Fact sheet: The TargetEconN framework – a cost-minimization model for Nitrogen management

Summary

The TargetEconN model is an integrated economic and biophysical social planner model which minimizes the costs of meeting a nutrient load reduction target in a specific water body. The model is calibrated for the watershed to the Danish Fjord Limfjorden. The optimization routine enables calculation of the optimal spatial location of nitrogen (N) abatement measures, taking into account the spatial differences in costs and the potential of implementing the different measures at field parcel level, as well as the nitrogen leakage reduction effects. Furthermore, the model includes nitrogen retention estimated for each sub-watershed representing the attenuation of N in ground- and surface water. The model hereby prescribes the spatial location, as well as the scale of each measure, to achieve the most cost-effective solutions. The model results are therefore suitable for comparison with the results from implementation of different economic incentives as e.g. nitrogen quotas, to see how well the economic incentive fits to the social optimum distribution of nitrogen abatement measures.

Main characteristics of the TargetEconN framework

General aspects:

- Model Architecture: The model minimizes costs from reaching a total nitrogen reduction target in a water body. The problem is solved as a mixed integer problem modelled in GAMS 24.3 using CPLEX 12 as solver. Data exists for all watersheds in Denmark and the analysis can therefore be extended to cover whole Denmark. However, as the N reduction goals are defined per water body, the model optimizes per water body in separate solutions.

- Model input (fig. 1): Field parcel level input for each of 12 different nitrogen abatement measure on spatial potential in hectares, effect in kg N/ha and costs in DKK/ha. Retention is given in percentage and available at sub-watershed level.

- Model output: Spatial distribution of the nitrogen reduction measures across the watershed, area used for implementation of measures, total costs and cost-efficiency.

The TargtEconN model

The optimization problem (eq. 1) minimises total costs, V, from reaching an N reduction target, T (eq. 2).

$\min_{x_{ik}} V = \sum_{i=1}^{I}\sum_{k=1}^{K} COST_{ik}(x_{ik})$, where $x_{ik} \in \{0,1\}$. (eq. 1)

The objective function $COST_{ik}$, calculates the costs of implementing abatement measures, $k \in \{1,2,\ldots,K\}$, at the field parcels, $i \in \{1,2,\ldots,I\}$. The control variable x_{ik} is binary and represents the choice of abatement measure *k* at field parcel *i.*

$\sum_{i=1}^{I}\left((1-RET_S)\sum_{k\in ks} E_{ik}POT_{ik}x_{ik} + (1-RET_T)\sum_{k\in kt} E_{ik}POT_{ik}x_{ik}\right) \geq T$ (eq. 2)

The total nitrogen reduction required, T, in the targeted main water body consists of the effect from the nitrogen abatement measures, E, implemented at a specified area, POT, taking retention, RET, into account.

Each field parcel in the watershed is characterised by a total retention, RET_T, which can be divided into groundwater retention and surface water retention. For some abatement measures we assume that there is no groundwater retention, but only surface water retention, RET_S. *ks* is the group of abatement measures where retention only include surface water retention, while *kt* denotes the rest of the abatement measures, where total retention is used.

The model is restricted to implement one measure only per field parcel (eq. 3).

$\sum_{k=1}^{K} x_{ik} \leq 1 \quad \forall i \in \{1,2,\ldots,I\}$. (eq. 3)

