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Published in:
20th International Farm Management Congress

Publication date:
2015

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Jacobsen, B. H., & Hansen, A. L. (2015). Economic gains from targeting measures based on detailed nitrate reduction maps. In *20th International Farm Management Congress: Healthy Agriculture for a Healthy World* (Vol. 1, pp. 189-202)

ECONOMIC GAINS FROM TARGETING MEASURES BASED ON DETAILED NITRATE REDUCTION MAPS

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Abstract

From 1990 until 2003 Denmark has reduced N-leaching from the root zone by 50%. However, more measures are required and in recent years the focus has been on how to differentiate measures in order to ensure that measures are implemented where the effect of N-reduction per ha of the measures is the highest. The purpose of the NiCA project has been to estimate the nitrate reduction potential in greater detail than before using a plot size of 1-25 ha. This article builds on these findings and presents the possible economic gains to the farmer when using this information. Targeted measures are especially relevant where the N reduction at the field level varies largely within the same farm. In this paper, the knowledge of spatial variation in N-reduction potential is used to plan where to place measures such as catch crops or set a side in order to gain the largest effect. The detailed N-reduction map is used on 10 farms in the Norsminde Catchment near Århus, Denmark. The findings suggest that the average farm would gain approximately 100-150 DKK per ha per year from targeted measures as opposed to not knowing where to place the measures. The analysis indicates that the economic gain is higher than the costs of providing the detailed maps, which are estimated to be 40-60 DKK/ha/year. When reduction requirements are increased, the economic gains are higher. When combined with new measures like mini wetlands and early sowing, the economic advantage is increased further. The paper also shows that not all farms can use the detailed information on N-reduction and so there is not a clear link between spatial variation in N-reduction at the farm level and possible economic gains for these farms.

Keywords: Nitrate reduction, spatially distribution, site specific regulation, targeting, non-point pollution, cost-effectiveness

1. Introduction

The leaching of nitrogen from the agricultural area is an environmental problem in many countries and so a number of national policies and European Directives (e.g. the Nitrate Directive and the Water Framework Directive) have been implemented to reduce the N-losses. In Denmark, a number of policies have been introduced since the mid 1980ties and they have managed to reduce the N-leaching by 50% from the 1980'ties until 2003 (Mikkelsen et al., 2010, Bøgesen et al., 2009, Jacobsen, 2009, Dalgaard, 2014). Despite this, more measures are needed to reach the targets required in order to obtain Good Ecological status (Grinsven et al., 2012 and Commission, 2012).

The measures introduced in Denmark have, so far, been based on a high degree of general regulation where all farms in Denmark are regulated in the same way (horizontal measures). The current N-quota system is linked to crops and soil type, but it is not differentiated with respect to N-reduction and the required N-reduction target for a given catchment. Today, the N-quota is 18% under economic optimum

(2014/15) and the farmers would very much like to apply the economic optimum in areas where N lost to the coastal waters is limited due to a high N-reduction (Knudsen, 2014). Other national measures such as the utilization requirements of N in manure, catch crops and the requirement of no cultivation in the autumn are all applied at the same level in the whole country. In other words, general regulation based on command and control is the main regulatory measure used, although measures like wetlands and riparian zones are, to some extent, targeted measures. Implementing the same measure across the country makes it easier from a regulatory perspective as a detailed model for the differentiation does not need to be used Jacobsen et al. (2015) and Jacobsen and Ørum (2014).

With the implementation of the Water Framework Directive, it is clear that the reduction requirements must be more differentiated than before as the need for further reductions varies between the 23 main catchments or River Basins in Denmark, so that each water body can achieve good Ecological status (Naturstyrelsen, 2014).

The efficiency of the existing general regulations is, on average, only 1/3, because roughly 2/3 of the nitrate leaching from the root zone is reduced in the subsurface before reaching the streams. Today it is impossible to differentiate between vulnerable areas from where nitrate leaching reaches the surface water with very little reduction, and robust areas where almost all leached nitrate is reduced. This is a constraint for designing cost-effective water management measures.

The basic problem is that N-loss from agriculture is diffuse pollution and so the polluter cannot be found directly as is the case with point source pollution. However, with new techniques and approaches, it is possible to estimate the losses in more detail than before. In other words, the idea is to regulate diffuse pollution almost as a point source pollution or at least as a diffuse pollution source where some knowledge of the local variation is used by the farmer and the regulator.

