MANAGEMENT OF REGIONAL GERMAN RIVER CATCHMENTS (REGFLUD) - GENERAL CONDITIONS AND POLICY OPTIONS ON DIFFUSE POLLUTION BY AGRICULTURE OF THE RIVER RHINE AND EMS –

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ABSTRACT

In a first section the paper gives an overview of the REGFLUD project that is commissioned by the German Min istry of Education and Research (BMBF)1. The project addresses the problem of diffuse pollution that is largely caused by agricultural production. The overall objective is the development and application of multi-criteria scientific methods to set up a decision support system (DSS). In the course of the project impacts of agri-environmental measures on water quality and on the agricultural sector are analysed using an integrated agricultural economic and hydrological model network. The evaluation of measures takes economic feasibility and social acceptability into account. In addition, the efficiency of institutional settings is analysed. The selected study areas cover a wide range of different landscape units with different hydrological, hydro- geological and socio-economic characteris tics which facilitates the extension of the approach to other landscapes and river basins in Europe. In a second section the potential impacts of a restriction of phosphorus manuring that is currently discussed within the amendment of the German manure regulation are presented in order to demonstrate the functioning of the project. Preliminary results for 12 selected regions within the study area indicate that a strict enforcement of this amendment would require a reduction of phosphorus supply by 40%. If this is associated with an equivalent cutback of livestock in these regions the agricultural sector will incur an income loss of more than 12%.

Keywords : agri-environmental policy evaluation; diffuse water pollution; river basin management; multi-criteria assessment

INTRODUCTION

In Germany considerable progress has been achieved regarding the improvement of water quality. However, diffuse water pollution – a source largely attributed to agricultural production - continues to be of concern (Ministry of Environment and Nature Conservation, Agriculture, and Consumer Protection of the Federal State of North Rhine-Westphalia, 2000). Regarding nitrate that can be essentially attributed to agricultural manuring more than 22% of the analysed groundwater measuring points in North Rhine-Westphalia exceeded the critical value of 50 mg/L of the drinking water regulation. Values between 100 and 200 mg/L were not reported infrequently and point up the problematic situation. Today agriculture is the main polluter of surface water with phosphate. The problem of diffuse water pollution is addressed by the REGFLUD project whose overall objective is the development and application of multi-criteria scientific methods to set up a Decision Support System (DSS) providing information to policy decision makers with respect to the implementation of the Water Framework Directive (WFD).

METHODS

Overview

The development of DSS basically encompasses the following tasks (sub-projects):

- Model based analyses of status quo and policy measures.
- Acceptability and evaluation of measures.
- Efficiency analysis of institutional settings.
- Combination of results within an user- friendly online decision support system.

A principle pillar of a decision support system is the modelling of the agricultural sector (cp. Figure 1). The implementation of alternative agri-environmental policies may on the one hand reduce potential nutrient emissions from agriculture into water bodies but on the other hand imply substantial farm income losses. In the course of the project comprehensive model based analyses of status quo and policy measures is carried out. Issues are encompassed such as a calculation of environmentally effective regional nutrient surpluses considering changes of land use, livestock, production intensity, agricultural income, employment, and capital. An area-differentiated and according to runoff components differenced analyses of the pathway-dependent entries of nutrients into water systems takes retention and degradation processes into account. Impacts of changes in the general agri-environmental conditions and policy measures on nutrient surpluses and nutrient discharges into water systems are analyse determining marginal costs of a reduction of agricultural

