Options for meeting WFD targets beyond 2015 in a highly polluted river basin in Germany

Claudia Heidecke[1], Andrea Wagner[1], Peter Kreins[1], Markus Venohr[2] & Frank Wendland[3]

[1] Thuenen Institute of Rural Studies, Bundesallee 50, 38116 Braunschweig, Germany. Ph: +49 531 596 5519, Fax: +49 531 596 5599, Mail: claudia.heidecke@ti.bund.de

[2] Department of Shallow Lakes and Lowland Rivers, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany

[3] Research Centre Juelich, Institute of Chemistry and Dynamics of the Geosphere (ICG), Institute 4: Agrosphere, Germany

Poster paper prepared for presentation at the EAAE 2014 Congress
'Agri-Food and Rural Innovations for Healthier Societies'

August 26 to 29, 2014
Ljubljana, Slovenia

Abstract

The Weser River Basin will most likely not meet European water framework directive nitrogen concentration targets by 2015. We use the AGRUM model network connecting hydrological and nutrient transport models with a German agricultural sector model to analyse current and future nitrogen surplus developments, water quality aspects and additional agri-environmental measures to discuss options for WFD targets until 2021. Results show that even with a full implementation of the nitrogen directive and with additional agri-environmental measures the objectives of the WFD can hardly be met.

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

1. Introduction

The implementation of the European Water Framework Directive (WFD) in Europe is progressing. The general goal of the WFD is to ensure a good water quality and quantity status for ground and surface waters in Europe by 2015. In Germany river basins, especially in intensive agricultural regions, have been struggling to meet the targets. It is already obvious for the Weser River Basin that WFD targets will not be met by 2015. The EU Commission has proposed two auxiliary dates, 2021 and 2027, as a back door which will be analysed in the paper.

We use a hydro-economic modelling network to analyse nitrogen surpluses, nutrient intakes and necessary reduction loads until 2021 for the Weser River Basin. Scenario analysis of the implementation of the fertilizer regulation within the nitrate directive shows the sensitiveness of the results. With a backward calculation, necessary reduction loads to meet the targets are provided as a basis for the analysis of additional agri-environmental measures and their associated costs.

2. Method

For the analysis in this paper we use a model network that was first established and applied to analyse nutrient leaching from agriculture in the Weser River Basin until the year 2015 building upon a base year 2003 (Kreins et al., 2010, Hirt et al., 2012). The model network is updated and used in this paper to analyse the development until 2021 building upon a more recent base year (2007) and including new data sets. The model network includes two hydrological and nutrient transport models with different focal points and an agricultural sector model. The different models and their interconnection shall be briefly described in the following with a main focus on the agricultural sector model.

The Regionalised Agricultural and Environmental Information System RAUMIS (Henrichsmeyer et al. 1996; Gömann et al. 2005) is applied for agricultural economic simulations and projections. 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. The spatial differentiation bases on a modified NUTS III level. The nitrogen surplus balance used includes mineral- and organic fertilizer, symbiotic and asymbiotic nitrogen-fixation on the supply side, and plant withdrawal and loss of ammonia on the demand side. Coefficients of mineral fertilizer use and the utilisation level of manure are calculated on the basis of single farm data, farm type and livestock density rates of cattle and pig production following the work of Osterburg and Schmidt (2008). Mais production for biogas plants and resulting slurry is treated similar to manure and added to organic fertilizer supply. 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.

Using the model RAUMIS a baseline is projected until the year 2021. An amendment of fertilizer regulations (FR) has been effective since 2006 regulating 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 an annual nutrient comparison on the basis of the field- stable balance of nitrogen. This balance may not exceed 60 kg nitrogen per hectare and year. Binding since 2009, stable, storage and output losses must be taken into account and compliance by all farmers is assumed in this paper. Since 2000 agri-environmental measures belong to the support of rural development and help to 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 led to a boom of energy maize as the most favoured crop and thus contributes to increases in nitrogen surpluses.

The nitrogen surpluses calculated by the agricultural sector model RAUMIS are decisive input parameters for the hydrological models. Two different hydrological approaches are used: the GROWA/WEKU and MePhos 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 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. To calculate necessary nitrogen reduction loads, first the nitrogen surpluses of RAUMIS are introduced to assess the nutrient concentrations for the baseline 2021. Then, in a second step, a backward calculation is made introducing the concentration targets of the WFD into the models as goal variables to evaluate the necessary nitrogen reduction load to meet these targets.

Finally, 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.

Various measures are discussed in the literature that are generally capable of reducing diffuse nutrient leaching by agriculture. Within a comprehensive literature survey (Osterburg and Runge, 2007) the ecological impacts and the capabilities of technical and organisational water protection measures were recorded for several criteria.

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 to the required nutrient reduction according to its potential.

The number of measures that could possibly be applied on the area in each county is determined based on the RAUMIS baseline land use and cropping results. Depending on the individual impact on nitrogen surplus by each measure a combination of the measures is selected specifically for each NUTS IV region.

