 more storage space than required to satisfy demand to have storage space for minimum 12 month manure production. The overinvestment cost is 2,189 € yr^{-1}.

Fields

Farm FI1 fertilises 54 fields with manure, totally 175 ha. The planned NPK amounts and driving distance are specified for every field. In some fields are planned N and P amounts zero. These fields are excluded from present analyses, because manure amount can be calculated only to the fields where planned NP amounts are bigger than zero. Thus, manure amounts are calculated to 31 fields, totally 142 ha.

The planned amount vary for:

N: 88-261 kg ha^{-1}
P: 6-7 kg ha^{-1}

K: 27-32 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farm's field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.

The distances between storage and fields are 0.12 to 5.5 km.

Table 3.6. Manure loading, transporting and spreading cost (based on Farm FI1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	-0.9442	15.482	0.074	-0.6281	12.927	-0.5979	0.9	0.09

Results of calculations

By the old and new data both are required 31 fields to spread all manure produced by farm. In both cases, some manure is not utilised because farm has less field area than required and 1,930 t is not applied by old data and 804 t by new data.

Manure transportation and spreading cost, € in total over all field area is

by old data 9,188 € and

by new data 8,140 €.

The decrease of this cost is 1,048 € if new data are used instead of old manure data.

The total cost decreases because the farm has 574 t less slurry by new data what should be transported and spread to the fields.

The total cost on mineral N is increasing only 76 €. Although by new data farm uses less slurry the slurry NH_4-N content is bigger and N demand planned to the fields is covered approximately in same extent. The total handling cost of mineral N increases 8 €.

The P and K amounts planned to the fields are totally covered by slurry in the case of old and new data both. Thus, the cost increase connected to P and K mineral fertilisers is zero.

The total cost on mineral fertilizers increases 84 € yr^{-1} in the case of new data.

The total cost increase on fields -965 € is sum of cost increase on manure handling (-1,048 € yr^{-1}) and on mineral fertilisers (84 € yr^{-1}).

The total cost increase. In the Farm FI1, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (1,225 € yr^{-1}) is sum of additional storage cost (2,189 € yr^{-1}) and total cost change on fields (-965 € yr^{-1}).

3.3. Germany

3.3.1. General data for calculations made for German farms

Table 3.7. General data for calculations made for German farms

	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	25	
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.79	
N content in mineral fertiliser	%	27	CAN
P element price in mineral fertiliser	€ kg^{-1}	1.84	
P content in mineral fertiliser	%	20	Triple superphosphate (46%) P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.64	
K content in mineral fertiliser	%	49.8	Kornkali, K_2O
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	24	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.7	

3.3.2. Farm DE3

Storages

Manure amount

Farm DE3 is a cattle production farm. In farm DE4 is required minimum storage capacity for manure, which is produced during 6 months. Slurry from dairy cows is emptied every 4 weeks to the lagoon (2,700 m³). The slurry of heifers as well as the slurry of the bulls is stored in tanks (800 m³, 1,000 m³). All stored slurry have a natural crust. Total amount of slurry storages is 4,500 m^3 and it corresponds to maximum 9,000 t annual production and in economic calculations this used as as old data for manure amount. The new amount for dairy cows is 3,069 t and for bulls 569 t was calculated based on animal places and default values by Friederike Lehn (PP7). The new amount for heifers was calculated by number of animal places and with the consideration that heifers produce 45% from slurry amount produced by dairy cows (by current Estonian manure standard), By Kalvi Tamm (PP13). Thus the manure production by new data is 4,881 t per year. It means that by new data farm has slurry storage capacity for 11.1 month.

Manure properties

Table 3.8. Manure properties in Farm DE3

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Dairy cow slurry	3.5	2	0.65	1.99	6.03
New data	Dairy cow slurry	5.93	3.56	0.96	7.38	11.17

Old data	Heifer slurry	3.5	2	0.65	1.99	6.03
New data	Heifer slurry	5.93	3.56	0.96	7.38	11.17
Old data	Bulls slurry	3.5	2	0.65	1.99	6.03
New data	Bulls slurry	4.5	2.7	0.71	3.81	7.3

Old data are from LKSH (2011)
New manure are from Manure Standards project, calculated with WP3 calculator.

By old data the

maximum hectare amount of manure, by N_{tot} or P is 39 t ha^{-1} and
minimum area, fertilised with dairy cow manure can be 140 ha.
minimum area, fertilised with heifer manure can be 42 ha.
minimum area, fertilised with bulls manure can be 52 ha.

By new data about dairy cows the

maximum hectare amount of manure, by N_{tot} or P is 26 t ha^{-1} and
minimum area, fertilised with manure can be 112 ha.

about heifers the

maximum hectare amount of manure, by N_{tot} or P is 26 t ha^{-1} and
minimum area, fertilised with manure can be 48 ha.

about bulls the

maximum hectare amount of manure, by N_{tot} or P is 35 t ha^{-1} and
minimum area, fertilised with manure can be 16 ha.

<u>Manure price</u>

The price of dairy cows and heifers manure increases 5.14 € t^{-1} if new data are used instead of old data. The bulls slurry is price increase 1.27 € t^{-1}. The price of manure (Table 3.8) is calculated by the data in tables 3.7 and 3.8, and formula 6. The manures contains by new data more NPK, therefore the new price is higher compared to the price calculated by old data.

<u>Income from selling</u>

Farm DE3 don’t sell any manure, so there is no income from selling of manure.

<u>Cost for manure export</u>

Farm DE3 don’t export any manure, so there is no costs related to export of manure out of farm.

<u>Cost of manure storage</u>

The existing slurry storage types are for:

1) dairy cows - lagoon, PE bottom, leakage indicator, fenced
2) heifers and bulls - concrete, cast in place, on the ground

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of all storages by old data is 17,228 € yr^{-1} and by new data would be 12,630 € yr^{-1}. The storage cost by old data is calculated by actual storage size 4,500 m^3. The storage cost by new data is calculated by storage size 2,441 m^3, which is required to store 6 month amount from 4,881

m^3 annual slurry production. It means that farm has 2,059 m^3 more storage space than required and the additional cost because of overinvestment is 4,598 € yr^{-1}.

Fields

Farm DE3 fertilises 5 fields with manure, totally 170 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount vary for:

N: 83 - 243 kg ha^{-1}

P: 16 - 55 kg ha^{-1}

K: 78 - 235 kg ha^{-1}.

By Friderike lehn (PP7), the planned N, P and K are calculated based on nutrient content of slurry (farm analysis results) and application rate + N, P and K amount via mineral fertilizer

Manure N: 50% efficiency factor

According to farm survey, only 170 ha UAA is used for manure application (total UAA of farm: 200 ha) -> according to the farmer, all 93 ha of arable land is fertilized with manure -> 77 ha of grassland remain for manure application (65 ha for grass silage production and 12 ha pasture)

Recalculation example: corn silage -> 40 t ha^{-1} application rate of manure -> 3.3 kg N/t * 40 t ha^{-1} *0.5 (efficiency factor) + 80 kg N (mineral fertilzer).

The distances between storage and fields vary from 2 to 3 km. The distances were assessed by the farmer.

Table 3.9. Manure loading, transporting and spreading cost (based on Farm DE3 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.3959	5.544	0.0436	-0.3498	5.4921	-0.4079	0.91	0.09

Results of calculations

By the old and new data both are required 5 fields to spread all manure produced by farm. In both cases, some manure is not utilised because farm has less field area than required, and 3,005 t is not applied by old data and 694 t by new data.

<u>Manure transportation and spreading cost</u>, € in total over all field area is

by old data 16,623 € and

by new data 12,598 €.

The decrease of this cost is 4,025 € if new data are used instead of old manure data.

The cost decreases because 1,808 t less slurry is transported and spread to the fields by new data.

The total cost on <u>mineral N</u> is decreasing 1,211 € because manure contains more NH_4-N by new data. Thus, less mineral N is required in the farm to cover planned N amount on the fields. In the same reason, the total handling cost of mineral N decreases 146 €.

The limit value of P (25 kg ha^{-1}) is covered by manure in same amount by old and new data both. Thus, there is no changes if to compare costs for mineral P and handling of P fertilisers.

The total cost on mineral K decreases 1,588 €, because manure contains more K by new data (see table 3.8). Thus the need for mineral K on the fields fertilised with manure is by new data less than by old data and total cost decreases. In the same reason the handling cost of mineral K decreases by 130 €.

The total cost on mineral fertilizers decreases 3,075 € yr^{-1} in the case of new data.

The total cost decrease on fields 7,100 € is sum of cost decrease on manure handling (4,025 € yr^{-1}) and on mineral fertilisers (3,075 € yr^{-1}).

The total cost decrease. In the Farm DE3, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost decrease in farm (-2,502 € yr^{-1}) is sum of additional storage cost (4,598 € yr^{-1}) and total cost change on fields (-7,100 € yr^{-1}).

3.3.3. Farm DE4

Storages

Manure amount

Farm DE4 is a pig production farm. In farm DE4 is required minimum storage capacity for manure, which is produced during 6 months. The farm has one 1,500 m^3 slurry storage and it corresponds to maximum 3,000 t annual slurry production. This value is used in economic calculations as old data for manure amount. The new amount (1,352 t) was calculated based on animal places and default values by Friederike Lehn (PP7). It means that by new data farm has storage capacity for 13.3 month.

Manure properties

Table 3.10. Manure properties in Farm DE4

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Pig slurry	3,6	2.8	0.74	1.99	5.48
New data	Pig slurry	5.65	4.05	1.46	2.79	8.94

Old data are from LKSH (2011)

New manure are from Manure Standards project, manure analyses

By old data the

maximum hectare amount of manure, by N_{tot} or P is 34 t ha^{-1} and
minimum area, fertilised with manure can be 89 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 17 t ha^{-1} and
minimum area, fertilised with manure can be 79 ha.

Manure price

The price of Farm DE4 manure increases 3.46 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.10) is calculated by the data in tables 3.7 and 3.10, and formula 6. The manure contains by new data more NPK, therefore the new price is higher compared to the price calculated by old data.

Income from selling

Farm DE4 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm DE4 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage from concrete, cast in place, on the ground

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 5,690 € yr^{-1} and by new data would be 4,078 € yr^{-1}. The storage cost by old data is calculated by actual storage size 1,500 m^3. The storage cost by new data is calculated by storage size 676 m^3, which is required to store 6 month amount from 1,352 m^3 annual slurry production. It means that farm has 824 m^3 more storage space than required and the additional cost because of overinvestment is 1,612 € yr^{-1}.

Fields

Farm DE4 fertilises 11 fields with manure, totally 73 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount vary for:

N: 100-210 kg ha^{-1}
P: 22-37 kg ha^{-1}
K: 42-70 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farm's field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.

The distances between storage and fields vary from 0.5 to 12.5 km. Some distances were assessed by the farmer and some by Raivo Vettik (PP13) with help of fields map.

Table 3.11. Manure loading, transporting and spreading cost (based on Farm DE4 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.3959	5.544	0.0436	-0.3498	5.4921	-0.4079	0.91	0.09

Results of calculations

By the old and new data both are required 11 fields to spread all manure produced by farm. In both cases, some manure is not utilised because farm has less field area than required, and 605 t is not applied by old data and 138 t by new data.