In Denmark, this has led to a strong focus on the option of more targeted regulation as included in the recommendations for the Danish Nature and Agricultural Commission which says that “A new, differentiated and targeted nitrogen regulation would mean, that the regulation can vary between types of fields and farms”. (p.41) (NLK, 2013).

What is meant by targeting is that measures such as catch crops or set-a-side are located on fields where the environmental effect in terms of N-looses to the aquatic environment is the highest. The N-leaching from the root zone is a function of parameters like crop rotation and livestock intensity, which will lead to a given level of N-leaching per hectare. What the farmer does not know is how much of the leached nitrogen is reaching the coastal waters. The idea here is to locate the measures where the effect in terms of N lost to the coastal waters is the highest. The farmer can then try to include this knowledge in his management decisions.

The idea of trying to target measures more is not new, but the key issue is how well and certain the identification of the different areas can be. Behind the total N-reduction used today, there is a large variation in the N-reduction on the way from the root zone to the streams and the coastal waters. It is clear that a higher degree of certainty of this path will allow for measures to be targeted to the areas where the effect is the highest, allowing for a cost-efficient implementation of measures. On the other hand, a more detailed application, based on very uncertain maps, would lead to measures implemented in the wrong location. This was why the NiCA project was initiated in order to use new techniques and approaches to gather new data using new approaches to the analyses in order to gain more knowledge about the N-retention at the local scale.

This paper will analyse the economic gains of using detailed knowledge of N-retention at the field level based on the analysis in the NiICA project. Section 2 deals shortly with the economic gains from site specific regulation, focusing on N-losses from agriculture, based on previous findings. Section 3 looks at the methods used within NiCA to improve the N-mapping. Section 4 shows the economic gains from detailed mapping and the impact it has on farming in two N-loss scenarios using 10 farms in the Norsminde sub-Catchment area as a case study area. Section 5 discus the findings from a general perspective and give some conclusions related to future regulation.

2. Background

General regulation, which is equal across the country, will lead to inefficient solutions as the effect of the N-loss reductions will vary between farms and between fields. However, sometime this is the only way to regulate due to lack of knowledge regarding the actual N-reduction from diffuse pollution.

Abildtrup et al. (2004) and Refsgaard et al. (2007) did look at the economic gains from more detailed N-mapping in Ringkøbing, Denmark. The findings show that there is a large variation in the environmental effect across the catchment area and so targeting the measurers will increase the effect per ha. The analysis also showed that the income lost from taking land out of production varies mainly with livestock density or the share of high income crops (potatoes). The applied measures were wetlands, catch crops, lower N application and reductions in livestock and they were only used in areas where the N-reduction was low and so the effect of the measures was high. The analysis indicates a clear advantage in terms of cost efficiency in targeting measures at both N-losses (kg N/ha) and income lost although the analysis did not show the economic gain from site-specific regulation.

With the Danish N-application today being 18% under economic optimum, further decreases in application will be very costly and so it makes sense to see whether allowing full application of nitrogen to fields with high N-reduction and lower N- application to fields with low N-reduction would be an economic advantage for the economic sector as a whole. This gain is unique to Denmark as it is one of the few countries where the N-application is below the economic optimum.

Jacobsen (2012) has carried out a general analysis on the advantage of more site specific regulation in Denmark. The analysis is based on two approaches where the first assumes knowledge of the N-reduction in the whole of Denmark. This knowledge is used to place the measures where they are most cost-effective. The whole area is divided into 5 retention classes and the potential area with each measure in each retention class is described for each of the 23 catchments. This approach is called the SMART approach. In the other approach, called the AVERAGE approach, the measures are selected based on the average effect in the Catchment. The reduction target is the same in both analyses. The reduction target in the 2012 analysis is 10,000 tons N. Another analysis based on the same approach, but with newer cost data and targets was carried out in 2014 (Jacobsen, 2014). In the analysis, the costs of some measures vary to some degree between catchments, but not between farms. The results in table 1 show that the costs of a targeted implementation of measures reduce the costs of achieving the same target by 16-27%. There seems to be a tendency to towards lower gains from targeting with higher reductions, which could be explained by the fact that there is less flexibility in terms of measures and location with high reduction requirements as the full potential is being used in some areas.

