IMPACT AND COST-EFFICIENCY OF ALTERNATIVE POLICY MEASURES TO REDUCE DIFFUSE POLLUTION CAUSED BY AGRICULTURE

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Abstract

Nutrient loading of waterbodies today is primarily attributed to agriculture. Objective of the article on hand is to quantify impact and cost-efficiency of actually discussed policy measures to reduce nitrogen field balances in reference of agricultural area applying the Regional Agricultural and Environmental Information System for the Federal Republic of Germany (RAUMIS). Modelling results for target year 2010 show that under unaltered conditions and due to decoupling of direct payments to farmers in respect of nitrogen surplus no articulate changes can be anticipated. A constraint of livestock density noticeably mitigates the balances in regions showing high surpluses in the initial situation, but produces high costs in refinement regions. A tax on mineral nitrogen reduces the sectoral surpluses significantly, but does not affect the output of manure. With respect to scientifically based policy advice aiming at a firm integration of water pollution control into the Common Agricultural Policy (CAP) of the European Communities (EC) it has to be stated that further research activities are indispensable.

Keywords: agriculture, cost-efficiency, nitrogen field balance, policy impact analyses, sector modelling

INTRODUCTION

In economically developed countries, nutrient loading of waterbodies today is primarily attributed to excessive mineral and organic fertilizing of agricultural area by farmers. For this reason - in connection with the aim to further reduce the nutrient concentration in watercourses - various quarters demand a firm integration of water pollution control into the EC´s CAP - targeting to bring down nutrient field balance surpluses being considered to be suitable “pressure indicators” for eutrophication to an appropriate level. In order to operationalise this entitlement scientifically-based, cost-benefit analyses of alternative policy measures have to be available. Indeed, there is a lack of suchlike analyses tracing back to the fact that neither costs nor – exceptionally - benefits of alternative measures have been quantified adequately.

It is the objective of the article on hand to partially close the above mentioned gap by quantifying nutrient field balance reduction costs due to alternative policy measures applying the Regional Agricultural and Environmental Information System for the Federal Republic of Germany (RAUMIS). For that purpose the following questions shall be processed:

- *What is the methodical design of RAUMIS?*

Besides a general presentation of the model system mainly the applied method of nitrogen balancing on county level shall be described.

- *What would be the impacts of alternative nitrogen reduction measures in target year 2010 in comparison to a reference scenario basing on updated Agenda 2000 policies?*

On the basis of the Agenda 2000 policy agricultural nitrogen surplus values projected by RAUMIS for target year 2010 do not change significantly in comparison to the status quo situation in 1999. The same holds after an introduction of the reform proposals of the EU Commission (COM) within the framework of the Agenda 2000 Midterm Review (MTR) (Kreins et al., 2002). Hence, further nutrient reduction measures actually discussed will be analysed, namely a federal wide consistently reimbursed tax on mineral fertilizer of 100 respectively 200 per cent, a constraint on livestock density of 1.5 respectively 1.0 livestock units (LU) per hectare agricultural area and a general nutrient surplus restriction subject to regional varying livestock density. In reference to the latter measure, the following restrictions of maximal permitted nitrogen surplus per hectare agricultural area will be formulated:

- maximum 40 kg N/ha in regions with 0 till < 0,5 LUs per ha
- maximum 60 kg N/ha in regions with 0,5 till < 1,5 LUs per ha
- maximum 80 kg N/ha in regions with 1,5 and more LUs per ha

Calculated reduction potentials will be compared with agricultural income losses associated with the implementation of a specific measure. In a final step the costs of decreasing balance surplus per hectare agricultural area can be computed in EURO per kilogramme nitrogen.

- *How do the modelling results have to be disposed?*

In this section the results shall be discussed against the background of their usability in policy advice. Closing, conclusions shall be drawn.