Manure transportation and spreading cost, € in total over all field area is

by old data 6,000 € and

by new data 3,613 €.

The decrease of this cost is 2,387 € if new data are used instead of old manure data.

The cost increases because the farm has less slurry by new data what should be transported and spread to the fields.

The total cost on mineral N is increasing 1,067 €. Although, the manure contains more NH_4-N by new data (45% more compared to the old data), is increase of P content relatively bigger (+97%). The manure amount per hectare drops from 34 to 17 t ha^{-1} because this is calculated by maximum P amount (25 kg ha^{-1}) allowed to use on the fields, by old and new data both. Higher NH_4-N content in manure doesn't compensate the decrease of manure amount per hectare. By new data the planned N amount is covered by manure in smaller extent and thus, the need for mineral N is increasing. In same reason, the total handling cost of mineral N increases 133 €.

The limit value of P (25 kg ha^{-1}) is fully covered by manure by old and new data both. Thus, there is no changes if to compare costs for mineral P and handling of P fertilisers.

The total cost on mineral K increases 325 €, despite of higher K content (+40%) in manure by new data. The reason for cost increase of mineral K is same as by cost increase of mineral N. In the same reason the handling cost of mineral K increases by 25 €.

The total cost on mineral fertilizers increases 1,550 € yr^{-1} in the case of new data.

The total cost increase on fields -837 € is sum of cost increase on manure handling (-2,387 € yr^{-1}) and on mineral fertilisers (1,550 € yr^{-1}).

The total cost increase. In the Farm DE4, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (775 € yr^{-1}) is sum of additional storage cost (1,612 € yr^{-1}) and total cost change on fields (-837 € yr^{-1}).

3.4. Latvia

3.4.1. General data for calculations made for Latvian farms

Table 3.12. General data for calculations made for Latvian farms

	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	-	No limit
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.64	

N content in mineral fertiliser	%	34.4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	1.8	
P content in mineral fertiliser	%	22.7	Amofoss (N12 P52%)
K element price in mineral fertiliser	€ kg^{-1}	0.6	
K content in mineral fertiliser	%	60	Potassium Chloride
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	34	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.7	

3.4.2. Farm LV1

Storages

Manure amount

Farm LV1 is a dairy cow farm with average yearly milk yield of 12.5 t per cow. In farm LV1 is required minimum storage capacity for manure, which is produced during 6 months. The farm has one 8,000 m^3 slurry storage and it corresponds to maximum 16,000 t annual slurry production. This value is used in economic calculations as old data for manure amount. The new amount (22,965 t) was calculated with help of WP3 calculator by State Plant Protection Service (PP12). It means that by new data farm has storage capacity for 4.2 month.

Manure properties

Table 3.13. Manure properties in Farm LV1

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle slurry	4.5	2.7	0.91	2.98	6.31
New data	Cattle slurry	5.21	3.126	0.74	3.87	6.99

Old data are from current Latvian national regulation: 23 December 2014 Cabinet Regulation No. 834
New manure amount and data are from Manure Standards project WP3 calculation tool

By old data the
maximum hectare amount of manure, by N_{tot} or P is 38 t ha^{-1} and
minimum area, fertilised with manure can be 424 ha.
By new data the
maximum hectare amount of manure, by N_{tot} or P is 33 t ha^{-1} and
minimum area, fertilised with manure can be 704 ha.

Manure price

The price of Farm LV1 manure increases 0.68 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.13) is calculated by the data in tables 3.12 and 3.13, and formula 6. By the new data manure contains more NK, therefore the new price is higher compared to the price calculated by old data

Income from selling

Farm LV1 don’t sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm LV1 doesn't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage lagoon, PE bottom, leakage indicator, fenced.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 14,854 € yr^{-1} and by new data would be 18,211 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 6 month amount from 22,965 m^3 annual slurry production.

The farm requires 3,482 m^3 additional storage space to satisfy demand to have storage space for minimum 6 month manure production. The additional cost is 3,358 € yr^{-1}.

Fields

Farm LV1 fertilises 41 fields with manure, totally 1,015 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount varies for:

N: 85-271 kg ha^{-1}
P: 50-90 kg ha^{-1}
K: 80-215 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farm's field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.
The distances between storage and fields vary from 0.01 to 10.4 km.

Table 3.14. Manure loading, transporting and spreading cost (based on Farm LV1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.2566	3.6339	0.0321	-0.3057	3.9893	-0.385	0.88	0.09

Results of calculations

By the old data are required 17 fields to spread all manure produced by farm. By new data are required 28 fields because the amount of slurry is bigger and allowed manure amounts smaller (32 t ha^{-1}) than by old data (38 t tha^{-1}).

Manure transportation and spreading cost, € in total over all field area is

by old data 29,171 € and
by new data 48,156 €.

The increase of this cost is 18,985 € if new data are used instead of old manure data.

The cost increases because the farm has 6,965 t more slurry by new data what should be transported and spread to the fields.

The cost on manure transportation and spreading is 1.8 € m^{-3} by old data and 2.1 € m^{-3} by new data. The reason for cost increase is bigger manure amount – this means more field area >> more far fields >> maximum transportation distance increases from 3.4 to 5.5 km >> increase of transportation costs.

The total cost on mineral N decreases by 12,761 € because farm has 6,965 t more manure by new data. Thus, smaller number fields should be fertilised only with mineral N. In same reason, the total handling cost of mineral N decreases by 2,130 €.

In same reason the total cost on mineral P and handling cost of that fertiliser are decreasing 4,381 and 416 € correspondingly.

The total cost on mineral K decreases by 18,985 €, because farm has more manure and it contains more K by new data (see table 3.13). Thus the need for mineral K on the fields fertilised with manure is by new data is less than by old data and total cost decreases. In the same reason the handling cost of mineral K decreases by -1,933€.

The total cost on mineral fertilizers decreases by 40,606 € yr^{-1} in the case of new data.

The total cost increase on fields -21,620 € is sum of cost increase on manure handling (18,985 € yr^{-1}) and on mineral fertilisers (-40,606 € yr^{-1}).

The total cost increase. In the Farm LV1, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (-18,262 € yr^{-1}) is sum of additional storage cost (3,358 € yr^{-1}) and total cost change on fields (-21,620 € yr^{-1}).

3.4.3. Farm LV2

Storages

Manure amount

Farm LV2 is a dairy cow farm with average yearly milk yield of 10.4 t per cow. In farm LV2 is required minimum storage capacity for manure, which is produced during 1 month. Farm LV2 has one 500 t deep litter storage and it corresponds to maximum 6,000 t annual dung production. This value is used in economic calculations as old data for manure amount. The new amount (5,818 t) was calculated with help of WP3 calculator by State Plant Protection Service (PP12). It means that farm had storage capacity for 1.03 months by new data.

Manure properties

Table 3.15. Manure properties in Farm LV2

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle deep litter	5.5	1.1	1.0	3.6	7.48
New data	Cattle deep litter	5.34	1.068	0.82	4.5	7.59

Old data are from current Latvian national regulation: 23 December 2014 Cabinet Regulation No. 834
New manure amount and data are from Manure Standards project WP3 calculation tool.

By old data the

maximum hectare amount of manure, by N_{tot} or P is 31 t ha^{-1} and
minimum area, fertilised with manure can be 194 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 32 t ha^{-1} and
minimum area, fertilised with manure can be 183 ha.

Manure price

The price of Farm LV2 manure increases by 0.11 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.15) is calculated by the data in tables 3.12 and 3.15, and formula 6. The manure by new data contains more K, therefore the new price is higher compared to the price calculated by old data

Income from selling

Farm LV2 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm LV2 don't export any manure, so there are no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is solid manure storage, concrete plate, pile height 1.5 m.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 5,831 € yr^{-1} and by new data would be 5,654 € yr^{-1}. The storage cost by old data is calculated by actual storage size (500 t).

The farm has bit more (15 t) storage space than required (485 t) by new data and the overinvestment cost is 177 € yr^{-1}.

Fields

Farm LV2 fertilises 9 fields with manure, totally 163 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount varies for:

N: 100-286 kg ha^{-1}

P: 63-88 kg ha^{-1}

K: 80-152 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farms field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.

The distances between storage and fields vary from 0.01 to 3.5 km.

Manure loading, transporting and spreading cost were calculated by factors in table 3.16.

Table 3.16. Manure loading, transporting and spreading cost (based on Farm LV2 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Solid	2	0.3406	6.0633	0.00153	-0.1924	6.3314	-0.1488	2.06	0.11

Results of calculations

By the old and new data both 9 fields are required to spread all manure produced by farm. In both cases, some manure is not utilised because farm has less field area than required, and 962 t is not applied by old data and 629 t by new data.

Manure transportation and spreading cost, € in total over all field area is

by old data 21,300 € yr^{-1} and

by new data 21,847 € yr^{-1}.

The increase of this cost is 547 € yr^{-1} if new data are used instead of old manure data. The reason is lower N amount in manure and thus bigger hectare amount of manure by new data.

The total cost on mineral N doesn't change if to compare old and new data. Because the N demand is covered by manure in same extent in the case of both scenarios. Also there is no change in mineral N handling costs.

The total cost on mineral P increases by 1,410 € yr^{-1} because of lower P amount in manure by new data. The total handling cost of mineral P increases by 120 € yr^{-1}.

The total cost on mineral K decreases by 701 € because of bigger K amount in manure and larger manure amount per hectare by new data. The total handling cost of mineral K decreases by 67 €.

The total cost on mineral fertilizers decreases 762 € yr^{-1} in the case of new data.

The total cost on fields (1309 €) is sum of costs on manure handling (547 € yr^{-1}) and on mineral fertilisers (762 € yr^{-1}).

The total cost increase. In the Farm LV2, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself.

The total cost increase in farm (1,486 € yr^{-1}) is sum of storage cost increase (177 € yr^{-1}) and total cost on fields (1309 € yr^{-1}).

3.4.4. Farm LV3

Storages

Manure amount

Farm LV3 is a dairy cow farm with average yearly milk yield of 11.9 t per cow. In farm LV3 is required minimum storage capacity for manure, which is produced during 9 month. Farm LV3 has one 19,000 m^3 slurry storage and it corresponds to maximum 25,333 t annual slurry production. This value is used in economic calculations as old data for manure amount. The new amount (26,031 t) was calculated with help of WP3 calculator by State Plant Protection Service (PP12). It means that farm had storage capacity for 8.76 month by new data.

Manure properties

Table 3.17. Manure properties in Farm LV3

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle slurry	4.36	2.616	0.97	2.77	6.20
New data	Cattle slurry	3.26	1.956	0.54	1.77	4.12

Old data are from current Latvian national regulation: 23 December 2014 Cabinet Regulation No. 834
New manure amount and data are from Manure Standards project WP3 calculation tool.

By old data the
maximum hectare amount of manure, by N_{tot} or P is 39 t ha^{-1} and
minimum area, fertilised with manure can be 650 ha.
By new data the
maximum hectare amount of manure, by N_{tot} or P is 52 t ha^{-1} and
minimum area, fertilised with manure can be 499 ha.

Manure price

The price of Farm LV3 manure decreases by 2.08 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.17) is calculated by the data in tables 3.12 and 3.17, and formula 6. The manure by new data contains less NPK, therefore the new price is lower compared to the price calculated by old data

Income from selling

Farm LV3 don’t sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm LV3 don’t export any manure, so there are no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage lagoon, PE bottom, leackage indicator, fenced.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 24,194 € yr^{-1} and by new data would be 24,568 € yr^{-1}.

