Agricultural costs for reducing nitrogen surpluses in the Weser river basin

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ABSTRACT

Agriculture is to a large part responsible for nitrate leaching into groundwater and rivers in Germany, especially in highly intensive agricultural regions. To evaluate the link between nitrogen surpluses from agriculture and nutrient leaching into ground- and surface waters, a model network to analyse current and future nitrogen surplus developments and water quality is set up by connecting hydrological and hydrogeological models with the German agricultural sector model RAUMIS. A set of different environmental measures and their costs is selected to fulfil surface and groundwater targets of the European water framework directive (WFD) for the case of the Weser River basin. Results show that with additional agri-environmental measures covering around 1 million hectares agriculturally used land with total costs of 100 million Euros the objectives of the WFD could be achieved until 2015. Sensitivity analysis allows a better valuation of the range of the costs. The costs and volumes are compared to regional farming characteristics and subsidies. Results show that costs of additional environmental measures would take up 5% of current direct payments to farmers. The work represents an interdisciplinary area wide modelling approach to evaluate agricultural input and measures together with an approach to quantify costs to achieve environmental objectives of the WFD.

Keywords: diffuse pollution / agricultural economic and hydrological modelling / cost of nutrient reduction measures / Weser river basin

1. Introduction and problem statement

Hydro-economic modelling approaches gain in importance to model the complexity and the raising number of actors in water management. Up to now, however, only a few approaches were capable of realistically analyse water management problems and have been used in decision making processes, as it is difficult to represent different actors, different scales and social and physical interaction and processes at a time (Heinz et al. 2007). The application of a hydro-economic modelling approach nevertheless can help to address some of these challenges. Especially behind the recent background of the Water Framework Directive (WFD) it is of utterly importance to provide quantitative analysis as a basis for decision making processes. The European Water Framework Directive[1] was established in 2000 with the objective to achieve a good ecological and chemical status of all surface water and a good quantitative and chemical status of all groundwater bodies in Europe until the year 2015. Now, in 2010, some studies reveal that this goal is very hard or unlikely to be achieved until 2015 but already rather speculate on year 2021 and 2027, which are the auxiliary dates set by the EU and regulated in the WFD.

[1] Directive 200/60/EC of the European Parliament and of the council of 23 October 2000 establishing a framework for Community action in the field of water policy

Since the focus of European policies on water management issues increased i.e. with the nitrogen directive (Directive 91/676/EEC), the groundwater directive (Groundwater regulation 2006/118/EWG), and with the Water Framework Directive (Directive 200/60/EC) more research has been conducted to evaluate the effects of policies on the reduction of nitrogen surpluses on economic impacts such as farm income or costs associated with the implementation of nitrogen reduction measures. Early studies of water quality management include e.g. an analysis by Schleich et al (1996) who use a linear programming model to analyse different costs for reducing phosphorus reduction and discuss area wide or hot spot approaches with respect to cost-efficiency; or an analysis by van der Veeren and Tol (2001) who evaluate the nitrate emission reductions with cost-effective allocation of measures for the Rhine River.

Since the implementation of the WFD studies about its potential effects and necessary measures have recently increased in Europe due to the urgency to provide measurement plans to fulfil the objectives of good quality of ground- and surface water bodies in Europe. The WFD also promotes the economic analysis of water management such as valuation of water resources, cost recovery and polluter pays principle, economic methods and economic instruments for water management (Morris 2004).

A specific focus on the agricultural costs of water pollution and effective measures and their cost in the scope of the WFD have been analysed by Fezzi et al. (2008) and Fezzi et al. (2010) and by Bateman et al. (2006).

Fezzi et al. (2008) evaluate four nitrogen reduction measures in the UK using data available from the Farm Business Survey. This work is extended by Fezzi et al. (2010) to allow a regionalisation of costs with the help of regression analysis. Bateman et al. (2006) use an interdisciplinary modelling network including Geographical Information Systems and the interaction of economic and hydrologic models to analyse agricultural land use and water pollution in England.

Moss (2004) discusses governance structures and policy implications for the implementation of the WFD in Germany. He points out that Germany is a special case where water management is traditionally organised in administrative structures rather than in river basin units and thus providing a challenge for analysing water management on the spatial scale.

In this paper a case study for the Weser river basin in Germany shall be presented with the aim to estimate and value the effects and the probability to actually achieve a good water quality status for the WFD (Kreins et al. 2010). A hydro-economic modelling approach is used to assess first, the development of nutrient intakes by agriculture, and then elaborate the necessary reduction loads of nitrogen by agriculture to be able to achieve the targets of the WFD by 2015. We select eight possible measures for nitrogen reduction that have been described in literature according to their costs and impact and that are classified as appropriate and have a high rate of acceptance among farmers to evaluate the necessary area and the cost to achieve the necessary nitrogen reduction loads for the Weser River basin specifically. We built on the work by Kreins et al. (2010) but extent the work by analysing minimum and maximum values of costs and impacts to be able to show a more comprehensive picture of the scope of the costs of measures. We finally compare the costs with other payments farmers receive from the European Union. Finally, we discuss the regionalisation of costs for one measure, the expansion of extensive grassland production using simulations of the agricultural sector model. We end with conclusions and future research options.

