December 21, 2017

Summary of the analysis regarding prerequisites for the Food and Agriculture Package

The Danish analysis (Petersen, 2017) is entitled "Analyse af forudsætninger for landbrugspakken".

The main theme of this analysis is the large uncertainty regarding the most appropriate value of the marginal leaching, and the lacking communication of this large uncertainty. The main focus of the analysis is the claims and calculations in Børgesen et al. (2015) by Aarhus University.

Regarding the scientific calculations underlying the Danish Agricultural Package (2015), Aarhus University relied entirely on the NLES4 leaching model (Kristensen et al., 2008). This model calculates an average marginal leaching of 18 %, meaning that 18 % of additional nitrogen fertiliser is presumed to be leached from the root zone, as a national average for Denmark. During the period 2003 – 2011 the average marginal leaching was assumed to be approx. 30 - 33 %, which is in accordance with the marginal leaching of the previously utilised NLES3 model, which is described by Kristensen et al. (2003).
This change from 30 – 33 % to 18 % caused a substantial easing in the additional measures needed to compensate for the extra added nitrogen fertiliser.

The aim of the analysis was to investigate the scientific evidence that supported this considerable change in presumed marginal leaching. Aarhus University claimed that the NLES4 model was superior to the previous NLES3 model mainly due to:

1. NLES4 is based on a larger number of observations (N = 1467) than NLES3 (N = 1299).
2. The NLES4-calculated marginal leaching is in better accordance with national and international studies.

Regarding claim no. 1, the analysis points out that an increased number of observations is not as such a quality criterion in terms of realistic calculations of marginal leaching.

Regarding claim no. 2, the acclaimed better accordance with national and international studies is based on field experiments from 5 scientific articles.

Regarding these 5 articles the analysis points out:

> Three of these articles (Engström et al., 2010; Delin and Stenberg, 2014; Manevski et al., 2015) treated one-year field trials with varying nitrogen applications. Aarhus University compared the marginal leaching from these three articles directly with the average long-term marginal leaching. As the long-term marginal leaching invariably will be higher than the one-year leaching, this is an obvious statistical error, leading to a bias.
> When making a more detailed numerical analysis of the marginal leaching from the trials, and comparing values with the NLES4 one-year average, all 10 field trials had considerable larger marginal leaching than NLES4.

The forth article (Wachendorf et al., 2004) assembles a number of field trials, and generates a formula for the leaching. From this formula the marginal leaching can be calculated, and the NLES4 long-term marginal leaching is compared with this calculation. But this approach generates a bias, as some of the trials have a shorter time-span than the 6 years it takes for NLES4 to reach the long-term marginal leaching level. Further, correcting for this bias is not possible without a comprehensive effort, as not all trial durations are directly accessible. Due to this bias which further cannot be corrected directly, this study cannot be used for proper, unbiased comparisons.

The fifths and last article (Pandey et al., 2015) compares 3 different cropping systems, one conventional and two organic systems. The one organic system has a separate crop rotation, whereas the other crop rotation involved is used both for the conventional and the other organic system. Aarhus University claims, that a simple two-dimensional linear regression (leaching versus total nitrogen input) for the three rather different cropping systems can represent some sort of common marginal leaching. This claim is incorrect, as the analysis explains in detail. There are many other factors (dimensions) involved, including the interaction between applied fertiliser and nitrogen fixation, the different dynamics of animal manure and mineral fertiliser, different crop rotations and different nitrogen soil pool developments. The two dimensions considered will not be able to span all the underlying factors/dimensions, and hence cannot constitute a true and accurate system comparison. Due to the profound methodologic problems of this oversimplification, this study cannot be used for scientifically correct comparisons with marginal leaching.

Claim no. 2 regards NLES4 being in better accordance with national and international studies. The analysis points out that the marginal leaching calculated by NLES4 is not supported by the 5 articles. The calculations that could be carried out without bias or other methodological problems showed a much higher marginal leaching than the modelled national average (see table 1, Appendix). This does indicate problems with the calculated average of 18 %, but the data set is comparatively small and further not representative for Denmark regarding crop composition. Therefore, the analysis does not claim that the assumed 18 % with certainty can be considered too low a value. What the analysis does claim, is that this value is very uncertain, and based on the current knowledge, the previous range of approx. 30 – 33 % is just as realistic as the present 18 %.