The farm has 523 m^3 less storage space than required (19,523 m^3) by new data and the additional cost is 374 € yr^{-1}.

Fields

Farm LV3 fertilises 19 fields with manure, totally 391 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount varies for:

N: 87-236 kg ha^{-1}

P: 19-114 kg ha^{-1}

K: 55-161 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farms field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.

The distances between storage and fields are from 0.2 to 8.0 km.

Manure loading, transporting and spreading cost were calculated by factors in table 3.18.

Table 3.18. Manure loading, transporting and spreading cost (based on Farm LV3 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.2159	3.6291	0.0331	-0.323	4.1234	-0.4107	0.88	0.09

Results of calculations

By the old and new data both are required 19 fields to spread all manure produced by farm. In both cases, some manure is not utilised because farm has less field area than required, and 10,329 t is not applied by old data and 5,855 t by new data.

Manure transportation and spreading cost, € yr^{-1} in total over all field area is

by old data 23,530 € yr^{-1} and

by new data 29,364 € yr^{-1}.

The increase of this cost is 5,834 € yr^{-1} if new data are used instead of old manure data. The reason is lower N amount in manure and thus bigger hectare amount of manure by new data.

The total cost on mineral N decreases only by 95 € yr^{-1} because the N demand of most fields is covered by manure in same extent in the case of both scenarios. The total handling cost of mineral N decreases by 15 € yr^{-1}.

The total cost on mineral P increases by 6,586 € yr^{-1} because of lower P amount in manure by new data. The total handling cost of mineral P increases by 570 € yr^{-1}.

The total cost on mineral K increases by 2,956 € yr^{-1} because of lower K amount in manure by new data. The total handling cost of mineral K decreases by 291 € yr^{-1}.

The total cost on mineral fertilizers increases by 10,292 € yr^{-1} in the case of new data.

The total cost on fields (16,126 €) is sum of costs on manure handling (5,834 € yr^{-1}) and on mineral fertilisers (10,292 € yr^{-1}).

The total cost increase. In the Farm LV3, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (16,500 € yr^{-1}) is sum of storage cost increase (374 € yr^{-1}) and total cost on fields (16,126 € yr^{-1}).

3.4.5. Farm LV4

Storages

Manure amount

Farm LV4 is a pig production farm. In farm LV4 is required minimum storage capacity for manure, which is produced during 4 month. Farm LV3 has one 2,200 m^3 slurry storage and it corresponds to maximum 6,600 t annual slurry production. This value is used in economic calculations as old data for manure amount. The new amount (4,769 t) was calculated with help of WP3 calculator by State Plant Protection Service (PP12). It means that farm had storage capacity for 5.5 month by new data.

Manure properties

Table 3.19. Manure properties in Farm LV4

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Pig slurry	3.9	2.808	1.3	1.6	5.8
New data	Pig slurry	1.84	1.3248	0.41	0.65	2.31

Old data are from current Latvian national regulation: 23 December 2014 Cabinet Regulation No. 834
New manure amount and data are from Manure Standards project WP3 calculation tool.

By old data the

maximum hectare amount of manure, by N_{tot} or P is 44 t ha^{-1} and minimum area, fertilised with manure can be 151 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 92 t ha^{-1} and

minimum area, fertilised with manure can be 52 ha.

Manure price

The price of Farm LV4 manure decreases 3.49 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.19) is calculated by the data in tables 3.12 and 3.19, and formula 6. The manure by new data contains less NPK, therefore the new price is lower compared to the price calculated by old data.

Income from selling

Farm LV4 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm LV4 don't export any manure, so there are no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage from concrete elements, 1 m in the ground.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 8,333 € yr^{-1} and by new data would be 7,336 € yr^{-1}.

The farm has 610 m^3 more storage space than required (1,590 m^3) by new data and the additional cost because of overinvestment is 996 € yr^{-1}.

Fields

Farm LV4 fertilises 9 fields with manure, totally 316 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount varies for:

N: 117-131 kg ha^{-1}

P: 90-138 kg ha^{-1}

K: 70-108 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farms field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.

The distances between storage and fields vary from 1.3 to 10.0 km.

Manure loading, transporting and spreading cost were calculated by factors in table 3.20.

Table 3.20. Manure loading, transporting and spreading cost (based on Farm LV4 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)	Costs over distance limit, separate transporter

		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.2728	4.0721	0.0178	-0.2177	4.2365	-0.2515	0.88	0.09

Results of calculations

By the old data 4 fields are required to spread all manure produced by farm. By new data 1 field is required because the amount of slurry is smaller and allow bigger (93 t ha^{-1}) manure amounts than by old data (44 t ha^{-1}).

Manure transportation and spreading cost, € yr^{-1} in total over all field area is
by old data 14,157 € yr^{-1} and
by new data 8,752 € yr^{-1}.
The decrease of this cost is 5,405 € yr^{-1} if new data are used instead of old manure data. The reason is smaller total slurry amount in the farm.

The total cost on mineral N increases by 6,996 € yr^{-1} because the farm has less manure and the manure contains less N by new data. In the same reason the total handling cost of mineral N increases by 1,112 € yr^{-1}.

The total cost on mineral P increases by 11,924 € yr^{-1} because the farm has less manure and the manure contains less P by new data. In the same reason the total handling cost of mineral P increases by 1,021 € yr^{-1}.

The total cost on mineral K increases by 4,476 € yr^{-1} because the farm has less manure and the manure contains less K by new data. In the same reason the total handling cost of mineral K increases by 435 € yr^{-1}.

The total cost on mineral fertilizers increases by 25,964 € yr^{-1} in the case of new data.

The total cost on fields (20,599 €) is sum of costs on manure handling (-5,405 € yr^{-1}) and on mineral fertilisers (25,964 € yr^{-1}).

The total cost increase. In the Farm LV4, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (21,556 € yr^{-1}) is sum of storage cost increase (996 € yr^{-1}) and total cost on fields (20,559 € yr^{-1}).

3.5. Lithuania

3.5.1. General data for calculations made for Lithuanian farms

Table 3.21. General data for calculations made for Lithuanian farm

	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	

Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	-	Maximum amount is not defined
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.73	
N content in mineral fertiliser	%	34.4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	1.8	
P content in mineral fertiliser	%	20	Triple-Superphosphat (TSP), 46% P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.6	
K content in mineral fertiliser	%	50.6	Potassium Chloride
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	24	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.7	

3.5.2. Farm LT1

Storages

Manure amount

In farm LT1 is required minimum storage capacity for manure, which is produced during 6 months. The farm has one 2,400 m^3 slurry storage and it corresponds to maximum 4,800 t annual slurry production. This value is used in economic calculations as old data for manure amount. The new amount (3,042 t) was calculated with help of Manure Standards project WP3 calculation tool. It means that by new data farm has storage capacity for 9.5 month.

Manure properties

Table 3.22. Manure properties in Farm LT1

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle slurry	5.56	1.6	0.55	1.9	6.19
New data	Cattle slurry	3.8	1.48	0.62	2.7	5.51

Old data are from farm.
New manure amount and data are from Manure Standards project WP3 calculation tool.

By old data the

maximum hectare amount of manure, by N_{tot} or P is	31 t ha^{-1} and
minimum area, fertilised with manure can be	157 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is	45 t ha^{-1} and
minimum area, fertilised with manure can be	68 ha.

Manure price

The price of Farm LT1 manure decreases 0.68 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.22) is calculated by the data in tables 3.21 and 3.22, and formula 6.

Income from selling

Farm LT1 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm LT1 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage from steel elements, on the ground

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 8,489 € yr^{-1} and by new data would be 9,479 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 6 month amount from 3,042 m^3 annual slurry production.

The farm has 879 m^3 more storage space than required to satisfy demand to have storage space for minimum 6 month manure production. The overinvestment cost is 989 € yr^{-1}.

Fields

Farm LT1 fertilises 9 fields with manure, totally 208 ha. The planned NPK amounts and driving distance are specified for every field.

The planned amount vary for:

N: 19-77 kg ha^{-1}
P: 26-48 kg ha^{-1}
K: 22-32 kg ha^{-1}.

The planned amounts were calculated by mineral and organic fertiliser data used on fields in year 2017. The data source was farm's field book. If no planned NPK amount were provided, national fertilisation recommendations for specific crops were used.
The distances between storage and fields are 2.5 km.

Table 3.23. Manure loading, transporting and spreading cost (based on Farm LT1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	0.5118	4.566	0.0271	-0.2459	4.8171	-0.3184	0.82	0.08

Results of calculations

By the old data are required 8 fields to spread all manure produced by farm. By new data are required 5 fields because the amount of slurry is smaller and allowed manure amounts are bigger (45 t ha^{-1}) than by old data (31 t tha^{-1}).

Manure transportation and spreading cost, € in total over all field area is

by old data 15,514 € and
by new data 9,564 €.

The decrease of this cost is 5950 € if new data are used instead of old manure data.

The total cost decreases because the farm has 1,758 t less slurry by new data what should be transported and spread to the fields.

The total cost on mineral N is increasing 1,618 € because farm has 1,758 t less manure and manure NH_4-N content is smaller by new data. Thus, bigger number of fields should be fertilised only with mineral N. In same reason, the total handling cost of mineral N increases 166 €.

The total cost on mineral P and handling cost of that fertiliser are increasing 1357 and 97 € correspondingly, because farm has 1,758 t less manure by new data.

In the same reason the total cost on mineral K and handling cost of that fertiliser are increasing 1,136 and 96 € correspondingly.

The total cost on mineral fertilizers increases 4,470 € yr^{-1} in the case of new data.

The total cost increase on fields -1,480 € is sum of cost increase on manure handling (-5,950 € yr^{-1}) and on mineral fertilisers (4,470 € yr^{-1}).

The total cost increase. In the Farm LT1, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (-491 € yr^{-1}) is sum of additional storage cost (989 € yr^{-1}) and total cost change on fields (-1,480 € yr^{-1}).

3.6. Poland

3.6.1. General data for calculations made for Polish farms

Table 3.24. General data for calculations made for Polish farms

Calculation factor	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	-	Maximum amount is not defined
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	24	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.7	

3.6.2. Farm PL7

Storages

Manure amount

In farm PL7 is produced cattle manure and urine. Required minimum storage capacity is for manure, which is produced during 6 months. Farm PL7 has one 1,200 t solid manure storage for cattle manure and urine - it corresponds to maximum 2,400 t annual manure production. In addition, farm has a 360 m^3 tank for cattle urine, thus the calculated annual urine amount is 720 t. These values are used in economic calculations as old data for manure amount. The new amounts (2,200 t manure with urine and 700 t urine) were calculated by current polish manure standard by D. Wach (PP15). It means that farm had storage capacity for 6.6 month for manure with urine storage and for 6.2 month for urine by new data.

Manure properties

Table 3.25. Manure properties in Farm PL7

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle manure with urine	3.3	1	0.6	2.2	8.89
New data	Cattle manure with urine	4.77	1	0.99	5.48	17.09
Old data	Cattle urine	3.2	1	0.03	1.5	5.13
New data	Cattle urine	1.92	1	0.09	3.35	7.32

Old data are taken from Old data was taken from Polish standards (NH_4-N from manure analyses in Manure Standards project– Poland don't have normative)

New data are from analysis results 2019 (NPK and NH_4-N). NH_4-N was analysed by special request (it is not standard procedure).