2. **Methods**

For the analysis in this paper we use a model network that was established within the AGRUM Weser project (Kreins et al., 2010) to create a program of measures to prevent diffuse nutrient leaching from agriculture in the Weser River Basin. We built upon the work by Kreins et al. (2010) but extent the work by analysing minimum and maximum values to be able to show a more comprehensive picture of the scope of the costs of its measures. In the following section the model network is briefly described. We start with the agricultural sector model RAUMIS, then briefly present the two hydrological models included in the network, the GROWA/WEKU model and the MONERIS model and describe the interactions and the coupling of the three models for the analysis.

AGRICULTURAL SECTOR MODEL

For agricultural economic simulations and projections the Regionalised Agricultural and Environmental Information System RAUMIS (Henrichsmeyer et al. 1996; Gömann et al. 2004, 2005) is applied. RAUMIS aims at analysing medium and long-term agricultural and environmental policy impacts. The model consolidates various agricultural data sources with the national agricultural accounts as a framework of consistency. It comprises more than 40 agricultural products, 40 inputs with

exogenously determined prices, and reflects the whole German agricultural sector with its sector linkages. According to data availability, the spatial differentiation bases on a modified NUTS III level presenting single “region farms” as administrative bodies, i.e. 326 regions (NUTS III level).
The methodological concept of the modelling system RAUMIS is an activity based non-linear programming approach, which is medium term oriented in forecasting. The model is able to cover the entire agricultural sector according to the definition of the Economic Accounts of Agriculture and is consequently consistent to the agricultural sector.
Adjustments caused by changes in general conditions e.g. agricultural policies are determined using a positive mathematical programming approach (Howitt, 1995; Cypris, 2000) with the following non-linear objective function for each region:

$$\max_x \quad \Pi = \sum_i z_i(x_i)\, x_i \qquad \text{s.t.} \quad b_i \geq \sum_i a_i x_i \tag{1}$$

The objective function is a regional agricultural profit (Π) function maximizing the product of per unit margins z_i between the price and the costs of the *ith* netput and the level of each netput x_i. The objective function is non-linear since z_i‘s are functions of their realized netput level x_i. The problem is solved subject to a set of technical, political and economic constraints ($b_i \geq \sum_i a_i x_i$), e.g. land availability, set-aside obligations etc. and proceeds in two stages. In the first stage, optimal variable input coefficients per hectare or animal are determined. In the second stage, profit maximizing cropping patterns and animal herds are determined simultaneously with a cost minimizing feed and fertilizer mix.

In RAUMIS a set of agri-environmental indicators is linked to agricultural production. Currently, the model comprises indicators such as fertilizer surplus (nitrogen, phosphorus and potassium), pesticides expenditures, a biodiversity index, and indicators for greenhouse gas emissions. These indicators help to evaluate direct and indirect environmental impacts of policy driven changes in agricultural production. Regarding diffuse water pollution the indicator “nitrogen surplus” is of particular importance.
The nitrogen balance in RAUMIS follows PARCOM-guidelines (PARCOM, 1993) where the soil surface represents the system border. The long-term nitrogen balance averaged over several vegetation periods is calculated following the methodology developed by Bach et al. (1997). In order to satisfy nutritional demands of plants nitrogen is supplied by mineral fertilizer. Further exogenous sources are symbiotic and asymbiotic nitrogen-fixation, as well as atmospheric deposition. An endogenous fertilizer source is the nitrogen content in manure that is applied in plant production. Coefficients representing nutrient contents in manure, as well as utilization factors of plants, are taken from the literature and are also provided by experts of the Federal Ministry of Food, Agriculture and Consumer Protection. A loss of ammonia during manure storage and application is assumed at 40%.
The primary demand for nitrogen is based on the nutrient uptake of plants that are removed from the soil during the harvest. As a rule, regional balances of nitrogen supplies and extractions result in a positive figure. The 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 units. Nutrient requirements for each crop and region are based on expected crop-specific yields as well as soil and climate conditions and are calculated by linear yield-dependent requirement functions.
The nitrogen surplus represents a risk potential since it indicates the amount of nitrogen potentially leaching into ground and surface water. Starting from these agricultural nitrogen surpluses, hydrological modelling is required in order to get closer to the problem of diffuse water pollution, i.e., charges into water bodies.
Various factors drive the future development in agriculture and thus determine nutrient surpluses in the future and the need for action in the field of diffuse water pollution. In order to evaluate further regional policies (e.g. agri-environmental measures) aiming at a reduction of diffuse pollution, the first step is to analyse the impacts of expected developments of the driving factors on nutrient surpluses. Using the model RAUMIS a baseline is projected until the year 2015 which is a milestone for the implementation process of the WFD. Important driving factors are developments of political framework conditions such as the Common Agricultural policy (CAP), prices of agricultural products, and “conventional” measures to reduce nutrient surpluses. Some elements are the decoupling of product specific direct payments e.g. livestock and area premiums and the coupling of payments subject to the compliance of existing production standards (“cross compliance”). The existing obligatory set-aside was phased out from 2007