./. The Danish Ministry of Environment and Food referred to the acclaimed better accordance with national and international studies as justification for changing the calculation of the leaching in the answer no. 568 (MOF alm. del) given 31st March 2016 to Member of the Danish Parliament Ida Auken (attached).

<u>The curve function of the leaching in NLES4 is quite unrealistic</u>. Even when going from approx. 16 % below economic optimum for nitrogen fertilisation to 50 % above economic optimum an almost linear response is obtained, according to the figure below. It is common agronomical knowledge (e.g. Lord and Mitchell, 1998; Goulding et al., 2000; Delin and Stenberg, 2014) that a distinct rise in the leaching level will typically begin near economical optimum. The lack of realism regarding the response is also evident from figure 1 – 6 in the analysis (see Appendix).

A model that is unable to mimic this well-known effect appropriately, has hence been used for assisting in comprehensive decision making regarding environmental effects.

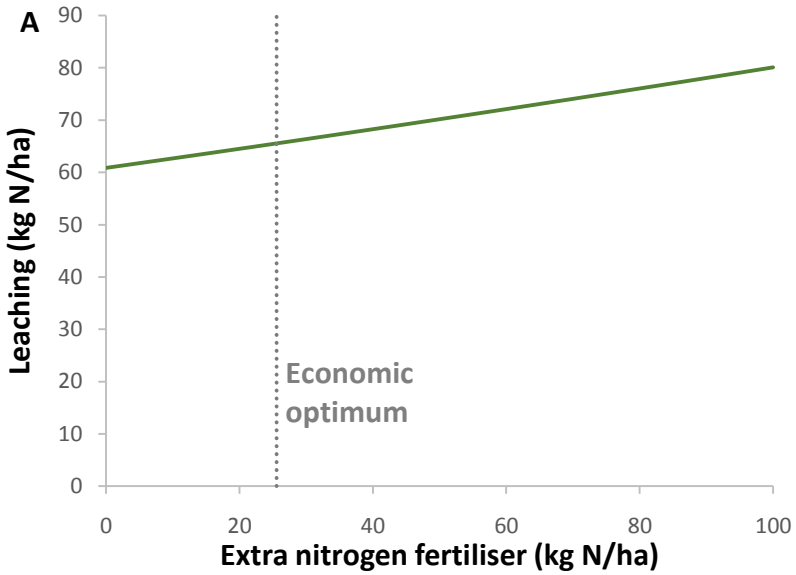


Figure. NLES4-calculated average for the Danish average nitrogen leaching. The starting point is nitrogen fertiliser application levels as in 2011. The vertical dotted line shows the economical optimum. The present figure is a part of figure 7 in the analysis.

The last part of the analysis is largely independent of the above calculations. This part considers the large and unexplained difference in marginal leaching between the two model versions NLES3 and NLES4. It is explained how this implies significant methodological problems with the calculations of the marginal leaching. The following key questions were never addressed during the preparation of the Food and Agriculture Package:

- To what extent is the difference in marginal leaching caused by differences in model structure and to what extent is it caused by differences in underlying data?
- What specific conditions in NLES3 and NLES4 (structure and data basis) constitute the reason for the difference in marginal leaching?
- Which model has the most accurate calculation of marginal leaching and what criteria can be used to determine this?

The analysis hence points out questions that need to be answered. The above three questions need to be clarified before it is possible to undertake any kind of fact-based discussion of whether adjustments should be made to the marginal leaching relative to the previous assumption of a value of 30 - 33%.

Conclusions of the analysis

The development of the NLES4 marginal leaching, relative to increasing nitrogen application, differs from the development calculated from experimental data (Figures 1B - 6B in the analysis, see also Appendix). In addition, the general level of marginal leaching calculated with NLES4 is significantly lower (table 1 in the analysis, see also Appendix) than the marginal leaching that can be calculated from the experiments.

Based on data selected by Aarhus University to support the general level of the nationwide NLES4-calculations with experimental results, it is concluded that the model used for calculation of marginal leaching underlying The Danish Agricultural Package, cannot be used for real-life estimations of nitrogen emissions resulting from the easing of the Danish fertilization rules.
Furthermore, the choice of using NLES4 rather than NLES3 is arbitrary, as this choice was not based on systematic quality criteria.