By old data the

manure with urine has

maximum hectare amount, by N_{tot} 52t ha^{-1} and

minimum area, fertilised with the manure - 47 ha;

urine has

maximum hectare amount, by N_{tot} 53 t ha^{-1} and

minimum area, fertilised with the manure - 13.6 ha.

By new data the

manure with urine has

maximum hectare amount, by N_{tot} 36 t ha^{-1} and

minimum area, fertilised with the manure - 62 ha;

urine has

maximum hectare amount, by N_{tot} 89 t ha^{-1} and

minimum area, fertilised with the manure – 7.9 ha.

Manure price

The price of manure with urine increases 8.2 € t^{-1} and price of urine increases 2.19 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.25) is calculated by the data in tables 3.24 and 3.25, and formula 6. The manure contains by new data more PK, therefore the new price is higher compared to the price calculated by old data.

Income from selling

Farm PL1 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm PL1 don’t export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The storage type is Solid manure storage, concrete plate, pile height 1.5 m; for manure with urine. The pure urine is stored in the Slurry storage from concrete elements, 1 m in the ground.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storages by old data is 18,093 € yr^{-1} and by new data would be 16,882 € yr^{-1}. The storage cost by old data is calculated by actual size of storages. The storage cost by new data is calculated by storage size which is required to store 6 month amount from 2,200 t annual production of manure with urine and 700 t of annual cattle urine production.

The farm requires storage space for minimum 1,100 t solid manure with urine and 350 m^3 urine by new data. It means that farm has 100 t more storage space for manure with urine and for 10 m^3 urine what provides additional cost of overinvestment – 1,211 € yr^{-1}.

Fields

Farm PL7 has 5 fields with manure, totally 41 ha. The planned NPK amounts and driving distance are specified for every field.

Table 3.26. Fertiliser prices used in calculations for farm PL7

Mineral fertiliser data	Unit	Value	Comments
N element price in mineral fertiliser	€ kg^{-1}	0,81	
N content in mineral fertiliser	%	34,4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	4,5	
P content in mineral fertiliser	%	8,7	Polifoska 6 NPK(S) 20%P_2O_5,30%K_2O, (7%S)
K element price in mineral fertiliser	€ kg^{-1}	1,6	
K content in mineral fertiliser	%	24,9	Polifoska 6 NPK(S) 20%P_2O_5,30%K_2O, (7%S)

The planned amount varies for:

N: 100-160 kg ha^{-1}

P: 11-30 kg ha^{-1}

K: 30-80 kg ha^{-1}.

The planned amounts were calculated by advisor or farmer based on plants uptake and soil status.

The distances between storage and fields vary from 0.5 to 2.5 km. The data about distances were supplied by farmer

Table 3.26a. Manure loading, transporting and spreading cost (based on Farm PL1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor	Cost factor	Cost factor a_2,	Cost factor b_2,	Cost factor	Cost factor	Basic cost,	Cost addition,

		a_1	b_1	power	power	a_s	b_s	€ t^{-1}	€ t^{-1} km^{-1}
Slurry	5	0.4312	3.8328	0.0421	-0.3116	2.7962	-0.2935	0.91	0.09

Results of calculations

By the old and new data both are required 5 fields to spread all manure produced by farm. By old data some manure is not utilised because farm has less field area than required, and 616 t manure with urine and 104 t urine is not applied by new data.

By new data 1,661 t manure with urine is not applied to the fields. However, by new data all 750 t urine is applied to the fields.

Manure transportation and spreading cost, € in total over all field area is
by old data 8,397 € yr^{-1} and
by new data 5,587 yr^{-1} €.
The decrease of this cost is 2,810 € yr^{-1} if new data are used instead of old manure data. The reason is 546 t smaller amount of manure with urine applied to the fields.

The total cost on mineral N is increasing 213 € yr^{-1} because of smaller amount of manure with urine per hectare by new data. The total handling cost of mineral N increases 20 € yr^{-1}.

The total cost on mineral P is decreasing 200 € yr^{-1} because of bigger P amount in manure by new data. The total handling cost of mineral P decreases 12 € yr^{-1}.

The total cost on mineral K is decreasing only 6 € yr^{-1} because most of K demand of fields is covered by manure in the case of old and new data both. The total handling cost of mineral K decreases 0.4 € € yr^{-1}.

The total cost on mineral fertilizers increases 13 € yr^{-1} in the case of new data.

The total cost on fields (-2,797 €) is sum of costs on manure handling (-2,810 € yr^{-1}) and on mineral fertilisers (13 € yr^{-1}).

The total cost increase. In the Farm PL7, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost decrease in farm (-1,585 € yr^{-1}) is sum of storage cost increase (1,211 € yr^{-1}) and total cost decrease on fields (-2,797 € yr^{-1}).

3.6.3. Farm PL2

Storages

Manure amount

In farm PL2 is produced poultry deep litter. Required minimum storage capacity is for manure, which is produced during 6 months. Farm PL2 has one 2,400 t solid manure storage and it corresponds to maximum 4,800 t annual dung production. This value is used in economic calculations as old data for manure amount. The new amount (4,080 t) was calculated by current polish manure standard by D. Wach (PP15). It means that farm had storage capacity for 7.1 month by new data.

Manure properties

Table 3.27. Manure properties in Farm PL2

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Poultry deep litter	24	0.45	3.07	11.4	32
New data	Poultry deep litter	28	0.45	3.9	13.8	39

Old data are taken from Old data was taken from Polish standards (NH_4-N from manure analyses in Manure Standards project– Poland don't have normative)

New data are from analysis results 2019 (NPK and NH_4-N). NH_4-N was analysed by special request (it is not standard procedure).

By old data the

maximum hectare amount of manure, by N_{tot} or P is 7.1 t ha^{-1} and

minimum area, fertilised with manure can be 678 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 6.1 t ha^{-1} and

minimum area, fertilised with manure can be 672 ha.

Manure price

The price of Farm PL2 manure decreases 7 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.27) is calculated by the data in tables 3.24 and 3.27, and formula 6. The manure contains by new data less PK, therefore the new price is lower compared to the price calculated by old data.

Income from selling

Farm PL2 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm PL2 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is Solid manure storage, concrete plate, pile height 1.5 m.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 27,990 € yr^{-1} and by new data would be 23,792 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 6 month amount from 4,080 t annual manure production.

The farm requires storage space for minimum 2,040 t solid manure to satisfy demand to have storage space for minimum 6 month manure production. The cost of this storage is 23,792 € yr^{-1}. It means that farm has 360 t more storage space than required and the additional cost because of overinvestment is 4,199 € yr^{-1}.

Fields

Farm PL2 has 4 fields with manure, totally 58.5 ha. The planned NPK amounts and driving distance are specified for every field.

Table 3.28. Fertiliser prices used in calculations for farm PL2

Mineral fertiliser data	Unit	Value	Comments
N element price in mineral fertiliser	€ kg^{-1}	0.81	
N content in mineral fertiliser	%	34.4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	2.3	
P content in mineral fertiliser	%	17.4	Triple-Superphosphat (TSP), 46% P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.51	
K content in mineral fertiliser	%	49.8	Potassium Chloride

The planned amount varies for:

N: 145-300 kg ha^{-1}

P: 52-80 kg ha^{-1}

K: 99-140 kg ha^{-1}.

The planned amounts were calculated by advisor or farmer based on plants uptake and soil status.

The distances between storage and fields vary from 3 to 4.2 km. The data about distances were supplied by farmer.

Table 3.28a. Manure loading, transporting and spreading cost (based on Farm PL2 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Solid	2	0.3716	5.9713	0.0174	-0.1988	5.9238	-0.104	2.15	0.12
Slurry	5	0.4312	3.8328	0.0421	-0.3116	2.7962	-0.2935	0.91	0.09

Results of calculations

By the old and new data both are required 4 fields to spread all manure produced by farm. In both cases, some manure is not utilised because farm has less field area than required, and 4,386 t is not applied by old data and 2,187 t by new data.

Manure transportation and spreading cost, € in total over all field area is

by old data 3,065 € and

by new data 2,655 €.

The decrease of this cost is 410 € if new data are used instead of old manure data. The reason is 59 t smaller manure amount applied to the fields.

The total cost on mineral N is increasing 15 € because of smaller manure amount per hectare by new data. The total handling cost of mineral N increases 1.4 €.

The total cost on mineral P is decreasing 260 € because of bigger P amount in manure by new data. The total handling cost of mineral P decreases 17 €.

The total cost on mineral K is decreasing 91 € because of bigger K amount in manure and larger manure amount per hectare by new data. The total handling cost of mineral K decreases 9 €.

The total cost on mineral fertilizers decreases 361 € yr^{-1} in the case of new data.

The total cost on fields (-771 €) is sum of costs on manure handling (-410 € yr^{-1}) and on mineral fertilisers (-361 € yr^{-1}).

The total cost increase. In the Farm PL2, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (3,427 € yr^{-1}) is sum of storage cost increase (4,199 € yr^{-1}) and total cost on fields (-771 € yr^{-1}).

3.7. Russia

3.7.1. General data for calculations made for Russian farms

Table 3.29. General data for calculations made for Russian farms

Calculation factor	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	-	Maximum amount is not defined
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.19	
N content in mineral fertiliser	%	34.4	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	1.8	
P content in mineral fertiliser	%	20	Triple-Superphosphat (TSP), 46% P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.6	
K content in mineral fertiliser	%	50.6	Potassium Chloride
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	20	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0.2	

3.7.2. Farm RU1

Storages

Manure amount

In farm RU1 is required minimum storage capacity for manure, which is produced during 8 months. Farm RU1 has two manure storages: a 17,000 m^3 storage for slurry, which corresponds to 25,520 m^3 annual slurry production, and another storage for 2,260 m^3 deep litter, which corresponds to 3,390 t deep litter production. Farm RU1 has cattle herd producing by new data 27,647 t of slurry and 4,246 t deep litter annually. It means that farm has storage capacity for 7,4 month for slurry and 6.4 month for deep litter. The new data for manure amount were found by calculations on the WP3 tool (by Ekaterina Shalavina).

Manure properties

Table 3.30. Manure properties in Farm RU1

Storage	Manure type	Type of data	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Storage1	Cattle slurry	Old data	4.5	0.58	0.98	4.48	5.31
		New data	3.1	0.36	0.9	4.48	4.9
Storage2	Cattle deep litter	Old data	5.99	0.78	1.3	5.96	7.05
		New data	9.8	0.81	1.3	5.96	7.78

Old data about manure nutrient content are obtained by calculations based on the Russian regulatory document RD-APK 1.10.15.02-17 Guidelines for technological design of systems for removal and preparation for application of animal and poultry manure.
New data are from manure analyses made in frames of Manure Standards project.

Slurry:
by old data the
maximum hectare amount of manure, by N_{tot} is 38 t ha^{-1} and
minimum area, fertilised with manure can be 676 ha;
by new data the
maximum hectare amount of manure, by N_{tot} is 55 t ha^{-1} and
minimum area, fertilised with manure can be 504 ha.