Table 1. Cost of N-reductions in Denmark based on the SMART and AVERAGE approach (mio. DKK/year)

Year	Reduction (Ton N)	SMART (mio. DKK/yr)	AVERAGE (mio. DKK/yr.)	Economic gain from targeting (%)
2012	10,000	781	928	16
2014	7,773	626	825	24
2014	6,218	416	559	26
2014	3,887	169	231	27

Source: Jacobsen (2012) and Jacobsen (2014).

3. N retention mapping

The first retention map or N-reduction map is from 2007 and is based on a number of measurements combined with a modelling approach (Blicher-Matheisen et al., 2007). The map showed the N-reduction from the root zone to the coastal waters divided into 3 reduction classes (over 75%, 50-75% and under 50%). In 2009 the map was further developed and constituted now 489 sub catchments (Andersen et al., 2011) and five reduction classes (0-20%, 20-40%, 40-60%, 60-80% and 80-100%). The data show that the reduction at the national scale was almost equally divided between the four last classes and the area in the 0-20% was very limited. This map was used in the economic analyses in Jacobsen (2012) and Jacobsen (2014).

The newest retention map has been launched in 2015 and it is based on units of around 1,500 hectares (Højbjerg et al., 2015). The map has 3,000 units as opposed to the current map with 489 catchments, but the basic data is the same. The units are divided into the same five reduction classes as the previous map. Since the retention in the unit is placed within a range (e.g. 20-40%), the total area with the same retention can be over 3,000 ha. This would still indicate that the new retention map from 2015 is not detailed enough to be used in order to target measures at the field level.

3.1. NiCA retention mapping

In the NiCA project a new and more detailed mapping approach has been used in order to calculate the N-reduction level at a more detailed scale than before. The aim of the project was also to estimate the uncertainty on the estimated N-reduction, in order to analyse how this changes when going down in scale. The study was conducted in the 100 km^2 Norsminde Fjord sub catchment, where farmers and authorities have been actively involved in evaluating possible measures for reducing the nitrate load to surface water in a cost-effective manner (AQWAPLAN; Wright and Jacobsen, 2009).

The NiCA approach consists of a combination of methods. First, the geology was mapped in large detail using the novel airborne geophysical system MiniSkyTEM (or SkyTEM101), which is dedicated to identifying geological structures and heterogeneities in the upper 30 m. The results are compared to previous findings based on boreholes. Secondly, the effect of geological uncertainty was analysed by using multiple geological realisations generated stochastically and finally, the N-transport and reduction was simulated using the hydrological model MIKE SHE/MIKE 11. The approach is described further in Hansen et al. (2014b) and Refsgaard et al. (2014).

3.2. Average nitrate reduction and uncertainty

An average retention over a larger area (e.g. sub-basin) provides a more certain estimate since it is based on many measurements, but it will not necessarily estimate the N-retention in the individual field very well due to spatial variation. On the other hand, estimation for a field might be precise for that area, but with few measurements to support the value the estimate will be uncertain, although it is locally determined.

The resulting average reduction and uncertainty maps are seen in figure 1. There is a large spatial variation in N-reduction levels for both the SkyTEM geologies (figure 1a) and the borehole geologies (figure 1b) with reduction levels ranging from 0 – 100%. The average reduction is slightly higher using SKyTem (69%) than when using boreholes (61%).

The results show that the uncertainty on the estimated nitrate reduction is larger for the borehole based geologies than for the Skytem based (25% against 19%, figure 1c and 1d). The analysis shows that both geology and the position of the redox zones have an impact on the N-reduction. The resulting graph from the upscaling analyses is seen in figure 2. It is seen that the uncertainty using a 100 m scale is relative large and that the uncertainty is decreasing with increasing plot scale. The uncertainty is reduced from 20% to 10% when moving from a scale of 100 m to a scale of 500 m, but from there and upwards in size the uncertainty is almost the same (around 10%).