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nutrient emissions. The integrated modelling approach provides indicators such as nutrient entries into surface water that adequately describe the impact on the condition of the environmental good to be protected i.e. water. A change in nutrient entries can directly be related to the bene fit that users attribute the change in the environmental quality. In a first step the value users/the public attribute to improvements of water quality is qualitatively surveyed in expert interviews and is quantified in a second step using a standardized questionnaire asking residents about their willingness to pay. The measures are evaluated with regard to both costs and benefits. In addition, institutional arrangement allowing an efficient implementation of measures are elaborated.
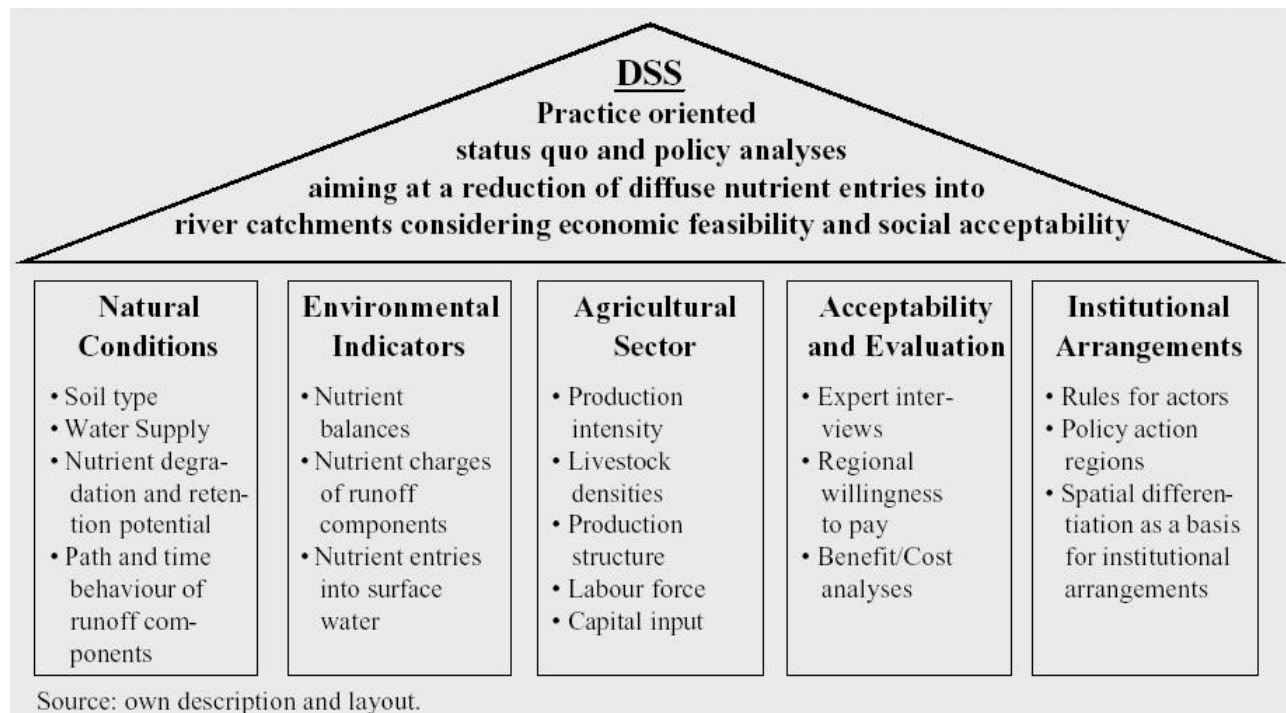

Figure 1: Concept of the Decision Support System of REGFLUD

Model based analyses of status quo and policy measures

Analyses of the agricultural sector are conducted with the Regional Agricultural and Environmental Information System RAUMIS (Henrichsmeyer et al., 1996) which is designed for a continuous usage in the scope of long-term agricultural and environmental policy impact analyses. Figure 2 gives an overview about the methodological design of RAUMIS. The model consolidates various agricultural data sources and generates base model data with the national agricultural accounts as a framework of consistency. It comprises more than 50 agricultural products, 40 inputs with exogenously determined prices, and reflects the whole German agricultural sector with its sector linkages. A continuous spatial distribution of agricultural production is approximated by some 326 regions basically on a county level ("Landkreis"). These Regions are treated as single "region enterprises" that autonomously reach their production decisions. Hence, adjustments of production on national level base on the aggregated responses of the "region farms". Adjustments caused by changes in general conditions such as agricultural policies are determined using a so-called positive mathematical programming approach (Howitt, 1995) with a non- linear objective function.