Deep litter:
by old data the
maximum hectare amount of manure, by N_{tot} or P is 28 t ha^{-1} and
minimum area, fertilised with manure can be 119 ha;
by new data the
maximum hectare amount of manure, by N_{tot} or P is 17 t ha^{-1} and
minimum area, fertilised with manure can be 245 ha.

Manure price

In the Farm RU1 the price of slurry decreases 0.4 € t^{-1} and price of deep litter increases 0.72 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.30) is calculated by the data in tables 3.29 and 3.30, and formula 6. The slurry contains by new data less N, P and K, therefore the new price is lower compared to the price calculated by old data. The deep litter contains by new data more N, therefore the new price is higher compared to the price calculated by old data.

Income from selling

Farm RU1 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm RU1 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The slurry storage type is slurry storage from concrete elements, 1 m in the ground. The deep litter storage type is solid manure storage, concrete plate, and pile height 1.5 m.

The costs of storages are calculated with formulas in paragraph 2.2.1.

Calculated cost of slurry storage by old data is 18,579 € yr^{-1} and by new data would be 19,171 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 8 month amount from 27,467 m^3 annual slurry production. The farm requires 1,418 m^3 additional slurry storage space to satisfy demand to have storage space for minimum 8 month slurry production. The additional cost is 592 € yr^{-1}.

Calculated cost of deep litter storage by old data is 26,357 € yr^{-1} and by new data would be 33,010 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 8 month amount from 2,830 t annual deep litter production.

The farm requires additional space for 570 t deep litter to satisfy demand to have storage space for minimum 8 month deep litter production. The additional cost is 6,653 € yr^{-1}.

Fields

Farm RU1 fertilises 6 fields with manure, totally 892 ha areas are (from 9 to 484 ha). The planned NPK amounts and driving distance are specified for every field.

The planned amounts are:

N: 168 kg ha^{-1}

P: 30-90 kg ha^{-1}

K: 40-90 kg ha^{-1}.

The planned amounts were obtained from the farmer upon request. On farms, the amount of NPK is usually determined depending on soil properties, type of crop and expected yield.

The distances between storage and fields vary from 6 to 11 km. The distance data were obtained from the farmer upon request.

Table 3.31. Manure loading, transporting and spreading cost calculation factors (based on Farm RU1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Deep litter	2	0.3406	6.0633	0.00153	-0.1924	4.1218	-0.1098	1.59	0.08
Slurry	5	0.1977	2.8055	0.032	-0.3055	3.1973	-0.3944	0.75	0.06

Results of calculations

By the old and new data both are required 6 fields to spread all manure produced by farm. The deep litter is spread to two fields, which are closest to the storage and slurry is spread to other four fields locating further from storages. The limiting factor by calculating the maximum manure amount per hectare is P or N content in manure and the maximum amount of N (170 kg ha^{-1}) what is allowed to apply with organic fertilisers or amount of P what is planned to every field.

By old data all the slurry and deep litter both can be used for fertilising of the fields. By new data, all the slurry can be utilised, but 639 t of deep litter is exceeding amount (3,606 t) required on the fields, planned to fertilise with deep litter. The reason is bigger amount of deep litter and higher content of N in deep litter by new data (see Table 3.30).

Manure transportation and spreading cost, € in total over all field area is
by old data 72,079 € and
by new data 75,482 €.
The increase of this cost is 3,402 € if new data are used instead of old manure data. The total cost increases because the farm has more manure by new data.

The total cost on mineral N is increasing 521 € because slurry (which is used on most of field area) NH_4-N content by new data is lower than by old data (see table 3.30). Thus, there is more additional mineral N required to cover planned amounts of N to the fields. In same reason, the total handling cost of mineral N increases 177 €.

The total cost on mineral P is decreasing 231 € because manure amount is bigger by new data than by old data. Thus, there is less additional mineral P required to cover planned amounts of P to the fields. In same reason, the total handling cost of mineral P increases 14 €.

The total cost on mineral K is zero on all fields what get manure by both scenarios because the K demand is fully covered by manure in the case of old and new data both. In same reason, there is no handling costs of mineral K.

The total cost on mineral fertilizers increases 452 € yr^{-1} in the case of new data.

The total cost increase on fields 3,855 € is sum of cost increase on manure handling (3,402 € yr^{-1}) and on mineral fertilisers (452 € yr^{-1}).

The total cost increase. In the Farm RU1, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (11,100 € yr^{-1}) is sum of additional storage cost (7,425 € yr^{-1}) and total cost increase on fields (3,855 € yr^{-1}).

3.8. Sweden

3.8.1. General data for calculations made for Swedish farms

Table 3.32. General data for calculations made for Swedish farms

	Unit	Value	Comments
Maximum amount of N with organic fertiliser	kg ha^{-1} yr^{-1}	170	
Maximum amount of P with organic fertiliser	kg ha^{-1} yr^{-1}	22	
Mineral fertiliser data			
N element price in mineral fertiliser	€ kg^{-1}	0.89	
N content in mineral fertiliser	%	27	Ammonium nitrate
P element price in mineral fertiliser	€ kg^{-1}	1.87	
P content in mineral fertiliser	%	20	Triple-Superphosphat

			(TSP), 46% P_2O_5
K element price in mineral fertiliser	€ kg^{-1}	0.7	
K content in mineral fertiliser	%	50.6	Potassium Chloride
Cost of mineral fertiliser storage, loading and spreading	€ t^{-1}	50	
Cost of mineral fertiliser transportation	€ t^{-1} km^{-1}	0,13	

3.8.2. Farm SE1

Storages

Manure amount

In farm SE1 is required minimum storage capacity for manure, which is produced during 8 months. Farm SE1 has one 1,560 m^3 slurry storage and it corresponds to maximum 2,340 t annual slurry production. According to the Swedish advisory tool Vera – based on existing national manure standards data Farm SE1 produces 1,356 t of manure yearly. This value is used in economic calculations as old data for manure amount. The new amount, 1,421 t was calculated with help of WP3 calculator. This means that when using old data, the farm had storage capacity for 13.8 months and by new data for 13.2 months.

Manure properties

Table 3.33. Manure properties in Farm SE1

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Cattle slurry	4.5	2.28	0.59	3.77	7,75
New data	Cattle slurry	5.0	3.0	0.7	4.0	8,56

Old data are taken from existing Swedish manure standards
New data are from manure analyses main frames of Manure Standards project.

By old data the
maximum hectare amount of manure, by N_{tot} or P is 37 t ha^{-1} and
minimum area, fertilised with manure can be 36 ha.
By new data the
maximum hectare amount of manure, by N_{tot} or P is 31 t ha^{-1} and
minimum area, fertilised with manure can be 29 ha.

Manure price

The price of Farm SE1 manure increases 0,81 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.33) is calculated by the data in tables 3.32 and 3.33, and formula 6. The manure contains by new data more NPK, therefore the new price is a bit higher compared to the price calculated by old data.

Income from selling

Farm SE1 don’t sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm SE1 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage from concrete, cast in place, on the ground

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 5,784 € yr^{-1} and by new data would be 4,487 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 8 month amount from 1,421 t annual slurry production.

The farm requires 947 m^3 storage space to satisfy demand to have storage space for minimum 8 month manure production. It is also advisable to have some safety margin, if we add 10% as a margin, 1,042 m^3 is needed. It means that farm has 518 m^3 more storage space than required and the additional cost because of overinvestment is 898 € yr^{-1}.

Fields

Farm SE1 has 56 fields, totally 137.5 ha. The planned NPK amounts and driving distance are specified for every field what got manure in year 2017, totally 16 fields.

The planned amount on these fields vary for:

N: 81-194 kg ha^{-1}

P: 15-30 kg ha^{-1}

K: 80-100 kg ha^{-1}.

The planned amounts were taken from the fertiliser plan made by farm advisor. The fertiliser plan it is based on expected yield and the need of nutrients for a certain crop at that yield.

The distances between storage and fields vary from 0.2 to 0.8 km. The distances were assessed by the farmer.

Table 3.34. Manure loading, transporting and spreading cost (based on Farm SE1 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Slurry	5	5	0.3803	5.3775	0.0435	-0.35	5.2519	-0.4038	0.9

Results of calculations

By the old data 13 fields are required to spread all manure produced by farm. By the new data is this number 16 and all the manure was applied to the fields. The limiting factor by calculating the maximum slurry amount per hectare is P content in slurry and the maximum amount of P (22 kg ha^{-1} as an average over five years) that is allowed to apply with organic fertilisers (the provisions of the

Swedish Board of Agriculture (SJVFS 2004:62) on environmental concerns regarding plant nutrients).

Manure transportation and spreading cost, € in total over all field area is
by old data 2,409 € and
by new data 2,718 €.
The increase of this cost is 310 € if new data are used instead of old manure data.

The total cost increases because the farm applied 65 m^3 more slurry to the fields.

The total cost on mineral N is decreasing 643 € because of higher concentration of ammonium nitrogen in the manure and bigger amount of manure - thus, manure covers a greater part of the crops' need of nitrogen. The total handling cost of mineral N decreases 134 €.

In same reason the total cost on mineral P and handling cost of that fertiliser are is decreasing 365 and 49 € correspondingly.

The total cost on mineral K is decreasing 485 €, the reason for cost decrease is a bit higher K amount of manure by new data (see table 3.33). Thus the need for mineral K on the fields fertilised with manure is by new data much less than by old data and total cost decreases. In the same reason the handling cost of mineral K decreases by 69 €.

The total cost on mineral fertilizers decreases 1,744 € yr^{-1} in the case of new data.

The total cost on fields (-1434 €) is sum of costs on manure handling (310 € yr^{-1}) and on mineral fertilisers (-1,744 € yr^{-1}).

The total cost increase. In the Farm SE1, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (-536 € yr^{-1}) is sum of additional storage cost (898 € yr^{-1}) and total cost on fields (-1,744 € yr^{-1}).

3.8.3. Farm SE3

Storages

Manure amount

In farm SE3 is required minimum storage capacity for pig manure, which is produced during 10 months. Farm SE3 has three slurry storages, the primary storage 2,350 m^3 and two additional storages 1,500 and 1,000 $m^3$and it corresponds to maximum 5,820 t annual slurry production. By the calculation with existing Swedish manure standards data should Farm SE3 produce 9,455 t of manure yearly. This value is used in economic calculations as old data for manure amount. The new amount (9,527 t) was calculated with help of WP3 calculator. It means that by old data farm had storage capacity for 7,4 month and by new data for 7,3 month. However, the farmer states that the storage capacity is enough for storing manure 10 months. When studying the concentration of dry matter in the analysis, a big difference can be noticed between different labs. The dry matter content in the ex-storage sample from lab 1 is 4.4 % and from lab 2 it is 8.1 %. Because of this big difference it is hard to estimate the amount of technical water going to the manure and therefore is the calculation of amount of manure a bit uncertain.

Manure properties

Table 3.35. Manure properties in Farm SE3 in both storages

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	Pig slurry	2.7	1.89	0.6	1.4	4.51
New data	Pig slurry	2.34	1.75	0.46	1.26	3.83

Old data are taken from existing Swedish manure standards
New data are from manure analyses main frames of Manure Standards project.

By old data the

maximum hectare amount of manure, by N_{tot} or P is 48 t ha^{-1} and
minimum area, fertilised with manure can be 199 ha.