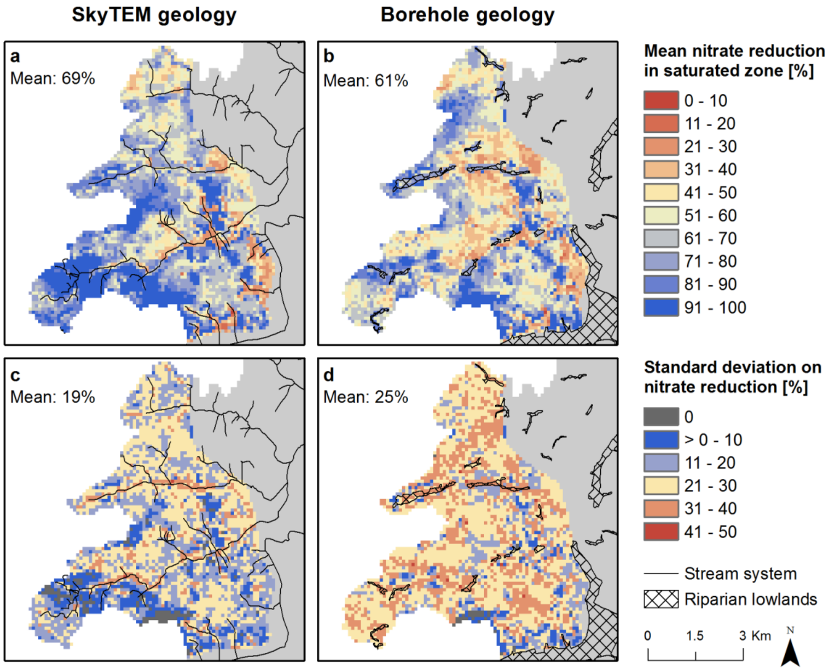

Figure 1 Spatially distributed average nitrate reduction potential and associated uncertainty on a 100 m grid scale. (a) Average nitrate reduction for SkyTEM geologies, (b) average nitrate reduction for borehole geologies, (c) standard deviation on nitrate reduction for SkyTEM geologies and (d) standard deviation on nitrate reduction for borehole geologies. The mean values seen on each map correspond to the mean across the area. The locations of streams and riparian lowlands respectively are shown only on some of the maps for graphical reasons, but in reality they are overlapping.

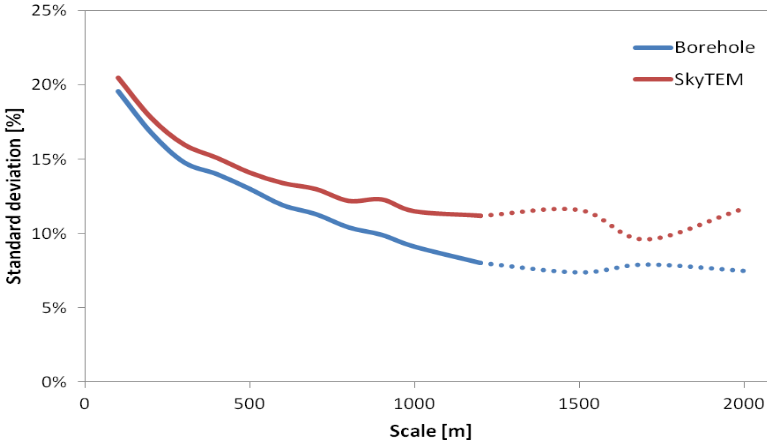

Figure 2 Spatial variation in nitrate reduction level as a function of scale. The spatial variation is calculated as the standard deviation across the average maps for the Borehole and SkyTEM based geologies

3.3. N-retention for the 10 participating farms

The average N-retention and spatial variation for all fields at each of the 10 farms are shown in Table A1 in Appendix A. The variation is calculated both if the information is available on a 100 m scale and if the information was only available as an average value for each of the fields at a farm. The average retention varies from 31% at farm 6 to 77% at farm 10 and is independent of scale. The spatial variation in retention (expressed as one standard deviation) within each farm varies from 14% at farm 3 and 4 to 26% at farm 1, when having the information on a 100 m scale. The spatial variation decreases if the information is only available on field scale and varies from 9% for farm 4 to 21% for farm 1.