The analysis thus demonstrates that there is no scientific support for the Food and Agriculture Package's lowering of the estimated marginal leaching at national level from 30 – 33 % to 18 %.

Appendix

This section addresses table 1 and figure 1 – 7 from the analysis.

Table 1. Results for calculation of the marginal leaching, based on data from Delin and Stenberg (2014), Engström et al. (2010), and Manevski et al. (2015). From Petersen (2017).

Article	Crops	Location	Marginal leaching at N-norm (%)	Factor relative to NLES4-average (%)
Delin, Stenberg	Winter oilseed rape	Götala, SV	14.0	175
Engström et al.	Oat	Götala, SV	23.8	298
Manevski et al.	Maize after maize	Foulum, DK	98.9*	1236*
Manevski et al.	Maize after maize	Jyndevad, DK	28.5	356
Manevski et al.	Maize after maize, cover crops	Foulum, DK	22.1	276
Manevski et al.	Maize after maize, cover crops	Jyndevad, DK	20.2	253
Manevski et al.	Maize after clovergrass	Foulum, DK	42.6	533
Manevski et al.	Maize after clovergrass	Jyndevad, DK	81.2	1015
Manevski et al.	Maize after cl.grass, cover crops	Foulum, DK	43.6	545
Manevski et al.	Maize after cl.grass, cover crops	Jyndevad, DK	64.2	803

*This value can be considered an extreme outlier.

These one-year trial results were compared with the average one-year model-derived result. All marginal leaching values were much higher than the average one-year model-derived marginal leaching at national level, which is 8 %. Ideally, all results should be compared to a specific NLES4 mimic of each experiment. Such specific comparisons are not attempted by Aarhus University and not attempted in the analysis.

Aarhus University selected five articles which were used for comparison with the NLES4 model results at a national level. The crop and cropping system composition in these 5 articles is far from representative for Danish agriculture. Conventional grown cereals are underrepresented, and maize and organic farming is overrepresented, relative to the present agricultural practice.

Two of these articles (Wachendorf et al. 2004; Pandey et al. 2015) were unfit for scientifically stringent comparisons with model results, as elaborated in the analysis. Wachendorf et al. (2004) regarded grass and clover grass, and Pandey et al. (2015) primarily regarded organic farming (6 organic trials and 2 conventional trials, carried out in 3 locations).

The below figures are shown with their original Danish text.

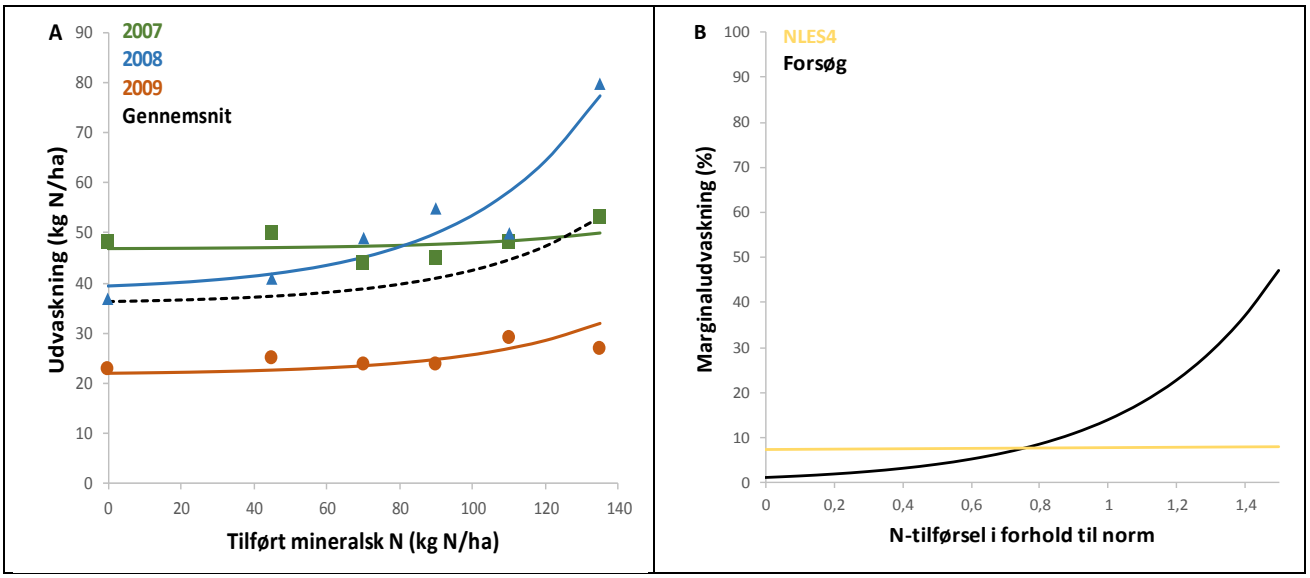
Figures 1-6, A, X-axis is applied nitrogen fertiliser (kg N/hectare).
Figures 1-6, A, Y-axis is applied nitrogen leaching (kg N/hectare).