By new data the

maximum hectare amount of manure, by N_{tot} or P is 37 t ha^{-1} and
minimum area, fertilised with manure can be 258 ha.

Manure price

The price of Farm SE3 manure decreases 0.68 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.35) is calculated by the data in tables 3.32 and 3.35, and formula 6. The manure contains by new data less NPK and therefore the new price is lower compared to the price calculated by old data.

Income from selling

Farm SE3 don't have any field and sells all of the manure out from farm. The income from selling of manure is decreasing 6,167 € caused by blander and cheaper manure if new data are used instead of old data.

Cost for manure export

Farm SE3 don't make any costs to export manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is slurry storage from concrete elements, 1 m in the ground.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of all storages by old data is 17,312 € yr^{-1} and by new data would be 21,001 € yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 10 month amount from 9,527 t annual slurry production.

The farm requires 3,090 m^3 additional storage space to satisfy demand to have storage space for minimum 10 month manure production. The additional cost is 3,689 € yr^{-1}.

Fields

Farm SE3 has no fields, thus there is no cost differences connected to fertiliser applications to the fields.

Results of calculations

The total cost increase. In the Farm SE3, the new data had economic impact on income from selling of manure and on storage cost. The total cost increase in farm (9,856 € yr^{-1}) is sum of income decrease (6,167 € yr^{-1}) and storage cost increase 3,689 € yr^{-1}).

3.8.4. Farm SE5

Storages

Manure amount

In farm SE5 is required minimum storage capacity for manure, which is produced during 10 months. Farm SE5 has one 1,575 t deep litter manure storage and it corresponds to maximum 1,890 t annual dung production. By the calculation made by A.K.Eriksson with existing Swedish manure standards data should Farm SE5 produce 1,260 t of manure yearly. This value is used in economic calculations as old data for manure amount. The new amount (1,089 t) was calculated with help of WP3 calculator by A.K.Eriksson. It means that by old data farm had storage capacity for 15 month and by new data for 17.4 month.

Manure properties

Table 3.36. Manure properties in Farm SE5

Type of data	Manure type	N_{tot} ex_storage kg t^{-1}	NH_4-N ex_storage kg t^{-1}	P ex_storage kg t^{-1}	K ex_storage kg t^{-1}	Manure price, € t^{-1}
Old data	9,257	38	7.6	8.6	17	62
New data	Poultry deep litter manure	25.72	6.43	7.22	17.4	49

Old data are taken from existing Swedish manure standards
New data are from manure analyses main frames of Manure Standards project.

By old data the
maximum hectare amount of manure, by N_{tot} or P is 2.6 t ha^{-1} and
minimum area, fertilised with manure can be 493 ha.
By new data the
maximum hectare amount of manure, by N_{tot} or P is 3 t ha^{-1} and
minimum area, fertilised with manure can be 357 ha.

Manure price

The price of Farm SE5 manure decreases 13.26 € t^{-1} if new data are used instead of old data. The price of manure (Table 3.36) is calculated by the data in tables 3.32 and 3.36, and formula 6. The manure contains by new data less NPK, therefore the new price is lower compared to the price calculated by old data.

Income from selling

Farm SE5 don't sell any manure, so there is no income from selling of manure.

Cost for manure export

Farm SE5 don't export any manure, so there is no costs related to export of manure out of farm.

Cost of manure storage

The existing storage type is deep litter manure storage, concrete plate, and pile height 1.5 m.

The cost of storage is calculated with formulas in paragraph 2.2.1.

Calculated cost of storage by old data is 18,368 € yr^{-1} and by new data would be 10,579€ yr^{-1}. The storage cost by old data is calculated by actual storage size. The storage cost by new data is calculated by storage size which is required to store 10 month amount from 1,089 t annual slurry production.

The farm requires storage space for minimum 907 t deep litter manure to satisfy demand to have storage space for minimum 10 month manure production. It means that farm has 668 t more storage space than required and the additional cost because of overinvestment is 7,789 € yr^{-1}.

Fields

Farm SE5 has 43 fields with manure, totally 811 ha. The planned NPK amounts and driving distance are specified for every field what got manure in 2017, totally 18 fields and 435 ha

The planned amount varies for:

N: 110-200 kg ha^{-1}

P: 7-80 kg ha^{-1}

K: 11-120 kg ha^{-1}.

The planned amounts were taken from the fertiliser plan made by farm advisor. The fertiliser plan it is based on expected yield and the need of nutrients for a certain crop at that yield.

The distances between storage and fields vary from 0.1 to 8.2 km. The distances were measured with help of GIS, by A.K.Eriksson.

Table 3.37. Manure loading, transporting and spreading cost (based on Farm SE5 spreader data and calculated by Raivo Vettik)

Manure type	Distance limit, km	Costs until (included) distance limit (spreader is transporting)				Costs over distance limit, separate transporter			
		Cost factor a_1	Cost factor b_1	Cost factor a_2, power	Cost factor b_2, power	Cost factor a_s	Cost factor b_s	Basic cost, € t^{-1}	Cost addition, € t^{-1} km^{-1}
Deep litter	2	0.7233	11.06	0.0148	-0.174	11.4236	-0.1669	2.12	0.12

Results of calculations

By the old data 18 fields can be used to spread manure produced by farm. These fields had need for N and P both. If a field has no need for N or P by fertilisation plan, then the manure is not suitable fertiliser for that field. Calculations show that by old data 989 t of manure from 1,260 t were possible to use as fertiliser during one year. Else, planned P amounts would be exceeded.

By new data are required only 11 fields because the manure amount smaller and manure NH_4-N and P content lower (see table 3.36) than by old data. The limiting factor by calculating the maximum deep litter amount per hectare is P content in the manure and the maximum amount of P (22 kg ha^{-1}) what is allowed to apply with organic fertilisers (the provisions of the Swedish Board of Agriculture (SJVFS 2004:62) on environmental concerns regarding plant nutrients). All produced manure amount (1.089 t) were used for fertilisation.

Manure transportation and spreading cost, € in total over all field area is

by old data 11,087 € and

by new data 11,637 €.

The increase of this cost is 550 € if new data are used instead of old manure data. The reason is 99 t bigger manure amount applied to the fields.

The total cost on mineral N is increasing 303 € because of smaller N content in manure and less fields fertilised with manure by new data and thus, the planned N amount should be fully covered on seven more fields. The total handling cost of mineral N increases 64 €.

For the same reason the total cost on mineral P and handling cost of that fertiliser are is increasing 1,215 and 165 € correspondingly.

The total cost on mineral K is decreasing 726 €, although the planned K amount should be fully covered on five more fields. The reason for cost decrease is higher K amount of manure by new data (see table 3.36). Thus the need for mineral K on the fields fertilised with manure is by new data less than by old data and total cost decreases. In the same reason the handling cost of mineral K decreases by 103 €.

The total cost on mineral fertilizers increases 919 € yr^{-1} in the case of new data.

The total cost on fields (1,469 €) is sum of costs on manure handling (550 € yr^{-1}) and on mineral fertilisers (919 € yr^{-1}).

The total cost increase. In the Farm SE5, the new data had no economic impact on income from selling of manure, nor cost of exporting of manure because all the manure is used by the farm itself. The total cost increase in farm (9,257 € yr^{-1}) is sum of storage cost increase (7,789 € yr^{-1}) and total cost on fields (1,469 € yr^{-1}).

3.9. Summary of results

The calculation method is composed and data are collected from Manure Standards project pilot-farms to evaluate economic impact of change of knowledge about manure amount and properties in manure storages of farms. The calculation tool in Excel is built to analyse the economic impact of change of knowledges. Analysed were at least one pilot-farm from every country (except Denmark) around Baltic Sea, 15 farms in total (Table 3.38).

Impact of manure amounts

Annual manure production has impact on storage costs. The obligatory minimum storage capacity depends on region and manure type (Table 3.38 and Appendix 1, Table A1.4). Compared were storage costs by current capacity and by new data about manure amount.

In 5 farms were underinvested, it means that farm should make additional investment to satisfy requirement for minimum capacity. In some farms (EE1, LV1, LV3) the reason for underinvestment can be, that the milk yield per cows has been rising lot after building of manure storage and now, the manure amount per animal is much bigger than presumed by designing of manure storages. Thus, if manure storage for dairy cows is projected, then should be careful by predicting annual manure amounts for storage lifetime. Or, farm has to have alternative plan if yearly manure amount is bigger than it was planned by designing of the storage.

Another reason of underinvestment is that by designing of manure storage were used manure standard what essentially underestimated manure production.

In the 10 farms were overinvested to the manure storages - the existing storages are bigger than required by minimum number of months (Table 3.38).

One reason for overinvestment can be presumption that in some years the manure storage should contain more than predicted by national manure standard. This is probably mainly because of deviation of precipitations from many-year average.

For example in Estonia the variation between single years can be multiple. Estonian many-year average over country is 672 mm. Some regions have maximum precipitation over 1000 mm and driest minimum is about 300 mm per year. Average very wet year is about 800-900 mm. There are also regional differences: more have precipitations SW, S and W part of uplands. Less on coastal regions, more rainy area starts about 20-30 km from coast. The differences between regions in Estonia can be up to 200 mm per year (Triin Saue, PP13).

In Sweden is advised to have to have some safety margin, for example +10% from annual slurry production (Ulrika Listh, PP11).

Table. 3.38. Manure amounts, storage sizes and economic impact in project pilot - farms

Code of pilot-farm	Minimum storage capacity, months	Manure amount by old data, t	Manure amount by new data, t	Current storage capacity, t	Required storage capacity by new data, t	Increase of slurry storage costs, € yr^{-1}	Over- or under-investment
EE1	8	13,350	17,000	8,900	11,759	1,663	Under
FI1	12	4,800	3,100	4,800	3,100	2,198	Over
DE3	6	9,000	4,881	4,500	2,441	4,598	Over
DE4	6	3,000	1,352	1,500	676	1,612	Over
LV1	6	16,000	22,965	8,000	11,483	3,358	Under
LV2	1	6,000	5,818	500	485	177	Over
LV3	9	25,333	26,031	19,000	19,523	374	Under

LV4	4	6,600	4,769	2,200	1,590	996	Over
LT1	6	4,800	3,042	2,400	3,042	989	Over
PL7	6	3,120	2,900	1,560	1,450	1,211	Over
PL2	6	4,800	4,080	2,400	2,040	4,199	Over
RU1	8	28,910	31,893	19,260	21,262	7,245	Under
SE1	8	1,356	1,421	1,560	1,042	898	Over
SE3	10	9,455	9,527	4,850	7.939	3,689	Under
SE5	10	1,260	1,089	1,575	907	7,789	Over

The change of the manure amount has proportional impact on the change of total manure spreading and transportation costs. Except in the cases if manure amount is bigger than field area, available in the farm for manure application. In many pilot farms (9) the manure amount was bigger than amount allowed to spread to the fields, by old data, new data or in both cases (Table 3.39). The manure amounts per hectare are calculated by NP content in manure and by planned NP amount, by N limit in national regulations or by P limit by national regulations (in countries where P amount is limited by law). If these farms are actually applying all the farm manure to the farm fields, then there is over-fertilisation with some nutrients, which is not advisable from environmental nor economic point of view.

In that case is suggestable to use more careful planning of fertilisation, separate slurry to different fraction with different composition of nutrients, or sell the manure out form farm.