4. The economic analysis

The present regulation in Denmark is based on quotas for application, which has meant that the marginal value of N for the applied N is almost the same on most farms. As the applied N quota is set at the economic optimal N-level minus 18%, the marginal value of N is higher than the price of N. Because the quota is set at the farm level, farmers will shift the N application around to the fields with the highest return and in that way reach the economic optimal value per kg N for a given quota. In this case the marginal value of N is the same across all fields. This is the optimal N application from a farm economic perspective.

4.1. Description of the economic analysis

The economic analysis was conducted by SEGES and the Institute of Food and Resource Economics (IFRO) at the University of Copenhagen. The analyses have been made for 10 farms, and as part of the project, farmers were interviewed to get a better understanding of the possible crop rotations on their farm. The selected crop rotation represents what might be possible on the farms, although some plans might have been made based on a one-year horizon and not like an average long run plan. This might overestimate the gains on some of the farms. The scenarios are described in Table 2.

Table 2. Description of scenarios

Scenario		N-loss level
A	Economic optimal N-norms, no catch crops, no targeting	Higher than today
B	Sub-optimal N-norms, evenly divided catch crops	Present level
C	Sub-optimal N-norms and targeted catch crops	Present level
D	Optimal N-norms and targeted catch crops	Present level
E	Sub-optimal N-norms, evenly divided catch crops	-18 %
F	Sub-optimal N-norms, targeted catch crops	-18%
G	Sub-optimal N-norms, targeted catch crops, mini wetlands and early sowing	-18%

In the calculations, it is assumed that measures have a fixed, and not farm dependent, effect on N-losses. The model used assumes that the measures will give a certain amount of N per ha implemented. The effects and the costs of the measures are included in Table A2 the Appendix 2.

Scenario A is based on full N-application and no measures in terms of catch crops etc. are required. The key analysis includes scenario B-D with the current emission level and Scenario E-G with further reductions of 18%. The 18% is selected as a maximum for an additional N-reduction and this level is also used in the pilot project.

At the current N-emission level no new measures are included, but in the scenario with further reductions of 18%, mini wetlands and early sowing were included as an option (Eriksen et al, 2014). In the analysis, mini-wetlands are introduced with a cost of about 12,000 kr. per. ha mini wetland per year (see appendix A). On top of this cost, there is a loss of income from the area taken out of production and this varies from farm to farm. The increased N-norm represents 143 kg N per. ha mini-wetland and 62 kg N per. ha with drains connected to the mini-wetlands. Traditional wetlands provide an increase in N-norm of 263 kg N per. ha wetland. It can be mentioned that the effect is the average effect and is not determined by the effect the mini wetlands have on that particular farm. Thus, it is not certain that there is consistency between norm change and the effect that mini wetlands will actually have on the farm in question.

The 10 farms have an average area of 146 hectares, of which 93 ha are winter crops in Scenario A. The financial result is around 4,200 kr. per. ha, since not all fixed costs are included. The average N emissions on farms are 20 kg N per ha in Scenario A-C and 16 kg N per. Ha in Scenario D-F. It is only the part of the farm's area, which is located in Norsminde catchment, which is included in the calculations.

4.2. Economic returns by targeting in NiCA

In the analysis, the first scenario (A) represents the situation where the farmer can apply the optimal N-application on all fields and there are no requirements regarding catch crops etc. This scenario increases the income by 356 DKK per ha (+8%), compared to the current regulation. The N-losses to the coastal waters increase by 25% from 20 to 25 kg N per ha.

Scenario B is based on the current regulation and includes N-applications under the economic optimum and catch crops. Moving form scenario B to C, the farmer can implement more targeted measures based on the NiCA reduction maps, but the N-loss target for the farm is the same as in scenario B. The analysis shows that almost all farms have fewer but more targeted catch crops (from 10% to 8%) and it leaves room for more winter crops as catch crops are linked to spring crops. This change improves the gross margin by approximately 101 DKK per. ha. Note that the financial gain is calculated as an average for all fields on each farm, although the area where the rotation changes is a minor part of the farm. The results show that three farms have lower than average gains as they cannot utilize this knowledge, whereas one farm has a gain of over 200 DKK per ha.