Figures 1-6, B, X-axis is applied nitrogen fertiliser relative to the recommended amount.
Figures 1-6, B, Y-axis is applied marginal nitrogen leaching (%).

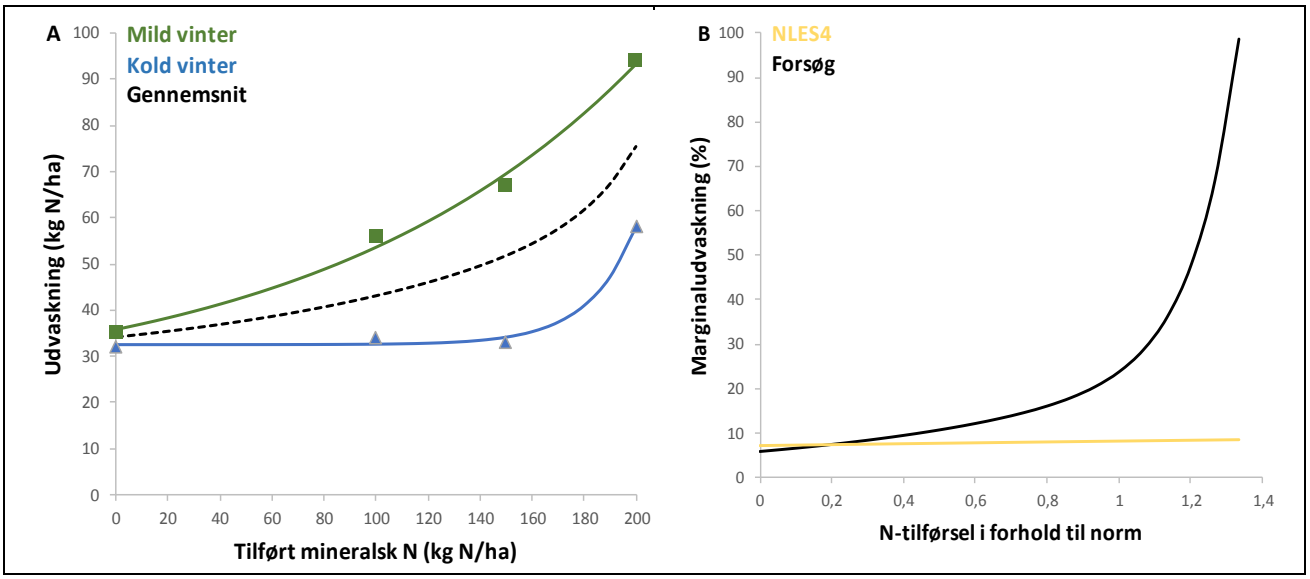
The yellow curve in figures 1-6, B, shows the national average marginal leaching at the given relative nitrogen application level.

Figure 7A, X-axis is applied nitrogen fertiliser *above* the level in 2011 (kg N/hectare) as national average.
Figure 7A, Y-axis is nitrogen leaching (kg N/hectare) as national average.

