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# *Spatial Analyses of Cost efficient Measures to reduce N-leaching*

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**Abstract**

The Nitrate Directive has only been implemented satisfactorily in a few EU countries. The Commission have accepted the Danish implementation of the directive based on the Plan for the Aquatic Environment II. The costs of this plan has been calculated to 70 million € or 2,0 € per kg N in reduced leaching. The farmers have paid 60% of the costs. The paper then describes an example of a regional analysis covering the River Basin of Ringkøbing Fjord in Denmark, which indicates the type of calculations needed to find the measures and costs in order to comply with parts of the Water Framework Directive (WFD). The analysis shows that the geographical position of the measures are very important in order to achieve the expected nutrient reduction. The current income varies a lot in the River basin and this might influence the choice of cost effective measures to reduce nutrient load. Furthermore a close link between environmental and economic modelling is required to insure the expected improvements for the environment at the expected costs. The paper concludes that finding the most cost efficient combinations of measures to achieve the complex goals for streams, lakes, fjords and groundwater represents a large challenge for researchers and policy makers.

**Key words:** Water Framework Directive, Reducing Nutrient losses, cost effective measures

## 1. Introduction

The environmental regulation has a growing influence on the activities farmers are carrying out across Europe and in the rest of the world. The regulations are getting gradually tighter, but also more complex as they now involve e.g. leaching of nutrients (nitrogen and phosphorus), pesticides, emission of ammonia or Green House Gasses and smell. At the same time, regulations regarding animal welfare and protection of biodiversity in the farmland also affects the farming practices. Sometimes the regulations on one area support reductions in another area, but sometimes the aims are conflicting.

This paper gives a short introduction to the national costs in Denmark of reducing nitrogen leaching following the Aquatic Programme II (section 2). As the future regulation will be more regionally based, the next section concerns the possible implementation of the Water Framework Directive using a regionally oriented analysis from the County of Ringkøbing in Denmark (section 3). The paper finishes with a short discussion of the future challenges with respect to the implementation of the WFD in Europe.

**2. The implementation of the Nitrate Directive in Europe**

Looking at the progress in the 1990'ties, the development in the nitrogen losses to the water system is different in different regions (European Commission, 2002). The overall conclusion is progress, but for some countries the development is mixed.

It is probably only the implementation in Denmark, Sweden, Finland and Austria which today comply fully to the requirements in the Nitrate directive. For the other countries analyses are under way and they might end with an acceptance of the implementation, but the commission have started court procedures against a number of the "old" 15 EU countries.

It is noted that England will increase its area with (Nitrate Vulnerable Zones) NVZ from 8 to 47% of the total agricultural area in England (not the United Kingdom). This increase in the NVZ-area is not expected to cause major changes in the farming practices and the environmental consequences will therefore probably be small. The implementation is not followed by subsidies or compensation (OECD, 2005). With respect to the WFD the focus in the UK is more on phosphorus losses than nitrogen although the nitrate concentration in the groundwater is increasing (RPA, 2003).

The Dutch introduced the MINAS system in 1998 following other strategies to reduce nitrogen losses (Jacobsen, 2002 and OECD, 2005). MINAS is a nutrient surplus accounting system where surplus over a certain level is taxed. The levy free nitrogen surplus has been reduced from 300 kg N pr. ha in 1998 to 140 kg N per ha for grassland on sandy soil over the past 10 years.

Some of the problems with the MINAS system have been high levy-free surplus, exclusion of mineral P as input, low levies, fictive transportation of animal manure (fraud) and many legal battles (Jacobsen, 2002 and OECD, 2005)). In short, the measures implemented from the beginning did not correspond with the change needed, but large progress in the reduction of nutrients has been made over the years. However, the progress has come to late to convince EU of the advantages of the MINAS system (Anonymous, 2005).

Another aspect has been the lack of self control which is an essential part of the Danish fertiliser system. The "self control" comes as farmers selling and buying animal manure have opposite interests, which ensures a market price and inclusion in the fertiliser accounts. In the Netherlands some farmers have levy free surpluses which were so high, that they have had room to "sell" unused N-surpluses to other farmers. This leads to fictive transport of manure in the fertiliser accounts from one part to another part of the country. In these cases, the buyer and the seller have had an interest in hiding the fact that the transportation was only made on paper.