Moving on to Scenario D, the farmers can now apply optimal N levels together with targeted catch crops and in-between crops (cover crops). It is noted that all farms now use the optimal N-allocation even though it might not be the optimal choice for all farms as no optimization procedure has been applied. The increased N-discharge from higher N applications is countered by an increased proportion of targeted catch crops and in between crops. The proportions of area with catch crops and in-between crops increase from 13% to 21% and the area with winter wheat is reduced. The economic gain from Scenario D compared to Scenario B is now 157 DKK/ha for the 10 farms. Some now have a gain of more than 300 DKK/ha compared to Scenario B, whereas some farms do not increase the income compared to Scenario B. In other words, some farms implement relative expensive measures to allow for a higher N-application and the result is that they do not have a higher income.

Table 4. Average economic results and N-losses for the 10 farms in the Norsminde Fjord catchment for the 3 baseline emission levels with no targeting

Scenario	**A**	**B**	**E**
N-quota (% of present level)	118	100	100
Economic result (Gross Margin) (DKK/ha/year)	4.542	4.186	3.914
Change in Gross margin (DKK/ha/year)	356	0	-272
N-loss to coastal waters (kg N/ha/year)	25	20	16

Target for N-loss (kg N/ha/year)	None	20	17

Source: Own calculations

Table 5. Average economic gain from targeted measures at current N-loss level (20 kg N/ha) on 10 farms in the Norsminde Fjord catchment

Scenario	**B**	**C**	**D**
N-quota (% of present level)	100	100	119
N-loss (kg N/ha/year)	20	20	20
Winter crops (% of area)	64	66	60
Catch crops (% of area)	10	8	16
In between crops (% of area)	3	2	5
Economic result (Gross Margin) (DKK/ha/year)	4.186	4.287	4.343
Change in economic result compared to scenario B (DKK pr. Ha per year)	0	101	157

Source: Own calculations

The economic gain (Scenario C) in relation to the variation in retention is shown in figure 3. It shows that not all farms can/will or are able to use the option of increased targeting. This can, as mentioned, be due to crop rotations or other management issues.

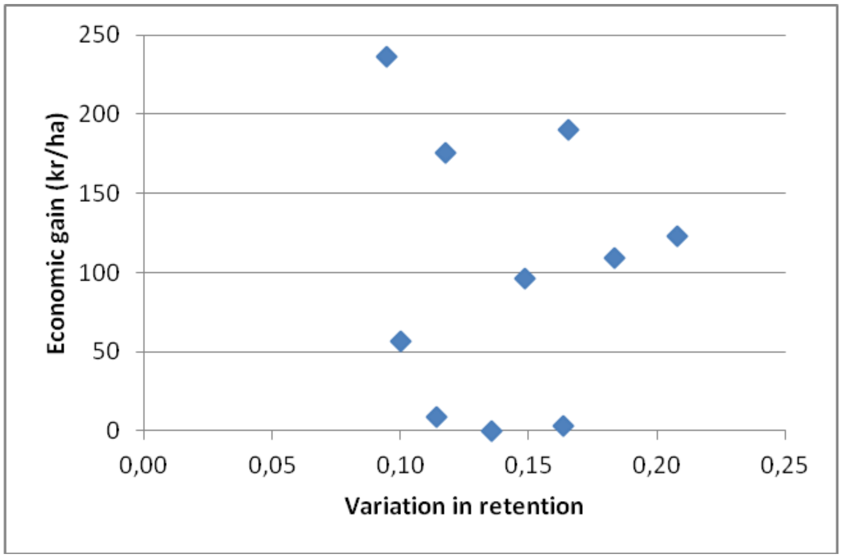

Figure 3 Economic gain from targeting compared to the economic gain in Scenario C.

Source: Own calculations

In Scenario E the N-losses are reduced by 18% compared to the current regulation and this reduces the income by 272 DKK/ha compared to Scenario B. The loss varies from close to zero to almost 700 DKK/ha among the 10 farms.

Table 6. Economic gain from target measures as well as new measures reducing the N-leaching by 18% (target is 16 kg N/ha) for 10 farms in the Norsminde Fjord catchment

Scenario	**E**	**F**	**G**
Nitrogen norm (% of current norm)	100	119	116
N-loss (kg N/ha/year)	16	16	16
Wintercrops (% of area)	53	53	64
Catch crops (% of area)	25	28	18
In between crops (% of area)	11	12	8
Mini wetlands (% of area)	0	0	0,1
Drained area related to mini wetland (% of area)	0	0	17
Wetland re-established (% of area)	0	0	3
Early sowing (% of area)	0	0	13
Economic result (Gross Margin) (DKK/ha/year)	3.914	4.120	4.308
Change in income compared to scenario E (DKK. pr. ha).	0	206	394

Source: Own calculations

Note: Area related to mini wetland represents the drained area where the water flow to the mini wetland area.