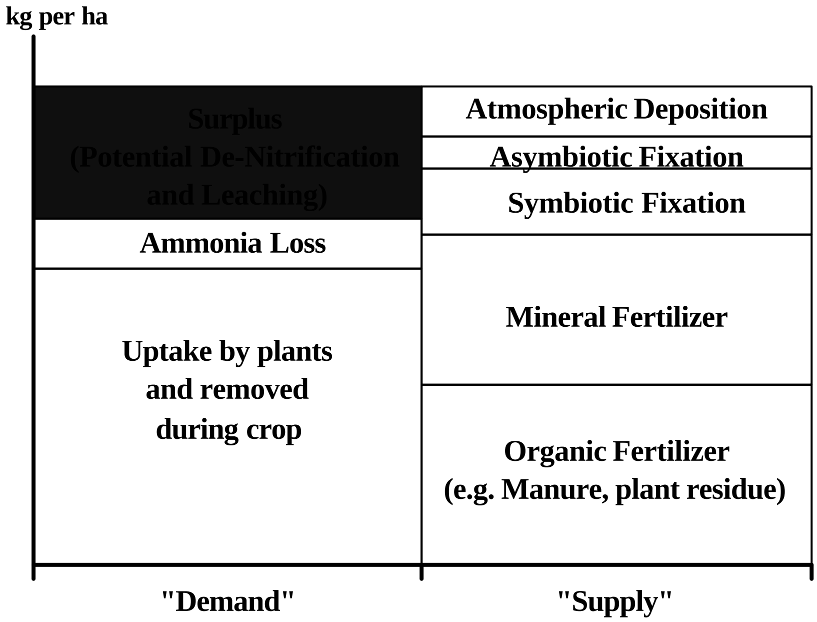

Figure 1 Structure and Elements of the Nitrogen Balance (source FAA- Description & Layout)

METHODS

The Regional Agricultural and Environmental Information System RAUMIS is designed for a continuous usage in the scope of long-term agricultural and environmental policy impact analyses and aims to support policy-makers in policy decision processes. During the last years the model has been extensively used for policy impact analyses carried out for the German Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL). Impacts of alternative policies being analysed are in particular the development of agricultural production, inputs, and the net agricultural value added as well as the resulting changes in environmental risk factors such as nitrogen surplus. A detailed description of general model design and functions is given in Henrichsmeyer et al. (1996). The concept of balancing nitrogen in RAUMIS as shown in Figure 1 follows the field principle (Strotmann, 1992) where the soil surface represents the system border. The primary demand for nitrogen bases on the nutrient uptake of plants that are removed from soil during the harvest. A further reduction of nitrogen occurs as a loss of ammonia (NH_4) during storage and application. Important inputs of nitrogen are organic and mineral fertilizer. Other sources are symbiotic and asymbiotic nitrogen-fixation, as well as atmospheric deposition. A nitrogen surplus results from the comparison of demand and supply and is displayed as quantity unit per acreage (kg per ha) on the regional level. This spill-over is regarded as a risk indicator because this amount is potentially available for de-nitrification and leaching into water bodies.

The listed positions of the nitrogen balance are calculated by the activity-based framework in RAUMIS. In order to obtain regional input and output positions, activity-specific coefficients are multiplied with the level of each activity e.g. area harvested or livestock. Nutritional requirements for each crop production activity and region are based on expected crop-specific yields as well as soil and climate conditions. Nitrogen use of individual crop production activities is calculated by linear yield-dependent requirement functions. The loss of ammonia during storage and application is adapted from the assumption that 40 % of the nitrogen in manure inaccessible to plants is converted into ammonia during storage and application.

The nitrogen supply from manure is derived from nitrogen contents in the excrements of farm animals. RAUMIS differentiates between four processes of manure and its application i.e. dung and liquid manure from cattle, hogs and poultry. Coefficients about the nutrient content in manure as well as the utilization factors of plants are taken from the literature and are provided by experts of the BMVEL also. Presumably, these coefficients are neither static over time nor identical between regions especially regarding (bio)technological progress and regional differences in feeding practices. However, due to missing information average sectoral parameters are assumed temporally and spatially constant in RAUMIS except for cows. The regional nitrogen content in cowshed manure is calculated subject to the share of green fodder. Following the concept that nitrogen from manure can replace nitrogen from mineral fertilizer, mineral fertilizer equivalents for manure are calculated based on different plant nitrogen utilization factors of dung and liquid manure from cattle, hogs and poultry. Arisen organic fertilizer is not imputed by 100 % to calculated demand, because firstly not 100 % of total amount are available for plants and secondly farmers practically do not impute 100 % by themselves. The application of organic manure in plant production is associated with unavoidable nutrient losses. These losses are being accounted for in the mineral fertilizer equivalent for organic fertiliser assumed in RAUMIS. The mineral fertilizer equivalent for dung is constantly 25% which implies that four kg of nitrogen from dung substitute one kg of nitrogen from mineral fertilizer. The coefficients for liquid manure regionally vary between 16 to 25% for cattle, 20 to 30% for hogs, and 26 to 39% for poultry.