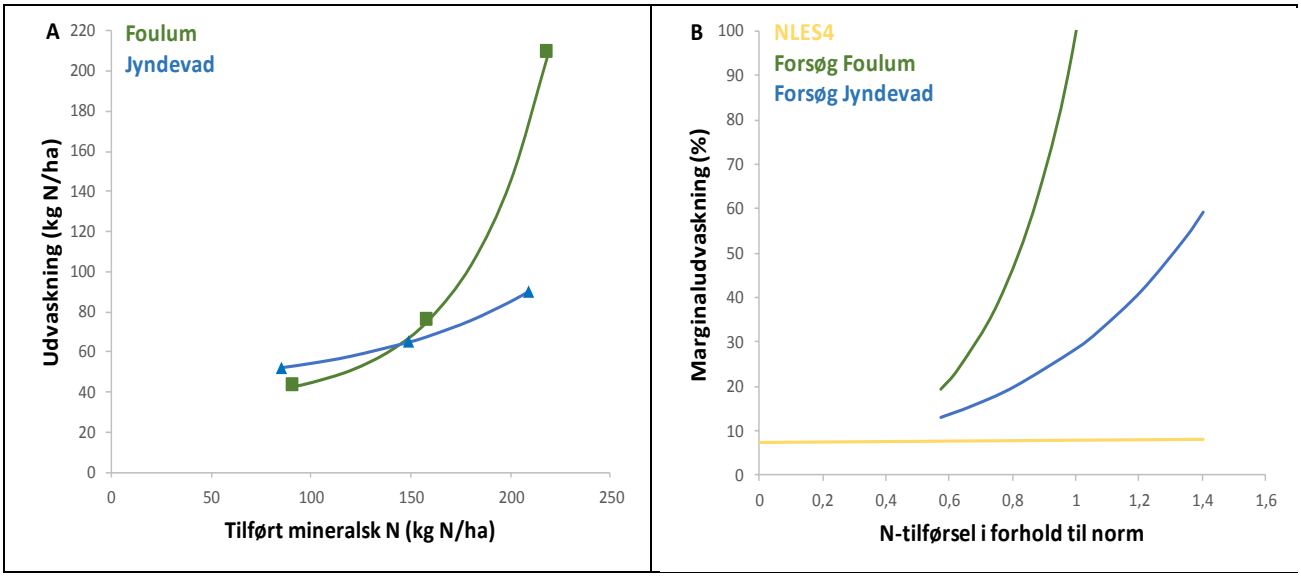
Figures 7B, X-axis is applied nitrogen fertiliser *above* the level in 2011 (kg N/hectare) as national average.
Figures 7B, Y-axis is marginal nitrogen leaching (%). This is shown at the 6-year and above level (black curve) and at the 1-year level (yellow curve).
The vertical, stipulated lines in Figure 7 show the economically optimal application.



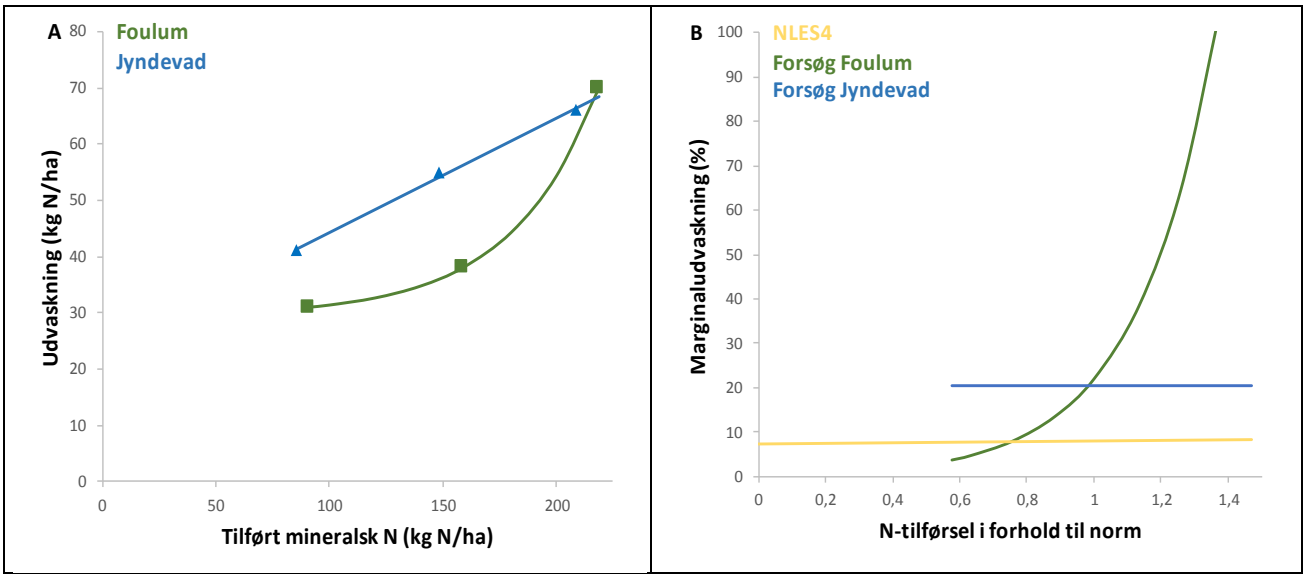
Figur 1. Udvaskning (A) og marginaludvaskning (B) fra havre tilført forskellige mængder kvælstofgødning, på basis af data fra Delin og Stenberg (2014).