Data

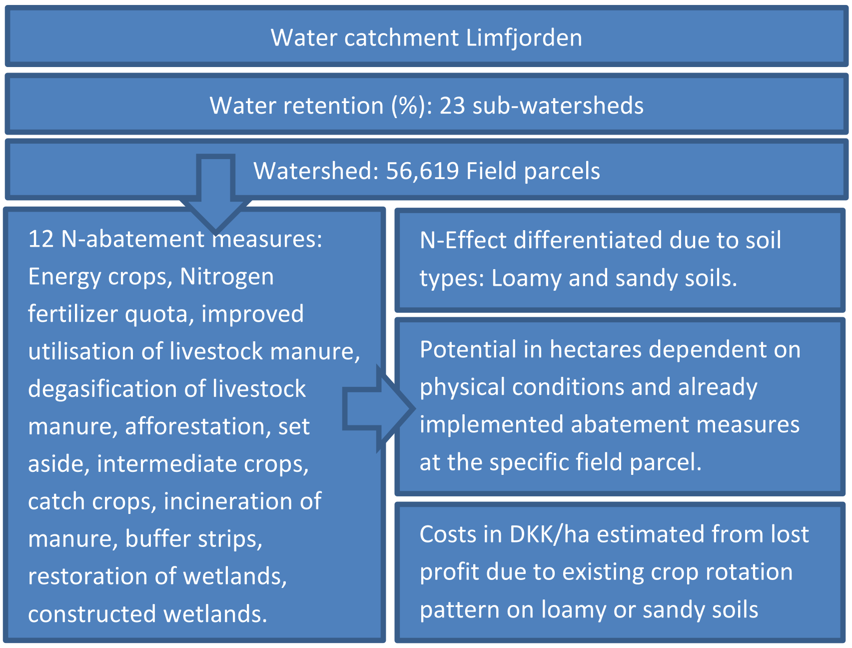

Figure 1: Data input

Current model limitations:
The model does not take the impact on effect from implemented upstream measures into account.

The problem is solved as an integer problem, entailing that only one measure can be implemented at the same field parcel. This is due to lack of data, as the data used do not include cross-effects between measures i.e. the effect from implementing different measures in different spatial location at the same field parcel or in coordination at same spatial location within the same field parcel.

Results

Running the model to reach the Water Framework Directive (WFD) specified reduction target for the Limfjorden water body at 4,165 ton N gives rise to an average cost-effectiveness at 52 DKK/kg N. (table 1). The model has been run to compare targeted regulation to an uniform regulation defined by an nitrogen quota implemented at all field parcels. Implementing a 10% reduction in nitrogen quotas across the whole watershed, reduces N losses with in total 810 tonnes/year at an average cost of 58 DKK/kg N. Meeting this N reduction target on 810 tonnes using the cost-minimization approach, allowing all N abatement measures to come into use, reduces the average costs significantly (table 1) to 13 DKK/kg N.

The spatial configuration of the model allows for mapping the results. The distribution of the annual costs when reaching an N reduction target of 4,165 ton for the Limfjorden catchment (fig. 2), shows the effect of taking retention, costs and soil

	Targeted regulation	Targeted regulation	Quota
N-target	4,165	810	810
Average costs, DKK/kg N	52	13	58
Total costs, m DKK/year	218	10	47
Regulated area, 1000 hectares	189	41	462

Table 1: Comparing targeted regulation to a uniform quota

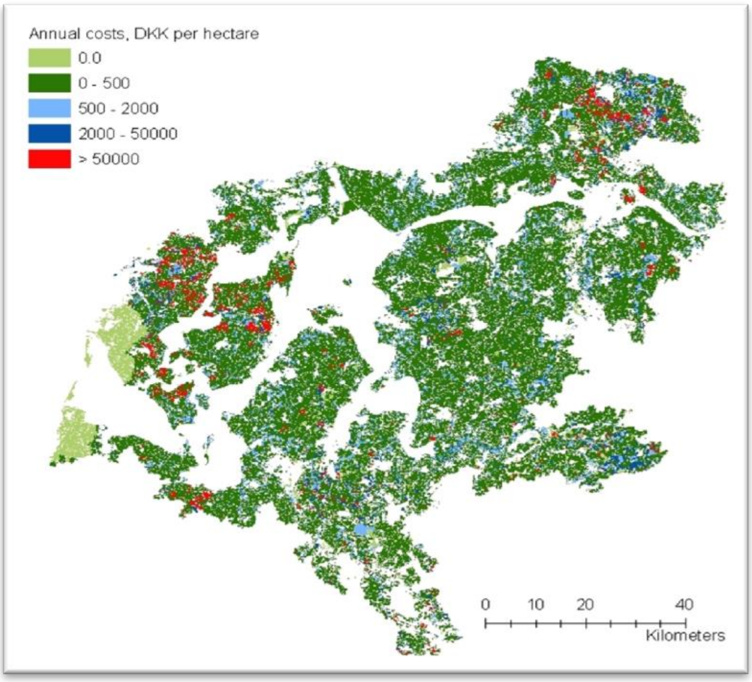

Figure 2: Targeted regulation, fulfilling a 4,165 ton target

Policy recommendations

The model results illustrates that spatial cost-minimization modelling integrating biophysical and economic data can be useful to model cost-effective choice of measures to reduce non-point agricultural pollution. The results clearly indicate that there are large differences in the cost-effectiveness of implementing uniform and targeted regulation, and that targeted regulation can be used to distribute the abatement effort and reduce abatement costs. Applying spatial models can be used as guidance for elucidating the optimal solutions for use in a targeted regulation.

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