Because of high transport costs it is assumed that organic fertilizer remains in the region and substitutes mineral fertilizer in crop production subject to regional rates and thresholds of substitution. A regional excess demand for nitrogen in plant cultivation is equalized by using mineral fertilizer in a way that the derived aggregated mineral fertilizer demand matches the amount of national fertilizer sales from the national agricultural accounts for the base years. The positions asymbiotic nitrogen fixation and nitrogen entry from the atmosphere are included as lump sum amounts, namely 30 kg per hectare for atmospheric entry and 1.4 kg per hectare for asymbiotic nitrogen fixation. Calculations for symbiotic nitrogen fixation are based on expert information and depend on the levels of pulses, clover and alfalfa.

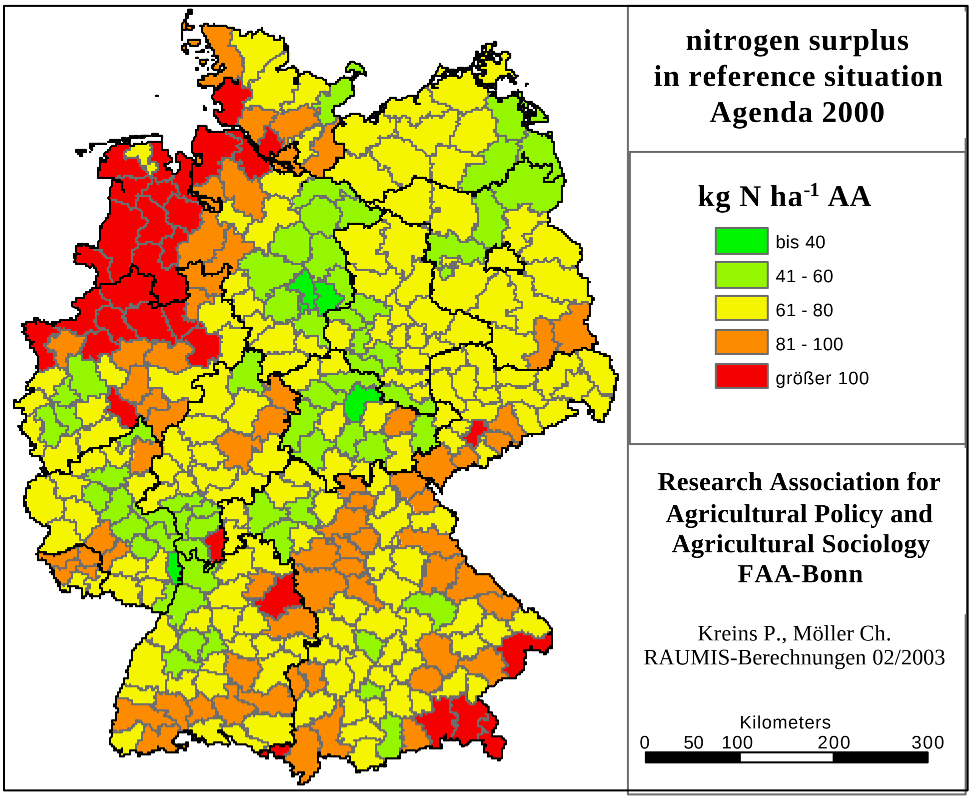

Figure 2 Nitrogen balance surplus in reference situation «Agenda 2000 » in target year 2010 in kg N/ha AA (Source: RAUMIS calculation, FAA-Bonn.)