onwards and was cancelled with the decisions on the Health-Check in 2009. Furthermore, the price support based market regimes of sugar and milk were changed and integrated into a system of direct payments to producers. The regulations on the milk market as well as the decoupling of livestock premiums are of importance for the nitrogen surpluses until 2015, because they induce a further decline of livestock herds.

Since 2006 the amendment of manure regulation became effective which regulates the “good farming practise” with respect to the application of manure, soil additives, culture substrates and pesticides on agriculturally used land. One requirement is the preparation of annual nutrient comparison on the basis of the field- stable balance of nitrogen. This balance is not allowed to exceed 60 kg per hectare and year of nitrogen from 2009 onwards taking stable, storage and output losses into account and is assumed in this paper to be complied by all farmers.

Since 2000 agri-environmental measures belong to the support of rural development and help achieve environmental objectives. Some of these measures are directly related to the protection of water bodies and already help to reduce nitrogen surpluses in the baseline. The promotion of renewable energies has lead to a boom of energy maize as the most favoured crop and thus contributes to increases in nitrogen surpluses. Table 1 summarizes the most important assumptions for the baseline in 2015 used in the AGRUM Weser project.

Table 1: Baseline assumptions for 2015

	Status quo 2003	**Baseline 2015**
Fertilizer Regulation	Not implemented yet	As implemented in 2006 maximum nitrogen surplus of 60 kg N per ha
Agri-environmental programmes	Period 2000 until 2006	Planned measures from 2006 until 2013
Direct payments	Coupled payments for specific activities	Decoupled payments
Obligatory set-aside	Obligatory	Not obligatory
Market regulation for milk and sugar	Price support	Reduction of price support and partly decoupled
Promotion of renewable energies	Premiums for energy plant	New promotion of energy plants of 23 Euros per ton
World prices	As observed	Increasing prices for agricultural products and inputs
Technical progress		Increase in technical performance

HYDROLOGICAL MODELS

The nitrogen surpluses that are calculated by the agricultural sector model RAUMIS are decisive input parameters for the hydrological models. Two different hydrological approaches are used: the GROWA/WEKU modelling system (Wendland et al., 2002; 2004; Kunkel and Wendland, 1997; 2002) for nitrogen inputs into groundwater; and the MONERIS model (Behrendt et al., 2003) for nitrogen inputs into surface water. The use of these models within the AGRUM Weser project for the analysis of the necessary reduction loads of nitrogen by agriculture have been described in detail by Kreins et al. (2010), Wendland et al. (2010) and Hirt et al. (2008). In short, the hydrological models enable a determination of regionally differentiated nitrogen loads into groundwater and surface waters on a high solution scale, whereas the GROWA/WEKU model uses a 100x100 m raster solution and the MONERIS model works with sub-catchments of river basins for spatial resolution (approximately 1,400 analytical units in the present study) on an annual basis. For the calculation of necessary nitrogen reduction loads, first the nitrogen surpluses of RAUMIS are introduced to calculate the nutrient concentrations for the baseline 2015. Then in a second step a backward calculation is made introducing the concentration targets of the WFD into the models as goal variables and evaluating the necessary nitrogen reduction load to meet these targets.

COUPLING OF MODELS

The structure of the model network as well as the interaction of the models is a key issue in interdisciplinary modelling approaches as an adjustment of the different spatial resolutions, i.e., administrative units in RAUMIS on the one hand and grids/raster cells in GROWA/WEKU or (sub) river basins in MONERIS on the other hand has to be made. In a first step the spatial allocation of nitrogen surpluses was disaggregated from the RAUMIS "region farm" level (NUTS III) to community level (NUTS IV). This was done with data available for the baseyear 2003 on NUTS IV level which is used to downscale the nitrogen surpluses in the baseline in 2015 from NUTS III to NUTS IV level. This has substantially reduced the aggregation error. In particular, the spatial allocation of agricultural land use and agricultural nutrient surpluses within region farms that are key data inputs from RAUMIS to the models GROWA/WEKU and MONERIS has thus been improved. In a second step, a prototype of a spatial allocation module is further developed. The module distributes observed agricultural land use, in particular crop shares and farming intensity, from administrative units to homogenous hydrological response units. GIS supported model interfaces improve the exchange of data, parameters and results between the models.