In Scenario F, the area with targeted catch crops and in-between crops is around 40%. It may come as a surprise, that the extent of winter crops can be maintained, but it may be because the analysis was conducted using a one-year approach and not in all cases based on an average crop rotation. The economic benefit is approximately 206 DKK per ha, as a result of the targeting. In other words, the targeting has a higher value with higher reduction requirements as the effect from Scenario B to C was 101 DKK per ha.

In Scenario G, the use of mini-wetlands and early sowing is introduced, as it allows for more winter crops, and it increases the financial results further. The extent of catch crops and in between crops in the study is now reduced to 26%. The extent of average mini-wetlands is 0.2 ha. per farm and it collects water from approximately 17% of the total agricultural land in the study. There are three of the farms which do not use mini-wetlands. Furthermore, there are re-established wetlands on 3% of the total area. The approach used in the analysis shows that a mini wetland of 0.2 ha and drainage connected from 4 ha has the same effect as 1 ha traditional wetland.

The gain from targeting and new measures is thus almost 400 kr. per. ha, but it should be noted, that around 150-200 DKK per. ha in this analysis (Scenario G) is obtained by means, that do not directly require knowledge of the individual field retention. However, the detailed mapping would allow for a more detailed calculation of the effect of mini wetlands on that farm. In general, increased reduction requirements will increase abatement costs per. kg N and it will mean that measures outside or almost outside the farmed area (e.g. mini wetlands) will be more attractive.

Furthermore, it is important to be realistic about the area which realistically can be converted to mini wetlands. In this case, the total area converted to mini wetlands is 2 ha on seven farms. The high up take of mini wetlands might be due to a very large plot of land in the north of the catchment area which is drained, which is why the scope of mini-wetlands is expected to be higher than the national average. The analysis also shows that early sowing is a popular instrument. Early sowing is cost neutral in the analysis, but it is estimated that some fields in Denmark will need additional pesticide treatment and the pickling of seeds to avoid reduction of yield (Eriksen et al., 2014). In that case, the costs are higher and early sowing might not be a cost-effective alternative.

5. Discussion and conclusions

Previous analyses in the literature have shown that targeted measures will reduce the total costs in order to achieve the same N-reduction target. The findings suggest that the targeting is both related to the effect of measures (kg N/ha) and the costs per ha of a given measure as neither is uniform across farms. Looking only at the areas where the environmental effect is the largest is, therefore, not always enough as the fields which should be taken out of production might be located in high income areas and this will increase the cost per kg N lost to the environment. Environmental targeting is therefore not always enough. It is clear that the focus has to be on measures related to specific areas, which can be controlled, as e.g. different nitrogen application levels within the farm cannot be controlled. So, if a farmer is given a quota based on the N-loss from the fields it is not likely that he will distribute the nitrogen accordingly as he will look for the highest farm economic gain. Measures like set-a-side or catch crops are in this aspect easier to control than application levels.

Danish analyses of targeting with respect to N at the national level show an economic gain of 20-30% compared to using average N-retention maps at the catchment level. The results indicate lower gains with higher reduction requirements. It is assumed that all the targeted measures can be implemented in the designated areas and it is, hence, a likely overestimation of the likely realistic possibilities. Furthermore, overlap between measures will lead to an overestimation of the effect of the measures.

The NiCA analytical approach has been successful in providing detailed maps of the N-reduction on a more detailed scale. The NiCA analysis has found relatively large spatial variation in the retention both at the plot and field level in the Catchment of Norsminde Fjord. The spatial variation in retention levels for the 10 farms is 9-21% when having the retention information at the field level, and 14-26% when having the information on a 100 x 100 m (1 ha) scale. The NiCA analysis has shown that the smaller the scale of the retention map, the more details and the higher spatial variation in retention levels are gained (figure 1). However, the uncertainty of the retention map increases when going down in scale (figure 2). Thus, these two issues counteract each other.