RESULTS AND DISCUSSION

Results for nitrogen field balance surplus

Under the assumed circumstances of reference scenario till 2010 – an updated Agenda 2000 - the average German nitrogen balance will hardly change and can be calculated at 77 kg N per ha agri-cultural area (Figure 2, Table 1). An entirely decoupling of direct payments and animal bounties of production does not have any significant effects on N - balance on the whole agricultural area. Restricting livestock concentration at 1.5 LU per ha agricultural area (1.0 LU per ha) induces little decrease of N – balance to 74 kg N per ha (70 kg N per ha) on national level, though this instrument – as well as the nitrogen surplus restriction scenario - takes purposeful effect in regions showing high livestock concentration and N - surpluses in the initial situation (Figure 3, Figure 4). In Vechta, the area with the highest N – balance in reference situation, the N – surplus will decline from 219 to, in fact, 81 kg N per ha agricultural area due to surplus restriction scenario. The examined tax on mineral fertilizer results in a higher reduction of average surplus on sectoral level though this intervention is only weakly correlated with the environmental problem. Thus, at regional scale this instrument induces only insuffcient effects in problematic regions which are characterized by high livestock density. Sure N-balance decreases due to nitrogen tax of 100 per cent for example in Vechta by 24 kg N per ha agricultural land – on the other hand the N-balance drops by 17 kg N per ha in Bergheim which is exemplary for a favourable crop farming region located in the "Köln-Aachener Bucht". The remaining stress potential in Vechta indeed still amounts to more than seven times as much opposed to Bergheim in the reference situation 2010. Contrary to surpluses in the regions Vechta and Bergheim, nitrogen values in typical grassland region Daun – located in low mountain range Eifel – are affected to a much lesser extent by the examined measures.

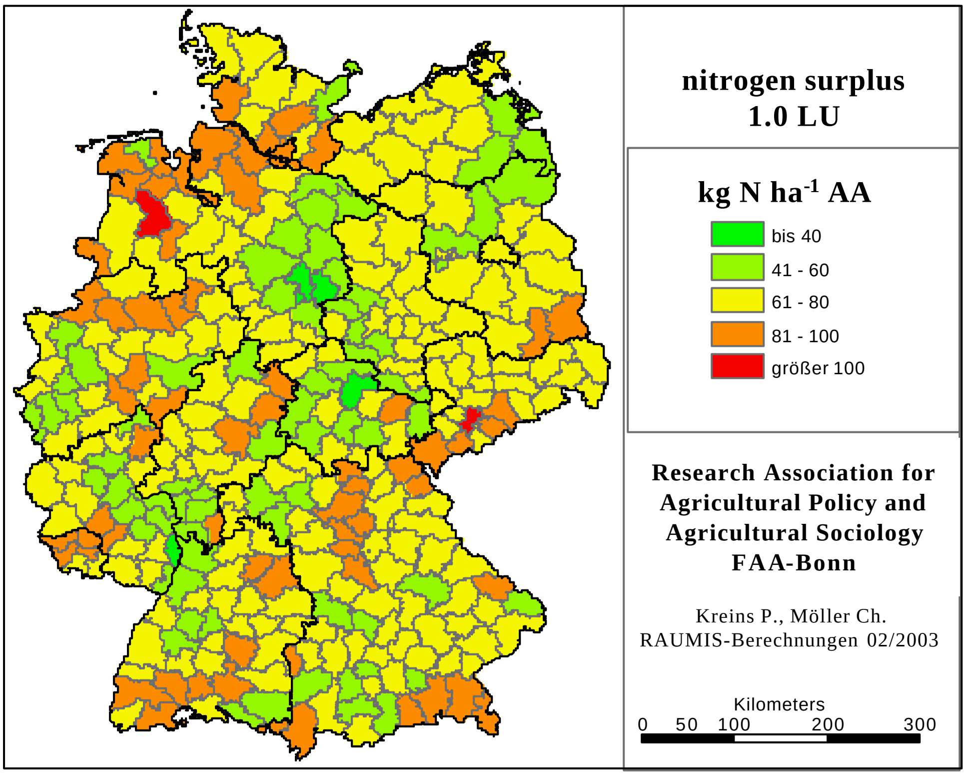

Figure 3 „Scenario 1.0 LU/ha 2010“: Nitrogen balance surplus in kg N/ha AA (source RAUMIS calculations FAA)