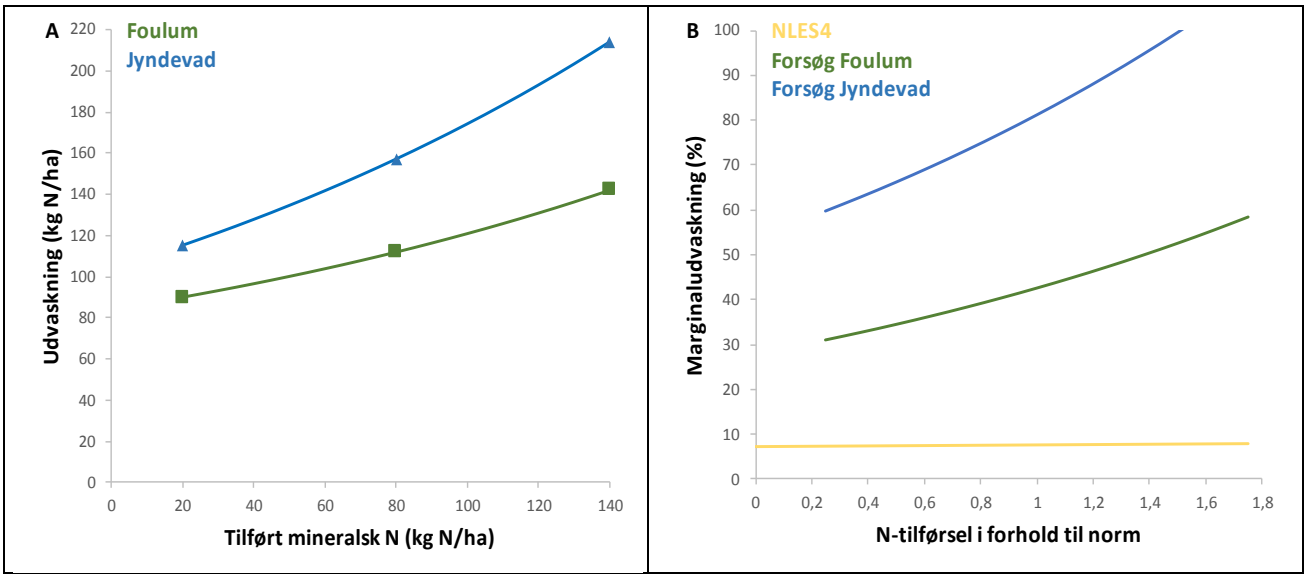
Figur 2. Udvaskning (A) og marginaludvaskning (B) fra vinterraps tilført forskellige mængder kvælstofgødning, på basis af data fra Engström et al., 2010.