3. Results

Nitrogen surpluses for 2007 and scenarios for 2021

A reduction of nitrogen surpluses is expected in the Weser River Basin as well as for the German average until 2021. This will be due to impacts of the policies and expected developments of prices and yields as assumed in the baseline. The average N-surplus (without atmospheric decomposition) declines from 69 kg N per ha agriculturally used area (UAA) by around 10 kg per ha UAA.

Figure 1 on the left shows nitrogen surplus in the Weser River Basin in the year 2021 without considering the implementation of the Fertilizer Regulation (FR).

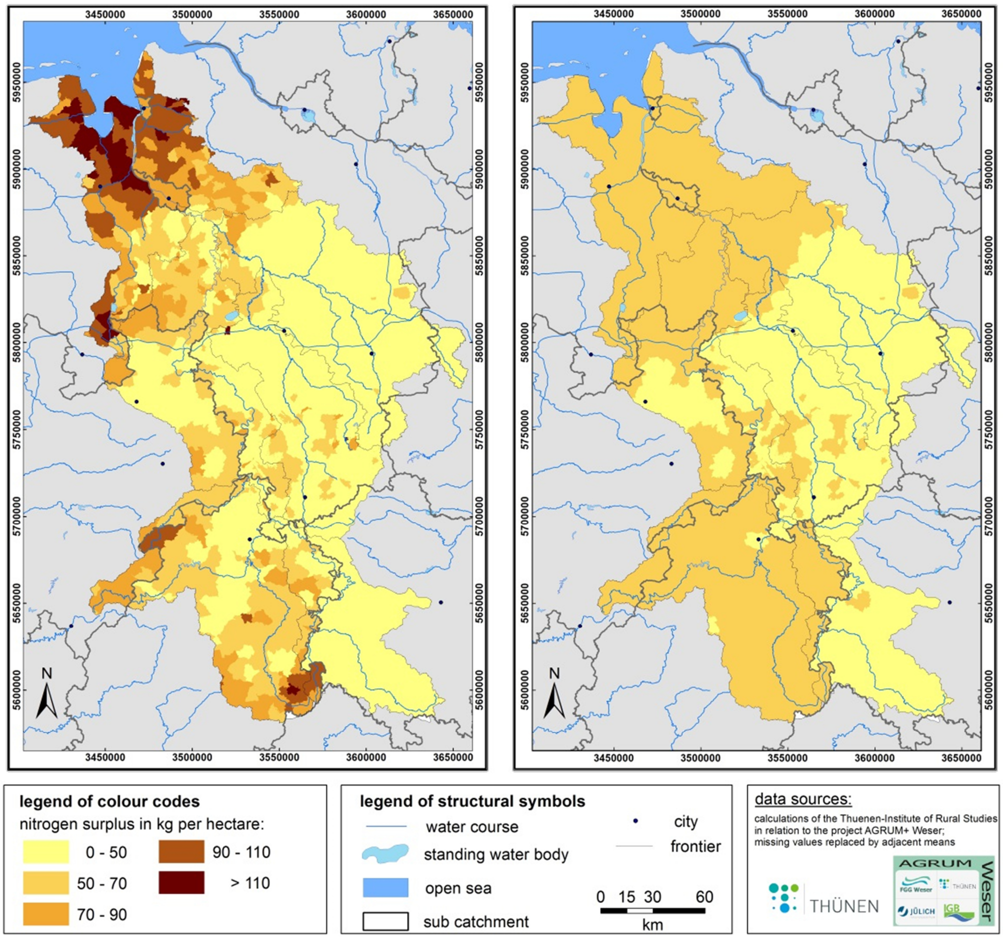

Figure 1: Nitrogen surpluses in the baseline 2021 without considering the implementation of the Fertilizer Regulation (left) and considering the FR and a transportation of manure (right) (kg N/hectare UAA without atmospheric deposition).

Assuming a full implementation of the FR until 2021 which implies that farmers are not allowed to exceed average nitrogen surplus of 60 kg N per ha UAA, nitrogen input has to be reduced in some counties especially in the Northern parts of the Weser River Basin and some parts in the South-West. Even if a transportation of manure is allowed within 80km, there is still a need to reduce nitrogen input of around 35 000 Tonnes N. This would be equivalent to a reduction in livestock of ten percent which is politically hardly feasible.

Necessary nitrogen reduction loads to meet the WFD

For the analysis of possible impacts of the nitrogen intake into groundwater in the baseline scenario of 2021, the N-surpluses from agriculture including the implementation of the Fertilizer Regulation (Figure 1 right) and adding atmospheric deposition of nitrogen were input quantities for the models GROWA/WEKU and MONERIS. The projected nitrogen surpluses and nitrogen leaching in the baseline scenario are 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 2.8 mg N/l at the gauge of Hemelingen (close to Bremen) for the Weser river basin considering coastal protection.

