Farm-N internet tool for calculation of static N-balances.

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1. Background.

The internet tool has been developing for strategic calculations of the consequences of alternative management and structure of animal farms. The calculated farm gate N-balance (external inputs minus external outputs) is norm distributed between N-losses to air, to ground water under root zone (1 m) and to changes in soil-N (Gyldenkærne et al (2005). In order to calculate the losses the internal Herd and Field balances are calculated. In order to demonstrate the typical consequence of management, the optimization of allowed fertilizer import is not included at this stage of the Farm-N tool. If the model was allowed to compensate changes in manure production with import of mineral fertilizer only little effects of management could be expected on overall farm gate N-surplus.

This text supply Jørgensen et al (2005) with more technical information's about the exact calculations.

2. Method.

In Denmark (DK) the allowed import of artificial fertilizer is calculated from *norm manure production*$_{Ab\ storage}$, multiplied with a "*legislation utilization-demand*". The "*Norm manure production*$_{Ab\ storage}$" is adjusted for (Type 1-correction on page 64 in Anon (2003)):

- milk production per cow: +/- 0.7% of $N_{ab\ storage}$, starting with the base production of 8,243 kg ECM-milk cow^{-1} year^{-1}.
- Live weight gain in piglets production: (KgOut – KgIn) * (22.3 + 0.173 * (KgOut – KgIn)) / 655.
- Live weight gain in slaughter pig production: (KgOut – KgIn) * (22.3 + 0.173 * (KgOut – KgIn)) / 3250.

The method does not include the possibility of optimization of allowed fertilizer import: If a dairy farmer has higher milk production than 8,243 kg milk cow^{-1} year^{-1} he could have higher allowed fertilizer import if milk-yield correction was not done. Also type 2-corrections (Anon, 2003) are not possible at the present stage. A type 2-correction is allowance of higher fertilizer import, if higher N-efficiency$_{Herd}$ can be documented per animal/stall group. The possible documentation in DK is control of animal productivity of animal products with measured feed- and N-use. The norm N-efficiency$_{Dairy}$ is 26.3 % for heavy dairy cows and for slaughter pigs the N-efficiency$_{Slaughter\ pigs}$ is 37.7 %.

The "*Norm manure production*" is adjusted for maximum allowed stocking rate: Pig farms max. 1.4 LSU ha^{-1}. Other farms max. 1.7 LSU ha^{-1} and cattle farms with more than 70% area with crop cover during autumn/winter (grass/clover/lucerne, maize, beets, winter crops and under sown grass/clover) max 2.3 LSU ha^{-1}. The allowed stocking rate is not included in the precent Farm-N tool. If the total amount of manure more than fulfil the allowed N-norm for the crops surplus manure is compulsory sold.

The "*legislation utilization-demand*" is defined per manure type, Anon (2003), page 20:

Pig slurry	75% fertilizer value of manure
Cattle slurry	70% fertilizer value of manure

Deep litter 45% fertilizer value of manure.

Other organic fertilizer is not treated at the present stage of the Farm-N model, primarily because other manure types are relatively rare in DK (Gyldenkærne og Mikkelsen (2004)) and especially on farms who need to makes calculations for environmental impacts of expansions.

Plant available *N-standard* = (fertilizer + *norm manure production*$_{Ab\ storage}$, multiplied with *legislation utilization-demand)* has a maximum allowance per crop, in year 2004 see page 52 in Anon (2003). In total there are 99 N-standards for different agricultural crops on three different soil types and for sandy soil there are standards for both irrigated and unirrigated. Figures from common crops are given in table 1:

Table 1. *Standards for maximum N-application at a certain annual net yield (yield-standard) are shown for some crops on two soil types in 2004.*

	Sandy, irrigated		Sandy loam, unirrigated	
	N-standard kg N ha^{-1}	Yield-standard t DM ha^{-1}	N-standard kg N ha^{-1}	Yield-standard t DM ha^{-1}
Grass crop				
Permanent pure grass	27-141[1)]	0-4	27-141[1)]	0-4
Established short lasting:				
Grass/clover, < 50 % clover	254	8.6[2)]	236	7.5[2)]
Establishing year after harvest of cover grain-crop:				
Grass/clover	54	1.3[2)]	53	1.15[2)]
Spring barley				
Cereal as previous crop	134	4.4[3)]	128	5.2[3)]
Grass/clover as pervious crop	69	4.8[3)]	63	5.6[3)]
Winter wheat				
Cereal as previous crop	175	5.8[3)]	177	7.2[3)]
Grass/clover as pervious crop	135	6.4[3)]	139	7.9[3)]

[1)]Depending on yield level
[2)] 1.15 kg DM SFU^{-1} (1 SFU = feeding value of 1 kg barley grain).
[3)]Grain yield

The overall principle is that crop specific N-fertilizer requirement (N-standard in table 1) is calculated after inclusion of the authorized "*legislation utilization-demand* of manure, with correction for farm structure (number of animals on specific stall type) and animal production level (milk yield cow^{-1} and meat production piglets^{-1}/slaughter^{-1}).