It should be noted that taxation of the Nitrogen surplus, at the farm level, is not considered legally sound in Denmark as the calculation can not be preformed objectively (Jacobsen et al., 2004, see also www.vmp3.dk for more reports in Danish). Therefore, it was suggested that the taxation was carried out at the sector level.

The MINAS system has been abandoned by 1st of January, 2006. (Anonymous, 2005). But even under the new regime there will be mandatory sampling, analyses and weighing of animal manure to ensure which amounts are actually transported.

**2.3. Measures and costs to fulfil the Nitrate directive in Denmark**

The implementation of the Nitrate directive in Denmark through the Action Plan for the Aquatic Environment II (Action Plan II) has been accepted by the EU. The Institute of Food And Resource Economics has carried out the analysis of the costs related to the measures used in this plan. Based on the results from the technical/biological evaluation of Action Plan II, the cost effectiveness of each measure is calculated (Jacobsen, 2004) (se table 1).

The total costs connected to the area related measures (top 4 in table 1) have been 27 million € per year. The expected area in the original plan was almost 300,000 ha, but only 150,000 ha has been achieved, which also have lead to lower costs. The area related measure carries half the costs, but only 16 pct. of the reduction in N-leaching. It should be noted that the area related measures which has benefits which have not been valued, such as lower phosphorus loss, lower pesticide usages and nature diversity.

***TABLE 1. Cost effectiveness for the different measures in Action Plan for the Aquatic Environment II***

| | Reduction in N-leaching | Total cost | Cost effectiveness |
|---|---|---|---|
| | Tonne N | Million €. | € / kg N |
| Wetlands | 800 | 0.7[3)] | 0.9 |
| ESA-areas | 700 | 7.7 | 10.9 |
| Forestry | 800 | 4.7[3)] | 5.9 |
| Organic farming | 3,700 | 14.0 | 3.8 |
| Changed feeding | 3,800 | 5.7 | 1.5 |
| Lower livestock density [1)] | 140 | 1.5 | 10.4 |
| Catch crops (6 pct.) | 3,000 | 6.4 | 2.1 |
| Increased utilisation of N in animal manure (15 pct.) [1)] | 10,110 | 6.7 | 0.7 |
| Reduced N-standards (10 pct.) [1)] | 12,850 | 22.8 | 1.8 |
| **Sum [2)]** | **35,900** | **70.2** | **2.0** |

Comments : 1 € = 7.45 DKK.

1) In the technical evaluation the effect of these measures has not been divided into the effect of each measure, which is why the estimation here is somewhat uncertain.

2) Changes in use of area and animal production as well as other matters are not included in the table.

3) Annuity based on 4 pct. interest and infinite lifetime.

Source: Jacobsen (2004).

One of the most important farm related measures has been the reduction of nitrogen standards by 10 pct. The total costs of a reduction of 10 pct. in N-standards are estimated to 23 million €. The 10 pct. reduction in standard nitrogen norms reduces the yield by 1.0 hkg per ha (barley or wheat) in the short run. The costs are calculated using a sector-model in order to include behavioural response to the N-norm. On top of that there is a long term effect. There is some uncertainty related to assessing the long term effect of lower N application and not covered by many trails. Changes in feeding have reduced the N-leaching more than expected and the costs related to the implementation are limited.

All in all, the cheapest measures are wetlands, better utilisation of N in animal manure and changes in feeding. The ESA-schemes (Environmental Sensitive Schemes) and lower density on

animal farms are among the most expensive when the cost is related only to the reduction in N-leaching. The area-related measures have not achieved the expected aim, mainly due to the lower area. On the other hand the reduction in N-leaching due to the farm related measures have achieved the expected level and on top of this comes the additional measures (structural changes and other changes), which ensure that the total aim of N-leaching has been achieved. The total cost is 70 million € and the cost effectiveness is 2.0 € pr. kg N in reduced leaching.

**3. Regional analyses to improve water quality**

The Water Framework Directive (WFD) (2000/60/EF) will guide most of the actions and regulations related to losses of nutrients in Europe in the coming years. The reason is that the aim of the directive is broader than previous directives as e.g. The Nitrate Directive as both groundwater and surface water are included. Another reason is the ambitious target that all waterbodies should achieve the state of Good Ecological Status, i.e. allowing only a slight deviation from a reference situation without human activity. For countries or regions with intensive farming like Denmark, The Netherlands etc. it will be hard to obtain good ecological status.