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. This leads to a necessary reduction load of 14 000 tonnes of nitrogen to meet the objectives for groundwater, and additionally a reduction of another 39 000 t of nitrogen to achieve a concentration of 2.8 mg N/l at Hemelingen assuming a good groundwater status.

Cost analysis of possible agri-environmental measures

Finally, measures for each NUTS IV region are determined that result in exactly the necessary reduction load described above. For groundwater, a measure combination that amounts to about 600 000 million hectares is necessary which would require funding of about 30 million Euros. The combination of selected measures is regionally different depending on the regional agricultural and livestock production pattern. In nine percent the reduction targets cannot be met even by considering an area-wide application of measures. For surface waters, additional measures on 1.3 million hectares are determined.

4. Discussion

In the Weser River Basin, ground and surface water targets for nitrogen will not be met by 2015. Even taken the auxiliary date 2021 into account, as has been analysed in this paper, it will be not possible to meet the targets if no further measures are taken. In this paper we have evaluated a set of regionally specific measures that, if applied under the given assumptions, could lead to a nitrogen surplus reduction in regions were groundwater targets have not yet been met. These measures would have to be implemented on around 2 million hectares UAA but still have not for all regions the potential to fulfil the necessary reduction requirements. It must be further stressed that the assumptions in this paper already imply a full implementation of the Fertilizer Regulation. This is a strong assumption since controls and data available up to present show only a slow improvement and adaptation to the Fertilizer Regulation. The assumptions further imply that 39 000 Tonnes of nitrogen are reduced which would have to be realised e.g. by a reduction of livestock by ten percent which for the current debate does not seem to be politically feasible.

5. References

Behrendt, H., Bach, M., Kunkel, R., Opitz, D., Pagenkopf, W.-G., Scholz, G., and Wendland, F. (2003). Quantifizierung der Nährstoffeinträge der Flussgebiete Deutschlands auf der Grundlage eines harmonisierten Vorgehens, UBA-Texte 82, 201 p.

Gömann, H., Kreins, P., Kunkel, R. and Wendland, F. (2005). "Model based impact analysis of policy options aiming at reducing diffuse pollution by agriculture- a case study for the river Ems and a sub-catchment of the Rhine", *Environmental Model Software* Vol. 20 (2), pp. 261-271.

Henrichsmeyer, W., Cypris, C., Löhe, W., Meudt, M., Sander, R., Sothen, F. von, Isermeyer, F., Schefski, A., Schleef, K.H., Neander, E., Fasterding, F., Helmke, B., Neumann, M., Nieberg, H., Manegold, D. and Meier, T. (1996). Entwicklung des gesamtdeutschen Agrarsektormodells RAUMIS96. Endbericht zum Kooperationsprojekt. Forschungsbericht für das BML (94 HS 021). Vervielfältigtes Manuskript, Bonn/Braunschweig.

Hirt, U., Kreins, P., Kuhn, U., Mahnkopf, J., Venohr, M., Wendland, F. (2012). Management options to reduce future nitrogen emissions into rivers: A case study of the Weser river basin, Germany. *Agricultural water management*, Vol. 115, pp. 118-131.

Kreins, P., Behrendt, H., Gömann, H., Heidecke, C., Hirt, U., Kunkel, R., Seidel, K., Tetzlaff, B., Wendland, F. (2010), Analyse von Agrar- und Umweltmaßnahmen im Bereich des landwirtschaftlichen Gewässerschutzes vor dem Hintergrund der EG-Wasserrahmenrichtlinie in der Flussgebietsgemeinschaft Weser. Endbericht des AGRUM Weser Projektes. Landbauforschung, Sonderheft Nr. 336. 308 Seiten.

Kunkel R. and Wendland F. (1997). WEKU - A GIS-supported stochastic model of groundwater residence times in upper aquifers for the supraregional groundwater management. *Environmental Geology* Vol. 30, pp. 1-9.

Kunkel R. and Wendland F. (2002). The GROWA98 model for water balance analysis in large river basins – the river Elbe case study. *Journal of Hydrology* Vol. 259, pp. 152-162.

Osterburg, B., and Schmidt, T. (2008). Weiterentwicklung der Berechnung regionaler Stickstoffbilanzen am Beispiel Niedersachsen. *vTI Agriculture and Forestry Research* 1/2 2008 (58):45-58.

Wendland, F., Kunkel, R., Grimvall, A., Kronvang, B. and Müller-Wohlfeil, D. I. (2002). The SOIL-N/WEKU model system - a GIS-supported tool for the assessment and management of diffuse nitrogen leaching at the scale of river basins. *Water Science and Technology* Vol. 45 (9), pp. 285-292.

Wendland, F., Kunkel, R. and Voigt, H.-J. (2004).Assessment of groundwater residence times in the pore aquifers of the River Elbe Basin. *Environmental Geology* Vol. 46, pp. 1-9.