The process of adjusting the spatial resolution of the models is supported by remote sensing information. Commonly used remote sensing data with classification into arable, grassland and forest was available for the entire Weser river basin. Due to the high spatial resolution of the model network, agricultural nutrient reduction measures can also be depicted and analysed at the sub-regional level.

DETERMINATION OF MEASURES

In the final step, the necessary measures and their associated costs are determined depending on the necessary reduction load of nitrogen to achieve the objectives of the WFD for groundwater and surface waters.

In literature various measures are discussed that are generally capable to reduce diffuse nutrient leaching by agriculture. Within a comprehensive literature survey (Osterburg and Runge, 2007) the ecological impacts and the capability of technical and organisational water protection measures were recorded for several criteria. It does not reflect the individual costs of a measure on farms, but rather represent average values. For this study eight measures of agricultural water protection are selected that are well accepted among farmers (compare Table 2). The selected measures feature substantial differences with regard to their impact on water quality and related costs as can be seen with the minimum and maximum impact or the minimum and maximum costs of applying the measures.

Table 2: Selected agri-environmental measures for water quality protection

Measure:	**Impact on N surplus (kg N/hectares)**	**(Min-Max)**	**Costs (€/hectares)**	**(Min-Max)**
No application of organic fertilizer after harvest	30	(20-40)	20	(10-30)
Intertillage	20	(0-40)	80	40-110
Groundwater protective application of dung	25	(10-40)	25	15-35
Extensive grassland production	30	(10-60)	100	80-150
Promotion of extensive farming	40	(20-60)	70	50-150
Reduced mineral fertilizer in cereal production	30	(20-40)	80	50-300
Cultivation of turnip rape	10	(0-20)	60	-
Organic farming	60	(30-120)	170	80-200

Source: Selection was made on the data provided by OSTERBURG AND RUNGE, 2007

The calculation of additional measures to meet the required regional reduction demand proceeds in two steps:

1. Regionally differentiated maximum reduction potentials of each measure are estimated depending on the specification and requirements of each measure. For example, the measure “intertillage” is only applicable after cereal or oilseed production.
2. The maximum potential of nutrient reduction was compared to the reduction demand to achieve the WFD targets. Afterwards the level of each measure was determined so that each measure contributes comparably according to its potential to the required nutrient reduction.

From the measures in Table 2 organic farming has been left out at first, because its extension cannot be easily realized, and because even if organic farms received higher incomes during the last years than conventional farms conventional farmers are still reluctant in Germany to transform their production. Solely in regions where the full application of measures is not sufficient, an extension of organic farming was considered to achieve the water management targets.
Depending on land use and cropping patterns in 2015 based on the RAUMIS baseline results, the amount of measures that could possibly be applied on the area in each county is determined. Depending on the individual impact on nitrogen surplus of each measure a combination of the eight measures is selected for each county specifically. We then apply sensitivity analysis to better validate model results.

3. Results

Results of nitrogen surpluses in 2003 and expected surpluses in 2015

In the Weser River Basin similar effects of the reduction on nitrogen surpluses are expected as on German average during the coming years due to impacts of the policies and expected developments of prices and yields as described with the assumptions of the baseline above. The average N-surplus (without atmospheric decomposition) declines from 70 kg N per ha agriculturally used area (UAA) by around 9 kg per ha UAA. An overview of the regional developments of N-surpluses in the river basin Weser on the basis of the baseline projection is depicted in Figure 1.