The home-grown feed (grain and roughage) is offered for herd use, and the feed import/crop sales are calculated from norm feed- and N-requirements of the herd - home-grown feed. Not fulfilled demand of feed is imported as barley grain and soya cakes. First the dry matter requirement is fulfilled and next the energy and protein norm-demand is fulfilled. Surplus feed and cash crops are sold.

The Farm-N model is initialized with norm-values for DM, energy (SFU) and protein demand per herd group. Sensitivities of different management scenarios can be calculated by altering:

- animal production, which will alter N-fertilizer import and feed import/surplus crop sales.
- crop rotation, which will alter N-fertilizer import and feed import/surplus crop sales.
- crop yield level, which will alter feed import/surplus crop sales, but not fertilizer import.
- animal N-uptake (N-efficiency$_{Herd}$), which will alter feed import/surplus crop sales, but not fertilizer import.

The flow diagram is in principle following the flow chard of NPfluxEGF_isk.xls. Storage changes are zero in order to calculate the steady state result of changed structure and management. Field is presented without "*harvestable crops*".

3. The sequence of calculation is

Farm
Define soil type, irrigation, yield level of crops and farm type

Field
Define crops and area in multiple crop rotations. Irrigation and Crop yield level can be altered per *Crop rotation*

Rotation
Define allowed "*Animal manure"* from storage; *"Maximum proportion grazed"* as % of crop yield; "*Proportion sold*" as % of crop yield directly sold from field and not available for feed and "*Straw use*" crop^{-1} rotation^{-1}.
The Farm-N model **calculate** the optimal crop rotation by maximizing
cash= income(crop yield * crop value) – expenses (Fertilizer * fertilizer cost), see Detlefsen (2004).
The crop yield and norm N-standard are given by table 1 and the optimization is made by a LP-optimization routine.

Cattle
Define herd number per stall type; *"Maximum proportion grazing*" by max. of energy SFU animal^{-1} year^{-1}; Energy corrected milk yield cow^{-1}; Relatively N-efficiency$_{Animal/Stall\ group}$ and "*Housing type*" per herd group.
Farm-N **calculate** Cattle herd norm feed demand (in SFU and DM) and N requirement from animal outputs and N-efficiency$_{Herd\ group}$. The N-efficiencies is mainly given in Poulsen og Kristensen (1998) and yearly updated as for year 2004 in Anon (2003). The manure$_{Ab\ animal}$ is calculated from uptake – products.
The norm feed- and N-requirement are given in the farm-N "*Documentation*". Shortly described first the DM-requirement is calculated. If not sufficient roughage is grown on the farm, the model import roughage until DM-demand is fulfilled. The quality of imported roughage is the same as the average of home-grown roughage. The remaining energy and N-demand is firstly fulfilled from home-grown grain since from imported grain and concentrate, se also Jørgensen et al. (2005).

Pig
Define number of animals: Sows, piglets and slaughter pigs with start and end weight per stall type. Norm feed and protein are pretyped mainly from data given in Poulsen and Kristensen (1998) and yearly updated.
Farm-N **calculates** Pig herd feed and N-use and production from typed values. All pig feed is imported.

Manure
Farm-N **calculate** $N_{ab\ animal}$ per manure type. $N_{ab\ storage}$ is calculated after deduction of grazed-$N_{ab\ animal}$ minus norm air losses in ammonia and denitrification from solide manure.
On crops with allowed application of manure the optimal distribution of manure types between crops is calculated in order to maximize the fertilization value of animal manure from norm "fertilizer equivalent" values per manure type and spreading month. In DK manure is only allowed spread on cereals in spring and on grassland within the growing season (UK-reference??). The fertilizer equivalent is roughly calculated as 100 % fertilizer value of manure ammonia-N, given the DK regulation that manure has to by either injected or hose spread in growing crops. A small net mineralization on about 10 % fertilizer value of organic manure-N is included in whole season growing crops (grass/clover, maize).

The "*Norm manure production*$_{Ab\ storage}$" is adjusted for (Type 1-correction on page 64 in Anon (2003)):

- Milk production per cow: +/- 0.7% of $N_{ab\ storage}$, starting with the base production of 8,243 kg ECM-milk cow^{-1} $year^{-1}$.
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Norm ammonia losses are calculated per crop and spreading method.

Balance
Farm-N **calculate turnover of manure**: production – housing, stall & spreading air loss, corrected for imported and exported manure. From the "*legislation utilization-demand*" defined per manure type, Anon (2003), page 20:

Pig slurry	75%
Cattle slurry	70%
Deep litter	45%

The fertilizer value of $manure_{Ab\ storage}$ is calculated after correction for farm specific milk and pig meat production. From the crop specific maximum N-standards minus fertilizer value of manure the import of fertilizer is calculated.

Farm-N **calculate turnover of feed in SFU and N:** Production + brought (import) – sold – feed use. The required feed import is calculated from herd DM requirement, calculated on the sheets *Cattle and Pig*. The remaining requirement of feed (SFU) and protein is fulfilled by a combination of barley grain and soya cakes. Minimum crude protein content in imported feed is 11 % crude protein of dry matter (=barley brain) and maximum 42 %(=soya cakes). If home-grown feed is in excess the feed is sold.

Results
A farm gate N-balance with norm N-losses and soil-N changes are calculated.

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