The NiCA analysis of 10 case farms shows an economic gain from measures targeted at selected fields of around 100 DKK/ha at the current N-loss level and the current N-norms. With an increase in N-application and more targeted crops, the total gain increases to around 150 DKK/ha. The analysis shows that not all farms are able to utilise the effect of targeting. In other words, even though a field has a high N-loss potential the farmer cannot restrict a given crop to this particular field every year in a normal crop rotation. Another option is to use set-a-side for the fields with very high N-losses in order to apply more nitrogen on other fields.

With further N-reductions (18%) the economic gain increases to 200 DKK/ha, when only targeting is used. When increased N-application is combined with new measures, the economic gain is 400 DKK/ha. Roughly half of this gain comes from using new measures such as mini wetlands and early sowing.

Acquiring more detailed maps can be costly. In the NiCA project, it is estimated that the detailed mapping procedure and data handling described cost 40-60 DKK per ha per year, which is lower than the gains. With more detailed regulation might also come an increased cost related to the implementation of new administrative systems, as they would need to be more complex to deal with the site specific regulation and the control of the measures. This is not included in the costs calculated.

It is assumed that larger spatial variation in N-retention at the field level increases the gain from targeted measures. This hypothesis is not supported in the analysis although 10 observations can only give an indication. The increased targeting in this project allows the fields to be selected and it is likely that the effect has a higher certainty than in previous mapping. Together with other projects, (e.g. the Pilot project, MST, 2015), more knowledge about the consequences and the economic gains from targeted measure has been found.

To what extent more knowledge can be used in applying more targeted measures is still an open question. It is likely that the regulatory set up will be more complex and the economic gains might not be large enough to clearly outweigh all the potential costs. Another issue is the farmers which will lose out. The knowledge gained can be used to establish which area could be taken out of production with more certainty than before.

6. Acknowledgement

The Authors would like to acknowledge the support received from The Danish Strategic Research Found for the NiCA research project (www.nitrat.dk). The authors would also like to thank Søren Kolind Hvid, SEGES for material and comments with respect to the economic analyses.

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Table 3. The cost and effect of measures included in the analysis

Measure	N-effect on leaching[2)] (kg N/ha)	Increased N-norm (kg N/ha)	Cost of measure (DKK/ha/year)
Catch crops - Seed - Sowing - Rotation N-effect	31	93	 0 - 290 0 - 220 136 / 200
In between crops - Seed - Sowing - Increased N value	16	48	 160 - 290 140 - 180 0
Set-a-side	48	143	[1)] Change in GM
Riperian zones	48	143	[1)] Change in GM
Energy crops	50	150	
Early sowing of winter wheat	6,2	18,6	0
Constructed mini wetlands	48 for area taken out and 21 kg N/ha drained	143 N/ha (main area) + 62 kg N/ha (drained area)	12,000 DKK
Wetlands	48 for area and 40 kg N/ha for adjacent area	263 kg N/ha	
Increased N application (optimal N application in wheat) +4,5 hkg/ha		29	

Source: MST (2015) (appendix 8)

[1)] Change in Gross Margin II is the change in income minus variable costs and machinery and labour (contractors). It is farm dependent.

[2)] The N-leaching effects have been calculated in N-Les4 by University of Aarhus. As a rule it is assumed that 1/3 of the applied N is lost from the rootzone. So the allowed increase in N-norm is three times the estimated effect on N-leaching.

Table A1. Total average nitrate reduction and spatial variation (standard deviation) for all fields for each of the 10 farms for information of the reduction on 100 m scale and field scale (i.e. only one reduction value is known for each field). The statistics are calculated for the average map based on the SkyTEM based geologies and all 3 redox scenarios. At field scale the size of each field is taking into account when calculating the total average and standard deviation.

	100 m scale		**Field scale**	
Farm	Average [%]	Standard deviation [%]	Average [%]	Standard deviation [%]
1	52	26	52	21
2	44	25	44	17
3	68	14	68	11
4	66	14	66	9
5	67	20	67	14
6	31	20	31	16
7	63	18	63	12
8	51	23	51	18
9	33	20	33	15
10	77	15	77	10