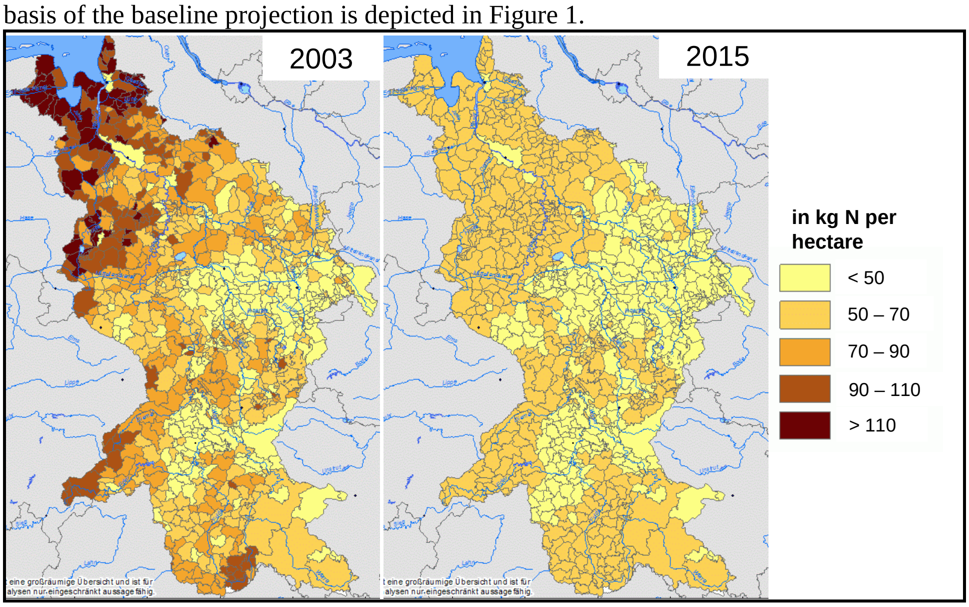

Figure 1: Nitrogen surpluses in the base year 2003 (left) and in the baseline scenario 2015 (right) (kg N/hectare UAA without atmospheric deposition); Kreins et al. 2010.

For the analysis of possible impacts of the nitrogen intake into groundwater in the baseline scenario of 2015, the N-surpluses from agriculture calculated by RAUMIS as well as the atmospheric deposition of nitrogen were input quantities for the models GROWA/WEKU and MONERIS. To be able to directly compare the nitrogen intakes calculated for 2003 and 2015 respectively, all model parameters of the hydrological models have been kept constant. This is mainly related to climate parameters that drive the water balance (precipitation and potential evaporation) and to a regional distribution of land use. Thus, the nitrogen concentration in the leachate could be calculated on the basis of long-term hydrological means.

With the implementation of the nitrogen surpluses of the baseline scenario a reduction of 40 mg NO_3 per litre to 30 mg NO_3 per litre on average is calculated for the Weser river basin from 2003 to 2015. However, model results also show that a lot of regions will still face nitrogen concentration of over 50 mg NO_3 per litre in 2015. In the South and East areas of the Weser river basin that are dominated by agriculture the reduction of nitrogen concentration generally amounts 10 to 25 mg NO_3 per litre. A reduction of 50 mg NO_3 per litre and more is noticeable in areas characterized by intensive livestock farming in the Western part of the Weser river basin.

As expected the reduction of nitrogen intake into groundwater is especially noticeable in regions where groundwater recharge and run-off is the dominant flow component. For this reason reduced nitrogen intakes can be found especially in the North of the river basin, generally in the range of 10 to 25 kg N per ha and year.

The nitrogen intakes into surface water bodies in 2015 are about 75.700 t/a taking into account the above described changes of the baseline scenario and are thus reduced by 17 % in 2015 in contrast to the situation in 2003.

Necessary nitrogen reduction loads for meeting the WFD

The projected nitrogen surpluses and nitrogen leaching in the baseline scenario have been evaluated with respect to the management objectives for achieving the good status of water bodies according to Article 4 of the WFD. The management objective for good ecological status of groundwater bodies is set to 50 mg/l of nitrogen in groundwater (groundwater regulation 2006/118/EWG). For surface water bodies the preliminary objective is 3 mg N/l at the gauge of Hemelingen (close to Bremen) for the Weser river basin considering coastal protection.

The potential “hot spot” regions as well as the necessary need for action for additional measures to meet the objectives are simulated with the models GROWA/WEKU and MONERIS. As an appropriate approximation the objective of 50 mg NO_3 per litre in groundwater is assigned to an average long-term nitrate concentration of 50 mg per litre in the leachate which is reflected in the models. With this procedure it can be assured that the value for groundwater is below the target value due to further denitrification processes or the target value is at least met.

The potential nitrate concentration in the leachate is calculated area wide for long-term averages based on the nitrogen surplus level of 2003 and quantified for expected N surpluses for 2015 from the baseline scenario, respectively. In order to achieve the target values for groundwater the maximum nitrogen surpluses are determined by applying a backward calculation under the assumption of a constant average leachate rate and a constant denitrification potential of the soil. These maximum N-surpluses lead to regional nitrate concentrations in the leachate not exceeding 50 mg per litre in the year 2015 considering atmospheric N Deposition, N inputs of non-agriculturally used areas and denitrification processes of the soil. The required nitrogen reduction can then be derived by comparing the maximum values with the calculated N surplus in 2015.