Comparative static policy impact analyses for a future target year require a scenario of reference because various parameters are changing in the long-run in addition to the variations of policy measures being investigated. Typically the scenario of reference is a projection of the development under "business as usual" conditions that are partially derived from trend and yield dependent regression analyses as well as from estimations of experts particularly regarding prices and farm structures. Deviating from the scenario of reference alternative policies and regulations are imposed on the model leaving all other parameters and variables constant. This procedure separates the policy impacts on agricultural production, land-use and agricultural income as deviations from the scenario of reference.
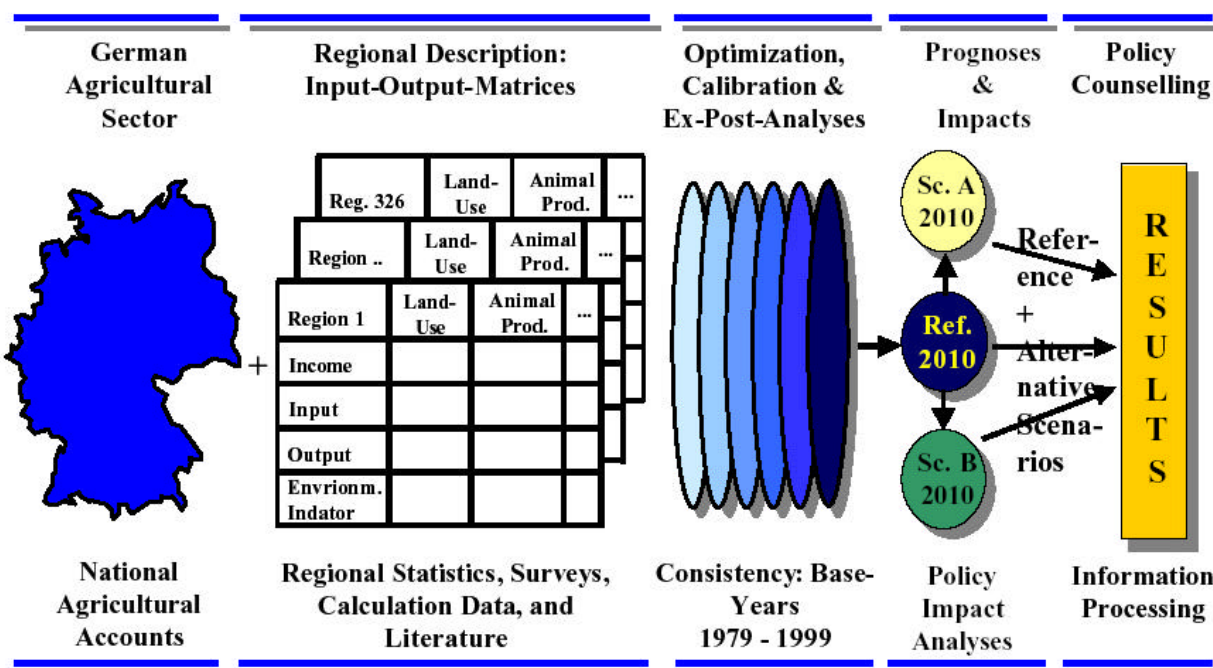
Figure 2: Methodological Design of RAUMIS