Compared to the Nitrate Directive, the WFD is far more focused on the environmental indicators in the rivers, streams, lakes and fjords – and less on the amount of nitrogen applied per ha. WFD is also linked to other directives such as the Habitat directive and The Groundwater Directive. The regional aspect will be more important than in the Nitrate directive. From an economic viewpoint, the interesting element in the WFD is the extended use of cost efficiency when choosing which measures to implement. In article 4 there is a possibility for member states to accept lower targets if the costs associated with the required measures on a given location are disproportional with the effect. It seems likely that derogations following article 4 require cost-benefit analyses. There is therefore a need for analyses which looks closely at the costs and the effect for each measure at a given location. The following section describes how regional analyses could be carried out using the River Basin for the Fjord of Ringkøbing as an example. The analyses represent the type of analyses required regarding inlets, i.e. larger water catchment areas, however less relevant with respect to streams, lakes or groundwater.

**3.1. Introduction to the Ringkøbing Fjord River Basin**

Ringkøbing County is situated on the western part of Jutland in Denmark. The County has contemplated what was needed to fulfil the requirements included in WRD. It is expected that a visibility in the Fjord of approx. 2 meters is required. To complicate matters even more, it is not just a question of a reduction in nutrients, but also a question of which salt content is preferred. The conclusion is that the current high-salt concentration strategy is not acceptable, although it has been easier to achieve the environmental goals set by the county with a high salt concentration. When the salt level is an issue, it is because it is possible via a lock to get seawater into the Fjord (Abildtrup et al., 2004).

The river basin covers an area of 347,700 ha of which 211,000 ha (61%) is agricultural land. The animal production constitutes 210,000 Livestock Units (LU), where one unit represent the production of 100 kg N (ab storage). One LU is 0,85 of a large dairy cow.

With a low-salt concentration strategy there is a need to reduce the nitrogen losses to the Fjord by another 20 % or 35 % on top of the 15% which is expected from measures already implemented in Action Plan II (se above).

***Table 2. Scenarios and aim for the River Basin of Ringkøbing Fjord***

| Scenario | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Salt concentration<br>N-reduction | 6-8 ‰<br>15% | 6-8 ‰<br>35% | 6-8 ‰<br>>50% | 8-15 ‰<br>15% |
| New aim for visibility (meters) | 1,3 | 1,5 | 2,0 | >2,0 |
| Reduction I N-losses to the Fjord (tonne N) | 870 | 2,030 | 2,790 | 870 |
| N-losses to the Fjord (tonne N) | 4,930 | 3,770 | < 3,010 | 4,930 |
| Measures | | Wet lands<br>Catch crops<br>Lower N application | Wet lands<br>Catch crops<br>Lower N application<br>Reducing livestock | |

Source : Abildtrup et al., 2004
Comment : The loss was 5,800 tonne N in 2001 and the aim for visibility in the fjord was 2 meters.

### 3.2. Environmental and economic setup

Danish Institute of Agricultural Sciences (DIAS) and Danish Hydraulic Institute (DHI) have estimated the Nitrogen loss pattern in the county. According to this, it has been possible to find the areas where nitrogen lost from fields have a large likelihood of reaching the Fjord and others where this is not the case. To further describe the area, maps showing both the livestock intensity and the income have been calculated. This will help to find the most cost efficient areas to take land out of production. The most expensive would be the ones where the current income is high and where none/little of the nitrogen which is leached actually reach the fjord.

In order to estimate the expected land rent, a land rent model was used. The farm land rent model is a static regression model based on the 10,000 accounts collected in the period 1996-2001 (FOI, 2004). In the specification of the model, knowledge of area, soil type, livestock intensity (own and surrounding area) and region are included. A total of eight farm types have been selected (se table 3) and a land rent was estimated for each type,

***Table 3. Farm types, main type of enterprise and dominating crops***

| Farm type | Main enterprise | Definitions |
|---|---|---|
| Ok | Organic farming (dairy) | Receive subsidy for organic farming |
| Ara | Arable farming | All remaining farms |
| Spe | Special crops | >10% vegetables or > 16 % off sugar, clover, seed, |

| | | |
|---|---|---|
| | | potatoes. |
| Seed | Special crops | > 16 % clover og grass seeds |
| Sugar | Special crops | > 16 %. sugar beet |
| Potato | Special crops –arable and pigs | > 16 % potatoes |
| Dairy1 | Dairy | > 16 % forage crops (grass, maize etc.) |
| Dairy2 | Dairy | > 60 % forage crops (grass, maize etc.) |

Source : Jacobsen et al., 2004

**3.3. Land rent**

The land rent is the net profit left for the land (se table 4). The net profit is the gross margin minus all costs, including capital costs (except costs of land). When estimating the farm capital only knowledge of the total assets are included in the accounts. Therefore, estimates of the land capital for each farm have been made. Furthermore, the livestock intensity on the farm, as well as in the municipality where the farm is situated, has been calculated and included in the model.