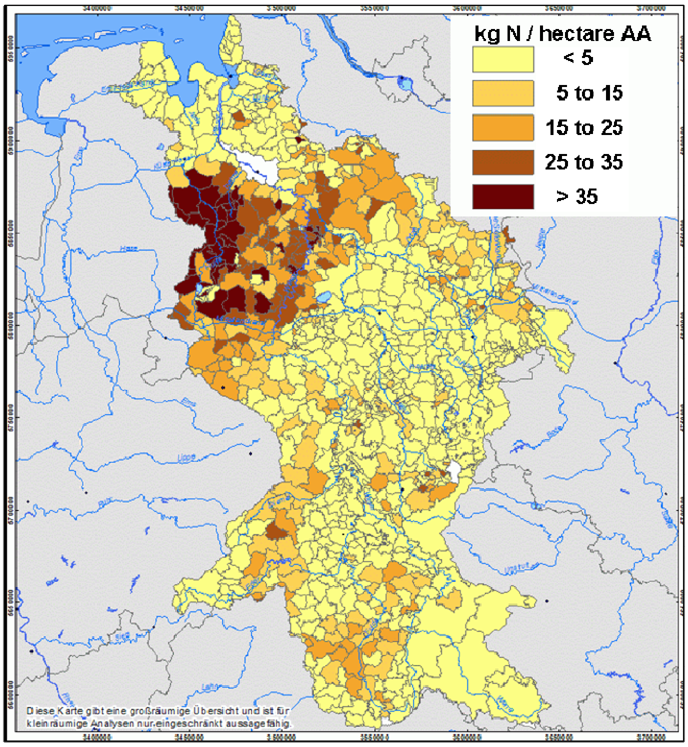

Figure 2: Required reduction of N-surpluses to achieve a nitrate concentration of 50 mg/litre for groundwater (kg N/hectare UAA; baseline scenario 2015).

Figure 2 displays the nitrogen reduction demands on NUTS IV level for groundwater only for the case that the management objective of 50 mg NO_3 per litre is transferred to each grid cell. As the WFD requires actions for the entire water body and not only for single agriculturally used grid cells, average values over all agriculturally used grid cells are taken for the presentation of reduction demands. It is obvious that taking into account this compensation effect between agricultural used areas yet lead to a decrease of the reduction demand. For the entire Weser river basin this yields a nitrogen reduction demand of 23,000 tonnes per year. This is equal to an average nitrogen surplus reduction of 19 % whereby the reduction might be regionally very different.

Cost analysis of possible agri-environmental measures

Finally the measures are determined that result in exactly the necessary reduction load described above. Table § shows the average results for the Weser river basin and the results of the sensitivity analysis of the impacts and costs of agri-environmental measures calculating measures with the maximum or minimum impact or cost respectively.

In the calculation first, the levels of measures to fulfil ground water targets have been determined, than the additional amount to also fulfil the surface water targets have been added. Table 3 shows the sum of all measures to meet groundwater and surface water targets. In total a measure combination that amounts to about 1.4 million hectares are necessary that would require a funding of about one hundred million Euros. Obviously the results are varying depending on the range of the minimum and maximum impacts and costs per hectares. Thus depending on the actual impact on each measure the total area with necessary measures can vary from 900,000 hectares to 2 Million hectares. Costs vary between 55 million to 162 million Euros respectively. Annex 1 shows the results of varying costs for each measure respectively.

Table 3: Areas and total costs for selected agri-environmental measures (Minimum and Maximum areas and costs by varying the possible impacts on N surplus as in Table 1)

Measure:	Total Area in Weser basin ('000 hectares)	(min-max)	Total costs in Weser basin ('000 Euros)	(min-max)
No application of organic fertilizer after harvest	106	81-113	1,587	1,215- 1,688
Intertillage	445	307-624	35,637	24,558-49,925
Groundwater protective application of dung	125	85-175	3,740	2,551- 5,240
Extensive grassland production	105	72-143	1,418	796- 2,988
Promotion of extensive farming	106	69-163	7,443	4,843- 11,434
Reduced mineral fertilizer in cereal production	209	145-292	16,734	11,564-23,400
Cultivation of turnip rape	179	123-250	10,730	7,407-15,009
Organic farming	99	10-304	16,753	1,716-51,758
Total	1,374	893- 2,064	94,042	54,650- 161,442

Source: Own calculation

A comparison with other subsidies for agriculture shows that farmers in the Weser river basin receive around 1.5 billion Euros of direct payments. Comparing this to the costs of 100 million Euros of agricultural measures to achieve a good groundwater status, this is just 5 percent from the direct payments. However, the share of cost for measures to direct payments is varying a lot between the different counties of the Weser river basin. Figure 3 displays the share of direct payments to calculated costs on the NUTS II regional scale. The shares vary greatly with some counties even reach shares of cost to direct payments of up to 40 percent, especially in the Western party of the Weser River Basin.