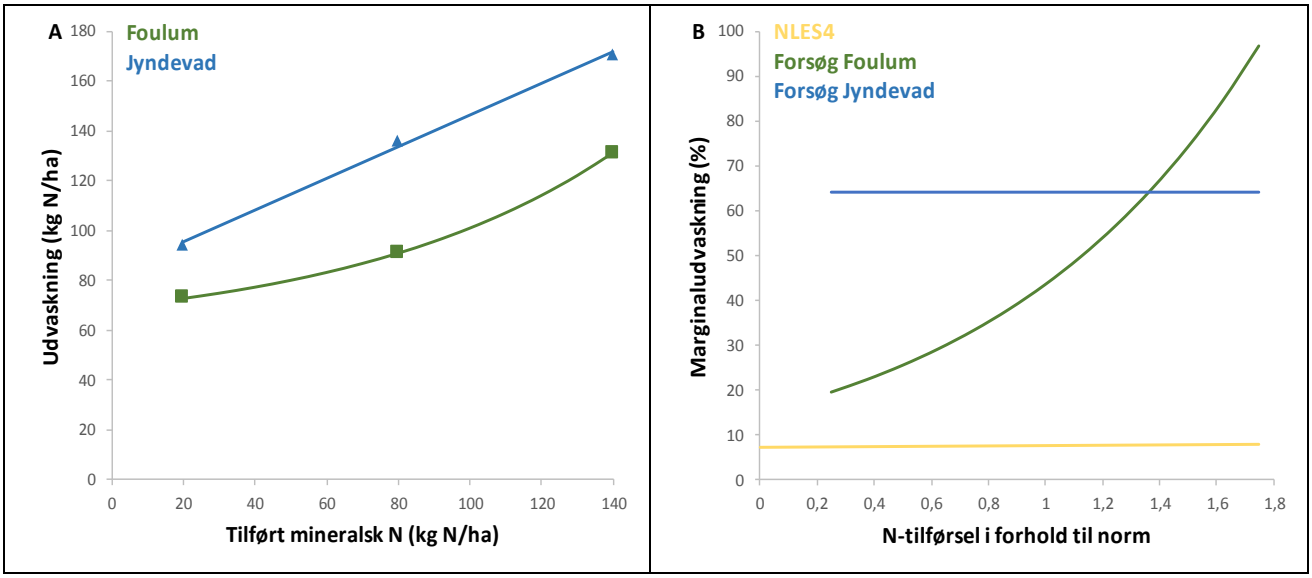
Figur 3. Udvaskning (A) og marginaludvaskning (B) fra majs der efterfølger majs, tilført forskellige mængder kvælstofgødning, på basis af data fra Manevski et al. (2015).



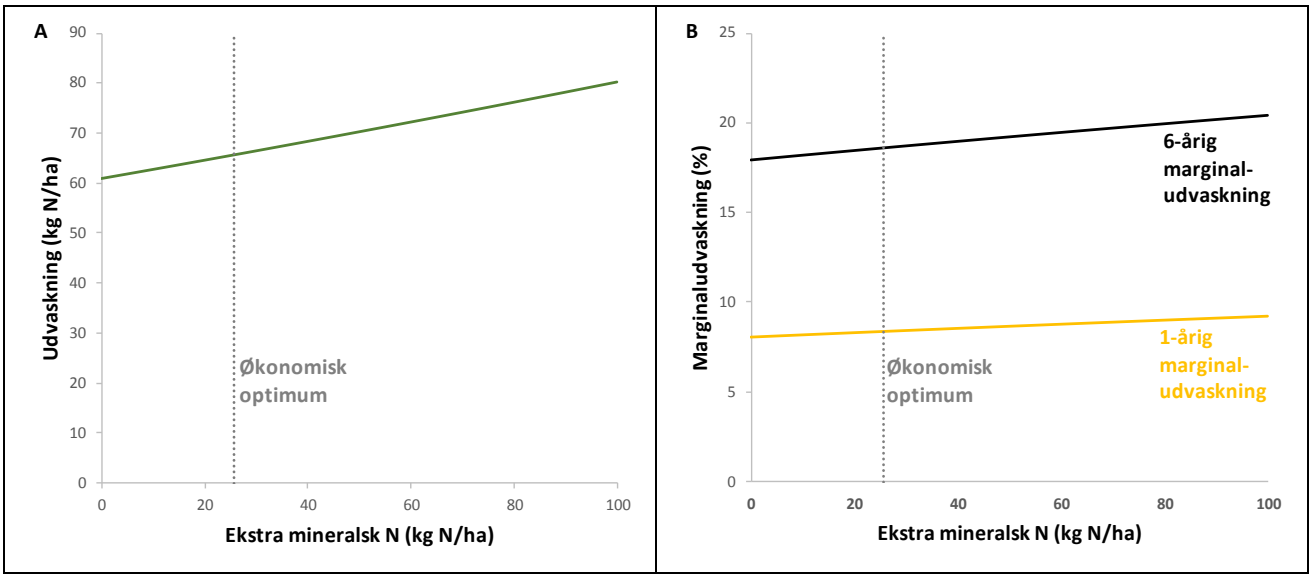
Figur 4. Udvaskning (A) og marginaludvaskning (B) fra majs med efterafgrøder der efterfølger majs, tilført forskellige mængder kvælstofgødning, på basis af data fra Manevski et al. (2015).