The aim of the model is to describe the land rent based on a range of farm specific factors mentioned above. The model is estimated for each of the 8 farm types above and for each municipality. The model is estimated in SAS/PROC GLM and in using the model an R^2 of 68,9 pct. was achieved. Only parameters which were significant (>99% or >99,9%) were included in the model. As part of the yearly variation in income is due to management, it is found to be satisfactory to be able to explain 69 pct. of the variation in the land rent. The model framework is possible to use throughout Denmark.

As an example the land rent for a farm without special crops in Funen can be found using the following model.

(1.) Land Rent = -211.519 + 43.006 Part
+ 5.315 Area + 8 $Area^2$
+ 1.842 Jb59 -1.037 Jb99 + 1.152 JbVv
- 1.254 LU-C - 2.279 LU-O + 4 $LU\text{-}O^2$
- 2.808 HaFree –10 $HaFree^2$ - 4.666 HaFree LALI
+ 9 $HaFree^2$ LALI + 3.375 HaFree $LALI^2$

Where

Part = Parttime or fulltime

Area = total area cropped
JB59 = Area on clay soil
JB99 = Humus soil
JBVV= Area with permanent pasture
LU-C = Livestock units cattle
LU-O = Livestock units other
HaFree = area free to be used for livestock manure
LALI = Local area livestock intensity

Each farm has a geographical reference which allows the land rent valued to be placed on a map. As seen on figure 4.1. and 4.2, there is some correlation in some areas between livestock intensity and marginal land rent. Some of the areas where potatoes are grown (the north east of the river

basin) also have a high land rent. The analyses also show that the marginal land rent per livestock unit is low in livestock intensive areas. The explanation is that the increasing transportation costs etc. reduces the marginal gain per livestock unit.

***Table 4. Calculation of land rent***

| |
|---|
| Gross margin I |
| - Variable costs |
| Gross margin II |
| - depreciation and interest on buildings and machinery |
| - interest on livestock capital |
| - estimated cost for unpaid labour (family) |
| **Land rent** |