The calculation tool don't take into the account of over-fertilisation with potassium (K). In the future is suggestable to compare economic impact if manure amount is calculated by condition where either planned NP or planned NPK amount is not exceeded.

Table. 3.39. Economic impact on manure transportation and spreading costs in project pilot - farms

Code of pilot-farm	Increase of manure transportation and spreading costs, € yr^{-1}	Increase of manure amount, t	Use of manure on the fields
EE1	2,537	4,289	All the manure is spread by old and new data.
FI1	-1,048	-1,700	Field area is too small by old and new data.
DE3	-1,808	-4119	Field area is too small by old and new data.
DE4	-2,387	-1,648	Field area is too small by old and new data.
LV1	18,985	6,965	All the manure is spread by old and new data.
LV2	547	-182	Field area is too small by old and new data.
LV3	5,834	698	Field area is too small by old and new data.
LV4	-5,405	-1,831	All the manure is spread by old and new data.
LT1	-5,950	-1,758	All the manure is spread by old and new data.

PL7	-2,810	-220	Field area is too small by old and new data.
PL2	-410	-720	Field area is too small by old and new data.
RU1	3,402	2,983	All the manure is spread by old data. Field area is too small by new data
SE1	310	65	All the manure is spread by old and new data
SE3	-	42	All the manure is sold out from the farm.
SE5	550	-171	Field area is too small by old data. All the manure is spread by new data.

Manure amount has also impact on export cost of manure, but none of analysed pilot-farm had any export cost.

One farm (SE3) sells all the manure. Although by new data the manure amount is bit bigger, the manure itself is blander and cheaper and thus, the income is decreasing (6,167 € yr^{-1}).

Manure amount influences also the costs connected to the mineral fertilisers. If amount of manure-based nutrients in the farm are increasing, thanks to bigger amount of manure, then the mineral fertiliser costs are decreasing (see the tables 3.39 and 3.40).

Impact of manure properties

The change of concentration of plant nutrients in manure has impact on costs connected to the mineral fertilisers. Analysed manure properties are N_{tot}, NH_4-N, P and K content in the manure.

In all participating countries is allowed to bring maximum 170 kg ha^{-1} total nitrogen (N_{tot}) with manure to the fields. Some countries have similar limitation for phosphorus (P) (Table 3.40). In most cases this restriction or P amount, planned to the fields by fertilisation plan, is determining the maximum amount of manure per hectare. Thus, also the amounts of other manure nutrients (NK), applied to the fields, are then restricted by that manure amount.

In general, if content of some nutrient is bigger by new data, then costs related to this type of mineral fertiliser, are decreasing and vice versa. However, there are exception in above-described reason. For example in farm DE4. Although, the manure contains more NH_4-N by new data (45% more compared to the old data), is increase of P content relatively bigger (+97%). The manure amount per hectare drops from 34 to 17 t ha^{-1} because this is calculated by maximum P amount (25 kg ha^{-1}) allowed to use on the fields, by old and new data both. Higher NH_4-N content in manure doesn't compensate the decrease of manure amount per hectare. By new data the planned N amount is covered by manure in smaller extent and thus, the need for mineral N is increasing.

In most cases, the change of P content in manure has bigger economic impact than change of NK content. The reason is about two times higher price of P compared to the NK prices (Appendix 1, Table A1.1, A1.2 and A1.3).

In the economic analyses is calculated that NH_4-N content in the manure has same impact as mineral N. In some countries the content of NH_4–N is not analysed as standard procedure and this is not included to the national manure standard, only total N. Thus, the source for NH_4-N old value is not national manure standard, the source is other literature. New values are taken from analyses results of manure samples taken during Manure standards project. For more precise planning of fertilisation is advisable also in these countries to analyse the NH_4-N content in manure and define the values in national manure standards.

Table. 3.40. P limitations, change of manure properties and increase of costs on mineral fertilisers in project pilot - farms

Code of pilot-farm	Limitation of P, kg ha^{-1}	Increase of N_{tot} kg t^{-1}	Increase of NH_4-N kg t^{-1}	Increase of P kg t^{-}	Increase of K kg t^{-}	Increase of costs on mineral fertilisers, € yr^{-1}
EE1	25	-0,92	1,06	-0,58	-1,34	5,312
FI1	30	0,87	0,42	0,09	0,7	84
DE3	25	2,43	1,56	0,31	4,14	-3,075
		1	0,7	0,06	0,57	
DE4	25	2,05	1,25	0,72	0,8	1,550
LV1	-	0,71	0,43	-0,17	0,89	-40,606
LV2	-	-0,16	-0,03	-0,18	0,9	-762
LV3	-	-1,1	-0,66	-0,43	-1	10,292
LV4	-	-2,06	-1,48	-0,89	-0,95	25,964
LT1	-	-1,76	-0,12	0,07	0,8	4,470
PL7	-	1,47	0	0,39	3,28	13
		-1,28	0	0,06	1,85	
PL2	-	4	0	0,83	2,4	-361
RU1	-	-1,4	-0,22	-0,08	0	452
		3,81	0,03	0	0	
SE1	22	0,5	0,72	0,11	0,23	-1,744
SE3	22	-0,36	-0,14	-0,14	-0,14	-
SE5	22	-12,28	-1,17	-1,38	0,4	919

Important is to reflect possibly realistic data in manure standards about manure amounts and content of nutrients. And not only about NPK but also other macro (S) and micro (Zn, Cu, Mn and other) nutrients. Today, generally the content of these elements in manure is not taken into the account by planning the fertilising of crops - it can lead to over-fertilisation with these elements, which in turn can cause economic loss for farm and pollute environment.

If slurry is acidified then is also essential to have adequate information about manure pH and dry matter content, because these properties influence the acid consumption.

The total economic impact on farm level is shown in the table 3.41. In 5 farm are the cost decreasing and in 10 farm are the costs increasing.

The farms, where cost is decreasing is easier to advice to use new knowledges about manure amount and properties.

The question is what should do the farms where the cost is increasing. Suggestable is to make detailed analyses what is the reason for cost increase. Is the reason mainly connected to the storage size or planning of fertilisation? If manure is by new data blander than supposed then the expected yield has not been adequate by old data. If mineral fertiliser costs are increasing by new data, then theoretically the yield increase should compensate that cost.

Careful planning of fertilisers and optimal use of manure requires smart study. The more fields, crops, manure storages and manure types farm has, the more complex and labor-consuming is the analyses. A special manure management optimisation software would help the farmer to use manure as valuable substance in most effective and environmental-friendly way.

Table. 3.41. Manure types and increase of farm costs in project pilot - farms

Code of pilot-farm	Type of manure	Increase of farm costs, € yr^{-1}
EE1	Dairy cow slurry	9,512
FI1	Dairy cow slurry	1,225
DE3	Dairy cow, heifer and bulls slurry	-2,502
DE4	Pig slurry	775
LV1	Dairy cow slurry	-18,262
LV2	Dairy cow deep litter	1,486
LV3	Dairy cow slurry	16,500
LV4	Pig slurry	21,556
LT1	Cattle slurry	-491
PL7	Cattle manure with urine and cattle urine	-1,585
PL2	Poultry deep litter	3,427
RU1	Cattle slurry and cattle deep litter	11,100
SE1	Cattle slurry	-536
SE3	Pig slurry	9,856
SE5	Poultry deep litter manure	9,257

4. Conclusions and recommendations

The manure storages are designed by manure amount which is calculated current national manure standards. Thus, storage cost is very much depending on quality of data and calculation method described in the standard. Storage life-time is at least 30 years, thus the faults in predicting of suitable storage size can have decades-long impact. From economic and environmental point of view is highly essential to have manure standard with possibly correct data and calculation method to determine size of manure storage size.

Underestimated storage size has environmental risk, because of bigger danger to cause point-pollution with manure. To avoid it, should farm later build additional storage which makes storage cost higher compared to building proper size storage at once.

Overestimating causes binding of farm funds and investment-support funds with overinvestment and this money can't be used for other investments. The excess building activities and use of materials has additional load to the environment.

Recommendation. The national manure standard should be maintained periodically to check - are the data and calculation methods reflecting correctly current real manure amounts by different production and climatic conditions.

Recommendation. Suggestable is to calculate the storage size by national manure standard. Presumption for that is, that national manure standard is in good condition.

The change of the manure amount has proportional impact on the change of total manure spreading and transportation costs. The investment cost connected to the manure handling machines depends on manure amount in the farm. If farm has possibility to use spreading service or offer spreading service, then it gives some economic flexibility and the change of knowledges about real manure amount in farm hasn't essential impact on spreading cost per tonne of manure.

If farm has no possibility to offer or use manure handling service, then the choice of machinery with proper performance is much more essential. The choice is often made by manure amount predicted by farmer experiences or with help of national manure standard.

If machines have too low performance then the farm has problems with spreading the manure on suitable time or even within the period permitting manure application to the fields. This is risk from environmental point of view.

If machines have too big performance then it means often that they are too expensive and farm has made overinvestment. And again, overestimating causes binding of farm funds and investment-support funds with overinvestment and this money can't be used for other investments.

Recommendation. Suggestable is to encourage enterprises to offer and use manure handling service in the country.

Recommendation. Suggestable is to dimension the performance of manure handling machinery by manure amount which is calculated by national manure standard. Presumption for that is, that national manure standard is in good condition.

The manure amounts per hectare are calculated by NP content in manure and planned NP amount, by N limit in national regulations or by P limit by national regulations (in countries where P amount is limited by law). If manure amount in the farm is bigger than planned, then rises risk that manure amount is bigger than field area, available in the farm for manure application. If the farms still applies all the farm manure to the farm fields, then there is over-fertilisation with some nutrients, which is not advisable from environmental nor economic point of view.

In that case is suggestable to use more careful planning of fertilisation, separate slurry to different fraction with different composition of nutrients, or sell the manure out from farm.

Recommendation. Suggestable is to match farm field area and manure amount which is calculated by national manure standard. Presumption for that is, that national manure standard is in good condition.

The change of knowledge’s about nutrient concentration in the manure influences the possible price of manure. By trading with manure is important to have adequate information about nutrient concentration in manure.

Manure amount influences also mineral fertiliser costs in the farm. If amount of manure-based nutrients in the farm is actually other than presumed by national manure standard, then it has economic impact on crop production results. If farm has less manure nutrients in the farm than presumed then crops may be under-fertilised and probability to get expected yields is decreasing. If farm has bigger manure-nutrient pool than calculated then the risk of over-fertilisation increases which is not advisable from environmental nor economic point of view.

The change of concentration of plant nutrients in manure has impact on costs connected to the mineral fertilisers. In general, if content of some nutrient in manure is bigger by new data, then costs related to this type of mineral fertiliser, are decreasing and vice versa

In most cases P amount, planned to the fields by fertilisation plan is determining the maximum amount of manure per hectare. Thus, also the amounts of other manure nutrients (NK) applied to the fields are then restricted by that manure amount.

The change of P content in manure has bigger economic impact than change of NK content. The reason is about two times higher price of P compared to the NK prices.

Recommendation. The national manure standard should be maintained periodically to check - are the data and calculation methods reflecting correctly current manure properties by different production and climatic conditions.