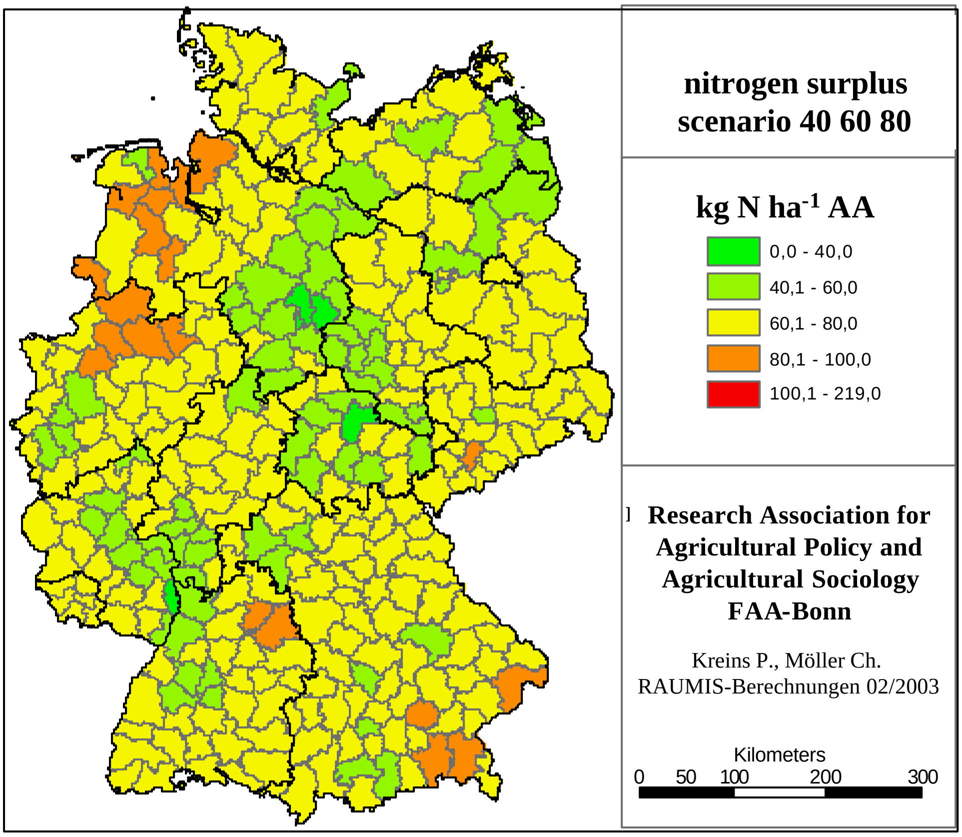

Figure 4 "Scenario 40 60 80 in 2010": Nitrogen balance surplus in kg N/ha AA (source RAUMIS calculations FAA)

Table 1: Nitrogen balance of the German agricultural sector and three selected regions in 2010 (in kg N per ha agricultural area)

	2010						
	Refe-rence	Decoup.	max. LU		N-tax		Surplus Red.
			1 GV	1,5 GV	100 %	200 %	40-60-80
Germany							
Supply of mineral fertilizer	116	112	116	117	91	69	110
Supply of organical fertilizer	79	77	63	73	79	79	64
Other N-supply	35	37	35	35	36	37	35
Supply overall	230	226	214	225	206	185	209
N – demand	129	125	126	129	123	114	123
Loss of Ammonia	24	23	18	22	22	24	20
N – balance	77	78	70	74	61	47	66
N - surplus in three selected regions							
Vechta (Livestock farming)	219	220	95	112	135	176	81
Bergheim (Crop farming)	43	45	43	43	26	13	43
Daun (Grassland)	68	63	68	68	60	56	66

Source: RAUMIS-Calculations, FAA Bonn, 2003.