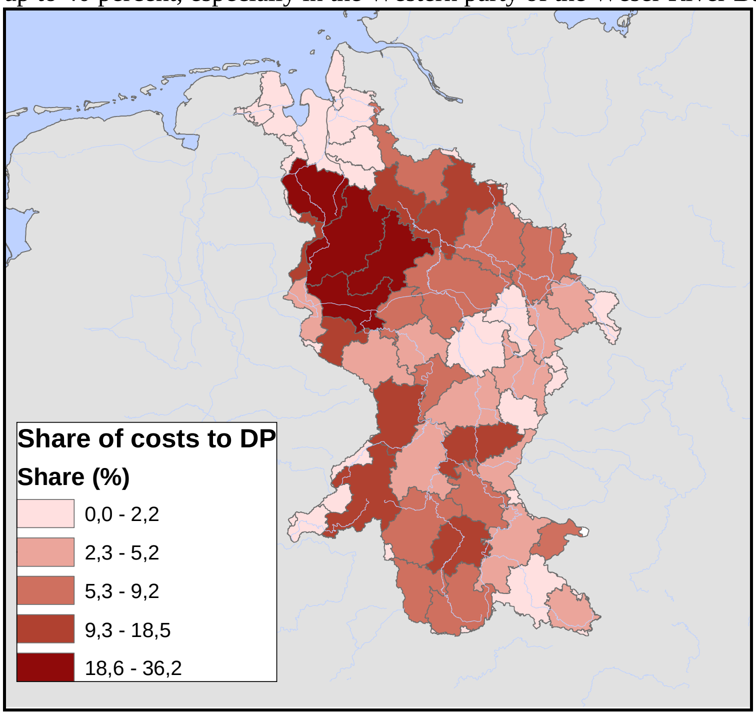

Figure 3: Share of costs for additional measures to direct payments on NUTS III level

Regarding the cumulative distribution of costs per ha it can be seen that around 60 percent of the counties only have to pay 10 Euros per hectare or less to meet the targets of the WFD (Figure 4). The highest costs per hectare in the Weser River Basin calculated as the share of the total agriculturally used area (UAA) are 99 Euros per hectare. Only ten percent of counties would have to pay 40 Euros per hectare or more.

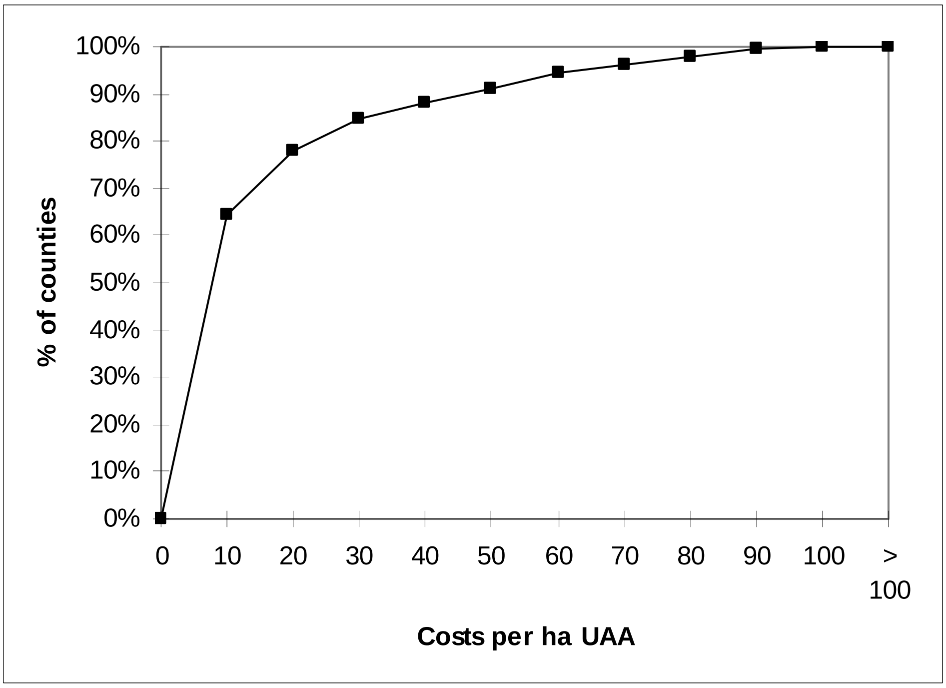

Figure 4: Cumulative distribution of costs per ha agriculturally used area (UAA) to fulfil the WFD for each county.

It is obvious that not only a difference exits between the costs and impacts of the different measures, but also a high heterogeneity exist between the different counties analysed, as the impact of each measure depends on regional peculiarities, but also the cost for each measure depends on the cropping patterns, the importance of livestock and other local characteristics.

´To evaluate the regional characteristics and their impacts on the validity of the results we evaluate one measure as an example to further regionalise impacts and costs for future analysis. We test the effect of the measure of grassland extension in each county with the RAUMIS model on the NUTS III regional scale.

If we introduce a premium for the expansion of extensive grassland successively in five steps. The expansion of extensive grassland is regionally different depending on the marginal cost of extensive grassland production in each county. The marginal costs vary depending on the amount of grassland in each county, on the share of grassland to total agriculturally used area (UAA) and on the amount of livestock.

By varying the amounts of premiums for extensive grassland we are able to simulate supply curves that can be used to differentiate the costs of measures in each county. Figure 4 shows the supply curves for all counties in the Weser River basin.