Source : Own description based on FOI Accounting statistics

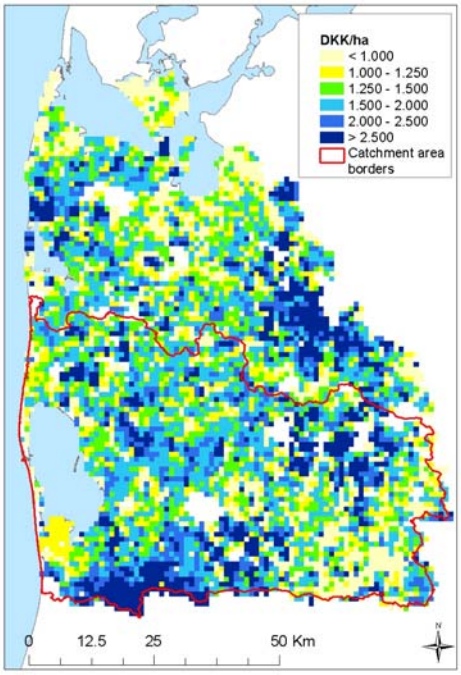


**Figure 1. Marginal land rent (DKK/ha)**
Source: Abildtrup et al. 2004
Note: 1 € = 7,46 DKK

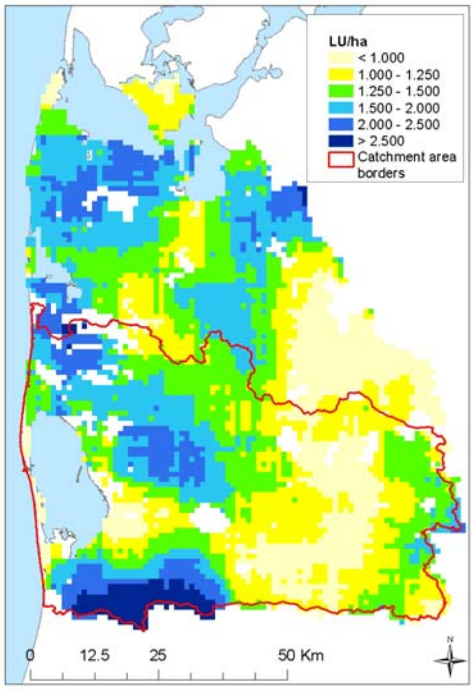


**Figure 2. Livestock intensity per ha (LU/ha)**
Source: Abildtrup et al. 2004
Note: 1 DE = 1 LU = 100 kg N (ab storage)

### 3.4. Measures and Costs

For each measure in table 2 the costs and the environmental effects have been estimated. For wetlands this include the loss of income for all the participating farms. It is assumed that the livestock will be moved to other parts of the area leaving the livestock numbers unchanged. The calculations therefore include both changes in income on the project area as well as the change in income where the livestock are reallocated to. We found significant differences in the cost of converting agricultural land to wetlands using our model. The costs were, in particular, dependent on the local livestock density.

For catch crops analyses based on other models have shown increasing costs as the share of catch crops at the farm level increases. The cost also varies with farm type.

Of the original 4 scenarios only scenario 2 and 3 were analysed closer, as scenario 4 is no longer an option as the County Council wants to reduce the salt content in the Fjord. Furthermore, scenario 1 does not reach the environmental aim, leaving only scenario 2 or 3 as the real options. In table 5, the cost for the primary sector as well as costs in associated industries, both up – and down are shown. Also the effect of employment have been forecasted based on input and output tables for Ringkøbing County. The analyses show that it will be expensive to reach the environmental goals in scenario 3, which is the likely aim under the Water Framework Directive. The calculations have been carried out for the county, which is the reason why the costs for state are not described in detail. The expected cost for the farms in scenario 3 is 6 million € due to high cost of reducing the livestock, i.e. 208 € per livestock unit by which the production is reduced. Based on this analyses the county is now looking for other measures aiming at an reduction somewhere in between scenario 2 and 3, which does not include a reduction in the numbers of livestock.

***Table 5. Yearly costs and effects on employment***

| | **Measures** | | | | **Scenario 2** | **Scenario 3** |
|---|---|---|---|---|---|---|
| | Wetlands | Catch crops | N-reduction | Reduction in livestock | 20% N-reduction | 35% N-reduction |
| Area (ha) | 4.185 | 5.900 | 8.300 | | | |
| Livestock units (LU) | | | | 29.000 | | |
| Costs for sector and county (1000 €.) | 335 | 160 | 0 | 5,880 | 495 | 6,375 |
| - of which for sector (1000 €) | 0 | 160 | 0 | 5,880 | 160 | 6,040 |
| - of which for county (with national funds) (1000 €) | 335 | 0 | 0 | 0 | 335 | 335 |
| Cost for county with no national funds (1000 €.) | 2,306 | 0 | 1,450 | 0 | 3,756 | 3,756 |
| Reduction in value for other sectors (1000 €) | 1,340 | 0 | 2,680 | 40,200 | 4,020 | 44,220 |
| **Employment effect (numbers full time)** | | | | | | |
| Total effect | 50 | 0 | 70 | 1.030 | 120 | 1.150 |
| - in primary farming | 30 | 0 | 40 | 550 | 70 | 620 |
| - in other sectors | 20 | 0 | 30 | 480 | 50 | 530 |

**Source :** Ablidtrup et al. 2004.

## 4. Discussion

The implementation of the Water Framework Directive will change farming in many livestock intensive regions in Europe if the environmental targets are to be met. In Denmark most of the streams comply with the Directive, but most lakes and Fjords do not. To comply with the WFD a 10 pct. reduction in agricultural land is not unlikely. Preliminary results from Germany, the Netherlands and the United Kingdom seem to indicate that many tough measures will have to be implemented to reach the targets. The WFD covers all water and the task of finding the most cost efficient combinations of measures to achieve the goals for streams, lakes, fjords and groundwater

will clearly be a challenge. Just finding cost efficient plans for fjords as Ringkøbing Fjord is difficult. More focus and effort on the economic analyses seems to be required as they are a central part of WFD. The conclusion is also, that in order to get derogations from WFD, well founded cost-benefit analyses will have to be performed. Achieving compliance with WFD in 2015 seems unrealistic for some countries and the Danish experiences is clearly that it takes time from measures are implemented to the aim in the water body is achieved.

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