Results for costs

Effects due to different scenarios on agricultural income as measured by changes of Net Agricultural Value Added (NAV) opposed to the reference scenario vary considerably. The constraint of livestock density reduces NAV on sectoral level by one per cent (Table 2). Indeed, the decline of income only affects a part of farms. In the refinement region of Vechta the agricultural income decreases by 46 per cent (LU 1.0) respectively 42 per cent (1.5 LU). However, by far the highest deficit appears in case of the surplus restriction scenario (-55 per cent). The examined nitrogen tax is - without consideration of transaction costs - budget neutral, but results in income losses for german agriculture up to 2 (100 % tax) respectively 5 per cent (200 % tax) whereas arable farming regions like Bergheim are mostly concerned.

Referring to the overall reduction of nitrogen surplus of 48 respectively 126 kt nitrogen on 16,5 Million ha due to the constraint of livestock concentration in sectoral average the decrease of agricultural income – measured by NAV at factor costs – amounts to 2.0 respectively 1.2 € per reduced kg nitrogen. Hereby a long term announced introduction of the constraint is assumed so farmers have the possibility to attune their investment planning adequately. In other respects the average income reduction – measured by Gross Added Value (GAV) at factor costs – is a multiple higher (9.4 respectively 8.0 € per reduced kg nitrogen). In intensive livestock farming regions like Vechta agricultural income declines at average 8.2 € (NAV) respectively 14.3 € (GAV) per kg nitrogen surplus reduction.

The introduction of a tax on mineral fertilizer (100/200%) results in a 276 respectively 497 kt lower nitrogen surplus in Germany whereas sectoral NAV decreases by 0.8 respectively 1.2 € per kg nitrogen on average. This contemplation does not include transaction costs accumulating for implementation and control.

CONCLUSIONS

As mentioned above, the modelsystem RAUMIS was developed as an instrument in the field of policy advice. Against this background, the question becomes evident how to achieve a reasonable disposal of modelling results in the range of agri-environmental consulting. Here shall be refered to considerations enclosed within the Introduction where it already was suggested additional specific information-bricks – stated as the following questions - are relevant:

- Which nitrogen concentrations in single waterbodies are exactly desired by society, i.e. which nitrogen concentrations entail the greatest (quantitative) benefits?
- By means of which modalities can the desired state indicators "nitrogen concentrations in waterbodies" be transformed into the correspondent pressure indicators "nitrogen field balances" according to natural coherences depending on site-related factors?

Answering these questions is necessary in respect of defining adequate policy measures basing on balanced cost-benefit relations.

It becomes clear, that the attained modelling results only attend a fragment of the information requirements. Consequentially, solely on its foundation a scientifically based recommendation cannot approve a bunch of measures but has to strongly allude to the existing deficits in literature in terms of area-wide information concerning quantified benefits of water pollution control as well as the relationship between nitrogen field balances and nitrogen concentration in connected waterbodies. A firm integration of water pollution control into agricultural policy demands further research activities.

Table 2: Change of agricultural income (NAV) due to the examined measures of water pollution control in Germany and in three selected regions in 2010

	Bill. €	**Percental change vis-a-vis reference**					
	Re-ference	Decoup.	max. LU		N – tax		Surplus Res.
			1 LU	1,5 LU	100 %	200 %	40-60-80
Germany	11,481	-3	-1	-1	-2	-5	-2
Vechta (Refinement)	0,130	-	-46	-42	+1	+1	-55
Bergheim (Arable farming)	0,048	- 1	-	-	-7	-13	-
Daun (Grassland)	0,012	+4	-1	-1	+2	-1	-
Change of agricultural income in €/kg N reduction vis-a-vis reference							
Germany 1)	-	-	-1,2	-2,0	-0,8	-1,2	-1,3
Vechta (Livestock farming) 1)	-	-	-7,7	-8,2	+0,9	+0,4	-8,3
Bergheim (Arable farming)	-	-	-	-	-2,5	-3,1	-
Daun (Grassland)	-	-	-	-	+0,9	-0,4	-

Note: 1) Several reasons for the fact that the calculated average costs per kg N reduction due to a constraint at one LU per ha are lower than due to a constraint at 1.5 LU per ha can be accounted. One reason is that not the N surplus per ha is restricted but the density of livestock. Another reason is that complex adjustment reactions within one region respectively different adjustments within the regions can lead to a more cost - efficient reduction per kg N surplus.
Source: RAUMIS-Calculations, FAA Bonn, 2003.

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