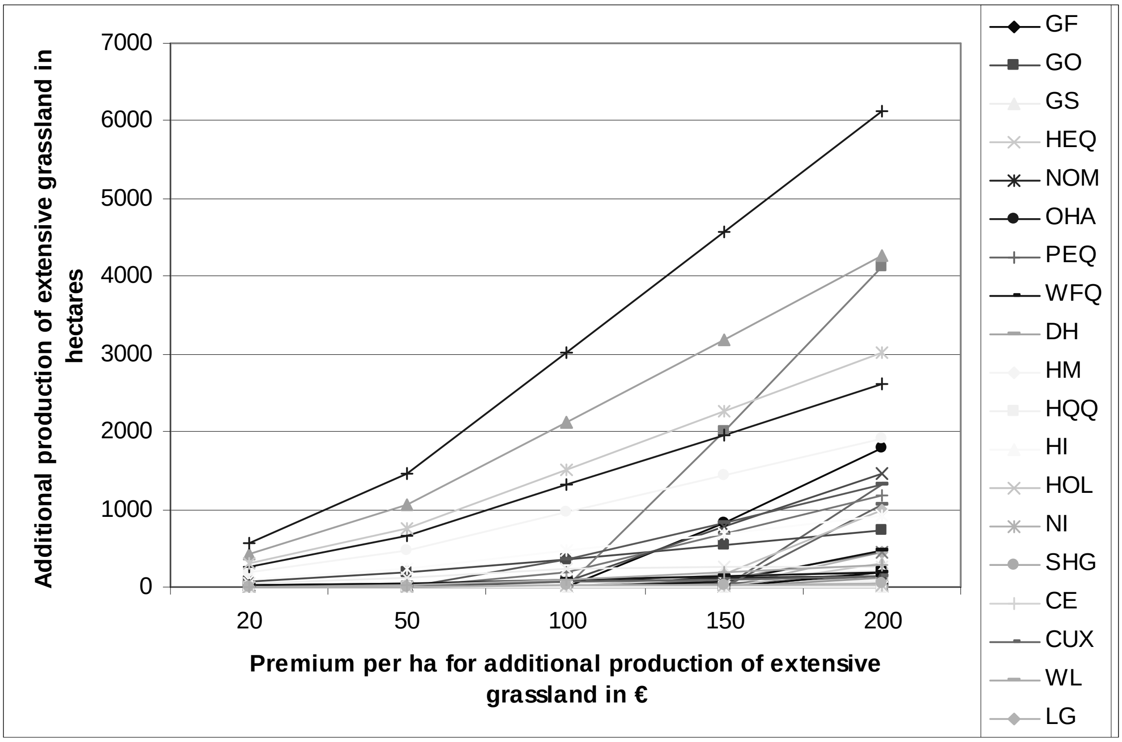

Figure 5: Supply curves of extensive grassland production in the counties of the Weser River basin.

Result show that with an additional premium of 200 Euros per hectares the expansion of extensive grassland is still not lucrative in 25 percent of the counties to expand this measure.

4. Discussion

Altogether, results for the Weser River Basin show that it is of utterly importance for the evaluation of water management strategies within the scope of the WFD to set up and apply hydro-economic modelling networks to be able to evaluate the impacts as well as cost of measures on a regionally differentiated basis. With one agricultural and two hydrological models we were able to calculate the nitrogen inputs and concentrations in 2015 as well as necessary reduction amounts of nitrogen surplus.
Results further show that measures to fulfil the good status of water to reach the objectives of the WFD would take up a range of 50 to 100 million Euros which would make up around 5 percent of current direct payments. For decision making processes it is thus important to evaluate the costs relatively to other payment in agriculture as well as other sectors.
Furthermore, measures have to be regarded regionally differentiated. For an economic analysis it is important to implement cost-effective measures. Up to now, it is very difficult to differentiate costs and impacts of argri-environmental measures as hardly any data is available from field experiments. With the help of linear programming models we could show that different marginal costs for measures exist between regions. For future research it is necessary to estimate marginal costs for various measures and to integrate these into the water management plans of the WFD.

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Annex: Areas and total costs for selected agri-environmental measures (Minimum and Maximum areas and costs by varying the possible costs of measures as in Table 1)

Measure:	Total Area in Weser basin ('000 hectares)	(min-max)	Total costs in Weser basin ('000 Euros)	(min-max)
No application of organic fertilizer after harvest	99	-	1,587	988- 2963
Intertillage	426	-	35,637	17,039- 46,857
Groundwater protective application of dung	119	-	3,740	1,778- 4,149
Extensive grassland production	99	-	1,418	1,062- 1,991
Promotion of extensive farming	101	-	7,443	5,070- 15,211
Reduced mineral fertilizer in cereal production	200	-	16,734	10,010- 60,060
Cultivation of turnip rape	171	-	10,730	10268
Organic farming	72	-	16,753	5,779- 14,449
Total	1287	-	94,042	155,948

Source: Own calculation