Figur 5. Udvaskning (A) og marginaludvaskning (B) fra majs der efterfølger kløvergræs, tilført forskellige mængder kvælstofgødning, på basis af data fra Manevski et al. (2015).



Figur 6. Udvaskning (A) og marginaludvaskning (B) fra majs med efterafgrøder der efterfølger kløvergræs, tilført forskellige mængder kvælstofgødning, på basis af data fra Manevski et al. (2015).



Figur 7. NLES4-beregnede landsgennemsnit for udvaskning (A) og marginaludvaskning (B). Udgangspunktet er kvælstofgødskning som i 2011. De lodrette stiplede linjer viser økonomisk optimum. Se afsnit 3 i Appendiks for detaljerne i beregningen af figurens kurver.

References

Børgesen, C.D., Thomsen, I.K., Hansen, E.M., Kristensen, I.T., Blicher-Mathiesen, G., Rolighed, J., Jensen, P.N., Olesen, J.E., Eriksen, J. 2015. Notat om tilbagerulning af tre generelle krav, Normreduktion, Obligatoriske efterafgrøder og Forbud mod jordbearbejdning i efteråret. Aarhus Universitet. Notat til NaturErhvervstyrelsen den 11. november 2015. http://pure.au.dk/portal/files/95991713/Notat_om_tilbagerulning_af_tre_generelle_krav_Normreduktion_Obligatoriske_efterafgr_der_og_Forbud_mod_jordbearbejdning_i_efter_ret_111115.pdf

Delin, S., Stenberg, M. 2014. Effect of nitrogen fertilization on nitrate leaching in relation to grain yield response on loamy sand in Sweden. European Journal of Agronomy 52, 291-296.

Engström, L., Stenberg, M., Aronsson, H., Lindén, B. 2010. Reducing nitrate leaching after winter oilseed rape and peas in mild and cold winters. Agronomy for Sustainable Development 31, 337–347.

Goulding, K.W.T., Poulton, P.R., Webster, C.P., Howe, M.T. 2000. Nitrate leaching from the Broadbalk Wheat Experiment, Rothamsted, UK, as influenced by fertilizer and manure inputs and the weather. Soil Use and Management 16, 244-250.

Kristensen, K., Jørgensen, U. og Grant, R. (2003) Genberegning af modellen N -LES. 12 pp. Baggrundsnotat til Grant, R. og Waagepetersen, J. (2003) http://www2.dmu.dk/1_viden/2_publikationer/3_ovrige/rapporter/vmpii/genberegning_af_modellen_nles.pdf

Kristensen, K., Waagepetersen, J., Børgesen, C.D., Vinther, F.P., Grant, R., Blicher-Mathiesen, G. 2008. Reestimation and further development in the model N-LES - N-LES3 to N-LES4. Det Jordbrugsvidenskabelige Fakultet, Aarhus Universitet og Danmarks Miljøundersøgelser, Aarhus Universitet. DJF rapport 139.
http://pure.au.dk/portal/files/2423945/DJF_rapport_Markbrug_139

Lord, E.I., Mitchell, R.D.J. 1998. Effect of nitrogen inputs to cereals on nitrate leaching from sandy soils. Soil Use and Management, 14, 78–83.

Manevski, K., Børgesen, C.D., Andersen, M.N., Kristensen, I.S. 2015. Reduced nitrogen leaching by intercropping maize red fescue on sandy soils in Northern Europe: a combined field and modeling study. Plant and Soil 388, 67-85.

Pandey, A., Li, F., Askegaard, M., Rasmussen, I.A., Olesen, J.E. 2015. Nitrogen balances in organic and conventional arable crop rotations and their relations to nitrogen yield and leaching losses. Agriculture, Ecosystems and Environment. Publication status unknown.

Petersen, B.M. 2017. Analyse af forudsætninger for landbrugspakken. The Danish Society for Nature Conservation, November 2017.
http://www.dn.dk/media/24635/analyse-af-forudsaetninger-for-landbrugspakken.pdf

Wachendorf, M., Büchter, M., Trott, H., Taube, F. 2004. Performance and environmental effects of forage production on sandy soils. II. Impact of defoliation system and nitrogen input on nitrate leaching losses. Grass and Forage Science, 59, 56-68.