Recommendation. Encourage slurry producing farmers to use slurry processing technologies which result with fractions with different N:P relations to give more flexibility by using manure nutrients on farm fields or to trade with the fractions.

In some countries the content of NH_4-N is not analysed as standard procedure and this is not included to the national manure standard, only total N. Thus, the source for NH_4-N old value is not standard but other type of literature. In the economic analyses is calculated that NH_4-N content in the manure has same impact as mineral N. If there is no information about real content in manure, then the economic analyses can't be adequate. Also, from environmental point of view is important to have data about NH_4-N content in manure because it has impact on ammonia emission and use of mineral N. For more precise planning of fertilisation is advisable to analyse the NH_4-N content in all countries.

Recommendation. For more precise planning of fertilisation is advisable also in all countries to analyse the NH_4-N content in manure and define adequate values in national manure standards.

Today, generally the content of other macro (S) and micro (Zn, Cu, Mn and other) nutrients in manure is not analyse nor taken into the account by planning the fertilising of crops - it can lead to over-fertilisation with these elements, which in turn can cause economic loss for farm and pollute environment.

Recommendation. For more precise planning of fertilisation is advisable in all countries beside NPK also to analyse content of other macro (S) and micro (Zn, Cu, Mn and other) nutrients in manure and define adequate values in national manure standards. An economic analyses should be made to determine, which elements are rational to define in manure standards.

If slurry is acidified then is also essential to have adequate information about manure pH and dry matter content, because these properties influence the acid consumption.

The change of knowledges about manure amount and properties may have positive and negative economic impact.

The question is what should do the farms where the cost is increasing by new data. Suggestable is to make detailed analyses what is the reason for cost increase. Is the reason mainly connected to the storage size or planning of fertilisation? If manure is by new data blander than supposed, then the expected yield has not been adequate by old data. If mineral fertiliser costs are increasing by new data, then theoretically the yield increase should compensate that cost.

Careful planning of fertilisers and optimal use of manure requires smart study. The more fields, crops, manure storages and manure types farm has, the more complex and labor-consuming is the analyses.

Recommendation. Encourage production of a special manure management optimisation software which would help the farmer to use manure as valuable substance in most effective and environmental-friendly way.

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Appendix 1. User Guide

User Guide

for calculation tool “Economic impact of change of manure standard”

The Economic analyses calculation tool is built in MS Excel and tested only in this software.

The file “Economic impact of change of manure standard” contains 4 spreadsheets:

1. **General** – sheet for overall calculation data
2. **Storages** – sheet for data about storages in the farm
3. **Fields** – sheet for data about fields in the farm
4. **Results** – sheet for calculation results.
5. **Database** –data, what are not changed by user.

The colour code on spreadsheets is that the uncoloured cells can be changed by the user. The cells with coloured background are calculated by Excel tool.

Some pages have frozen rows and columns, so if You don’t find some columns described here, move the lower slidebar to make the columns visible.

1. **Open sheet “General”** and enter
    1.1. Maximum amount of N and P with organic fertiliser per year and hectare what is allowed by national legislation.
    1.2. Mineral fertiliser data. There are pre-entered data already but if You find the some data are not correct, enter correct data. List of N prices and mineral fertiliser handling prices by country are in user Guide in in tables 1. The P and K prices can be added to tables 2 and 3 by contact persons from participating countries.
    1.3. Enter the cost of manure export from farm, if excess manure is taken over by some other company. Remarks:
        a) If export cost is 0, but manure is also not sold, then put the value 0.
        b) If the excess manure is sold out then clear the cell. The selling price is calculated by model on page “Storage”.
    1.4. Select manure spreading and incorporation method
    1.5. Minimum manure storage capacity (in months) in Your country. Lis of values by country in User Guide in table 4.
2. **Open sheet “Storage”** and enter

2.1 Storage ID, number from 1 to *n*. *n* is number of storages in the farm. The tool enables to enter maximum 5 storages. If there is need for bigger number of storages then addresses of cell ranges in formulas on sheet “Fields” should be adjusted.

2.2 Storage name what is taken from survey or chosen by tool user.

2.3 Select the manure type from dropdown menu. The manure handling costs depend on type of manure.

2.4 Storage capacity, tons. If slurry, then tons are equal to cubicmeters.

2.5 Existing knowledge about N_{tot}, NH_4-N, P and K content kg t^{-1} in ex-storage manure.

2.6 Improved knowledge about N_{tot}, NH_4-N, P and K content kg t^{-1} in ex-storage manure.

2.7 Improved knowledge about yearly manure flow in the storage. Existing knowledge is not asked because assumed is that storage capacity is calculated by existing knowledge. Thus, existing knowledge about yearly slurry amount can be calculated by storage capacity and minimum number of months.

2.8 Select storage type. The annual cost of storage is calculated by storage type and capacity.

3. **Open sheet “Fields”** and enter about all farm fields what is fertilised with manure:

3.1 Field ID, number from 1 to *m*. *m* is number of fields in the farm.

3.2 Field name what is taken from survey or chosen by tool user

3.3 Field area, ha

3.4 N, P, K amounts kg ha^{-1}, planned to apply to the fields with organic and mineral fertilisers both.

3.5 Driving distance from field to the manure storage, km. If several manure storages are in the farm, then distance of the storage should be used where manure is brought from. Use one-way distance, because cost of transportation includes also way back.

3.6 ID of storage, which manure is used to fertilise the field. Take the storage ID from sheet “Storages”. If You enter the storage ID, You see storage name in next column on right.

The maximum number of fields in present tool is 40. If You have more fields, add rows to the end of table. If You have less fields, clear redundant cells, except cells with Field ID.

<u>If all fields are entered, then sort the table rows B-H, so that it starts from smallest distance. Include to the sorting only filled rows.</u>

4. **Open sheet “Results**” and enter about all farm fields what is fertilised with manure:

4.1 Field ID, same numbers on sheet “Fields” from 1 to *m*. *m* is number of fields in the farm.

4.2 Storage ID. The number of storage from sheet “Storages”. The number of storage is chosen by field where the manure is transported to.

4.3 If You have more Fields than rows in the table, then

4.3.1 add rows above the row with last field. In that case, the calculation formula on row “Total” include also the added rows. For any case, check the formulas on row “Total”, are the addresses of added rows included.

4.3.2 copy some row with calculation formulas in same table and paste it on row added previously.

4.4 If You have less fields than in table, then clear redundant rows except cells with Field ID.

If you have added all the required information, then on last sheet, in row “Total economic impact” You see impact by single fields. Total impact in farm is calculated on same column on row “Sum of totals”.

If the result is negative, then the sum of costs decreased.

It means that costs by old data > costs by new data.

If the result is positive, then the sum of costs increased

It means that costs by old data < costs by new data.

Table A1.1. Mineral N- fertiliser prices, mineral N prices (100% N) prices and fertiliser handling costs in Baltic Sea region. Prices are without VAT.

Country	N-Fertiliser	Price of mineral N with delivery to 100 km € kg^{-1}	Fertiliser delivery[1)] € t^{-1} km^{-1}	Fertiliser handling[2)] € t^{-1}
Estonia	Ammonium nitrate N – 34.4%	0.72	0.7	24
Latvia	Ammonium nitrate N – 34.4%	0.64	0.7	34
Russia	Ammonium nitrate N – 34.4%	0.19	0.2	20
Sweden	Ammonium nitrate N – 27%	0.89	0.13	50
Lithuania	Ammonium nitrate N – 34.4%	0.73	0.7	24
Germany	CAN 27% 13.12.2017	0.79	0.7	24
Finland	Ammonium nitrate N – 34.4%	0.72	0.7	24
Poland	Ammonium nitrate N – 34.4%	0.81	0.7	24

Table A1.2. Mineral P- fertiliser prices, mineral P prices (100% P) prices in Baltic Sea region. Prices are without VAT.

Country	P-Fertiliser	Price of mineral P with delivery to 100 km € kg^{-1}
Estonia	Triple-Superphosphat (TSP), 46% P_2O_5, 20% P	1.8
Latvia	Amofoss (N12%-P52%)	1.8
Russia	Triple-Superphosphat (TSP), 46% P_2O_5, 20% P	1.8
Sweden	Triple-Superphosphat (TSP), 46% P_2O_5, 20% P	1.87
Lithuania	Triple-Superphosphat (TSP), 46% P_2O_5, 20% P	1.8
Germany	Triple-Superphosphat (TSP), 46% P_2O_5, 20% P	1.84
Finland	Triple-Superphosphat (TSP), 46% P_2O_5, 20% P	1.8
Poland (PL2)	Triple-Superphosphat (TSP), 46% P_2O_5, 17.4% P	2.3
Poland (PL7)	Polifoska 6 NPK(S) 20%P_2O_5,30%K_2O, (7%S), 8.7% P	4.5

Table A1.3. Mineral K- fertiliser prices, mineral K prices (100% K) prices in Baltic Sea region. Prices are without VAT.

Country	K-Fertiliser	Price of mineral K with delivery to 100 km € kg^{-1}
Estonia	Potassium Chloride, 50.6% K	0.6
Latvia	Potassium Chloride, 60% K	0.6
Russia	Potassium Chloride, 50.6% K	0.6
Sweden	Potassium Chloride, 50.6% K	0.7
Lithuania	Potassium Chloride, 50.6% K	0.6
Germany	Kornkali, 60% K_2O, 48.9% K	0.64
Finland	Potassium Chloride, 50.6% K	0.6
Poland (PL2)	Potassium Chloride, 49.8% K	0.51
Poland (PL7)	Polifoska 6 NPK(S) 20%P_2O_5,30%K_2O, (7%S), 24.9% K	1.6

Table A1.4. The required minimum manure storage capacity, in months, determined in national regulations. The data are asked from project partners.

Country	Minimum manure storage capacity, in months
Estonia	8
Latvia	8
Russia	
Sweden	It is very much up to farm size but in general 10 month for pig farms and 8 month for cattle farms (part of the time the animals are outdoors in summer, several spreading opportunities during summer on grassland). However, larger farms could have harder demands (individual permits) and small farms a bit less storage period.
Lithuania	6
Germany	6 (for liquid manure like slurry and dung water); as of 2020 minimum storage capacity for solid manure and compost will be 2 months
Finland	12 months. For farms with grazing animals it is possible to decrease manure left on pasture from storage volume. In this case the minimum capacity is typically 8 months. Capacity can also be decreased if manure is given out from the farm, e.g. for processing.
Poland	6 months for liquid natural fertilizers. 5 months.for solid natural fertilizers.
Belarus	6
Denmark	9 as general rule.

Appendix 2. Data survey to the partners

List of data required for calculation of economic impact was sent to project partners. Separate data were required for every pilot-farm.

Table A2.1 List of data required for calculation of economic impact

Manure storage data
Storage capacity, t
Existing yearly manure amount in the storage,
New yearly manure amount in the storage,
Manure data, ex-storage
Existing
N_{tot}
NH_4-N
P
K
New
N_{tot}
NH_4-N
P
K
Field data, about every field what can be fertilised with the manure in pilot farm
Field area, ha
Planned N amount, kg ha^{-1}
Planned P amount, kg ha^{-1}
Planned K amount, kg ha^{-1}
Driving distance to the manure storage, km (one way distance)
Description of manure handling machinery to move manure from storage to the field
Loaders
Transporters
Spreaders

Manure Standards

www.luke.fi/manurestandards

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