In RAUMIS a set of agri-environmental indicators is linked to agricultural production of which the nutrient balances (nitrogen, phosphorus and potassium) are of particular interest for the REGFLUD project. Figure 3 illustrates the structure and elements of nutrient balances in RAUMIS considering the complex indicator "nitrogen surplus" as an example. The long-term nutrient balancing complies with the PARCOM-guidelines (PARCOM, 1993) where the soil surface represents the system border.
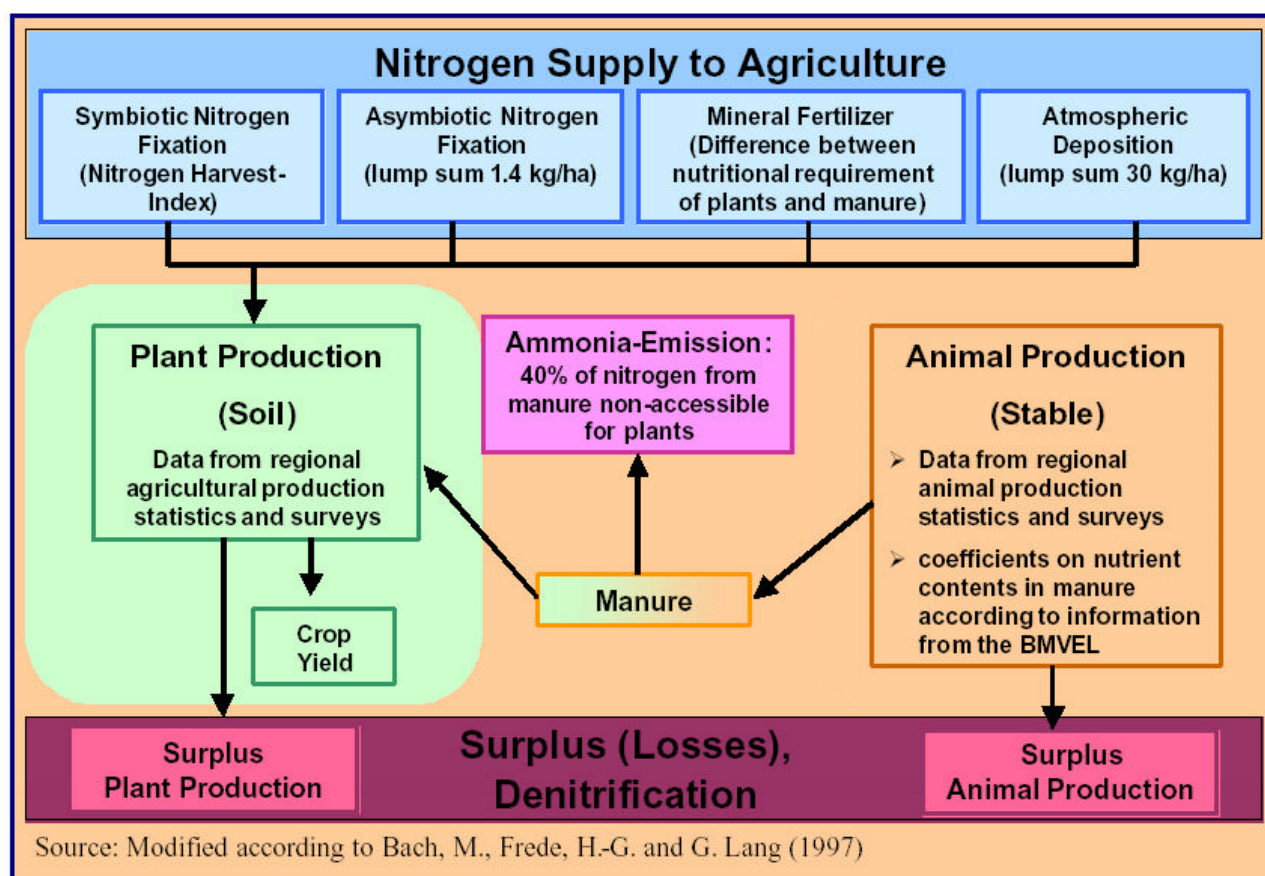

Figure 3: Structure and elements of the Nitrogen Balance in RAUMIS

The nutrients are in need of plant production and the uptake bases on expected crop yield. An intrasector source of fertilizer is the nutrient content in manure applied in plant production. A nitrogen specific nutrient loss occurs as ammonia

(NH3) emissions during storage and application. The nutrient supply from manure is derived from nutrient contents in the excrements of farm animals e.g. dung and liquid manure from cattle, hogs and poultry. Coefficents about the nutrient content in manure as well as the utilization factors of plants are taken from the literature and are provided also from experts of the Federal Ministry of Consumer Protection, Food, and Agriculture (BMVEL). Following the concept tha t nutrients from manure can replace nutrients from mineral fertilizer, mineral fertilizer equivalents for manure are calculated based on different nutrients utilization factors of dung and liquid manure from cattle, hogs and 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 nutrients 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. Further nitrogen specific sources are symbiotic (e.g. from pulses) and asymbiotic nitrogen- fixation, as well as atmospheric deposition. As a rule, balancing nutrient supplies and extractions (demands) leads to surpluses on agricultural area (AA) that potentially leach into ground and surface water.

The RAUMIS nutrient surpluses represent environmental risk indicators which enter the hydrological models GROWA98 (Kunkel/Wendland, 2002) and WEKU (Kunkel/Wendland, 1997) in order to assess the agricultural borne nutrient charges into water bodies. The approach applied in the REGFLUD project is designed for area-differentiated modelling on a supraregional scale. GROWA98 is used to carry out area differentiated water balance analyses. The mean long term total runoff is modelled as a function of the regional interaction of climate, soil, geology, topography and land use conditions. The model separates the total runoff into the direct runoff (interflow and surface runoff) and ground water runoff (ground water recharge). WEKU models the reactive nutrient transport in ground water. For details see Kunkel et al. (2003).

Acceptability and evaluation of measures

A variety of policy measures and strategies directly or indirectly influence the agricultural nutrient surpluses and thereby the problem of diffuse water pollution. The elaboration of appropriate policy measures and strategies within the REGFLUD project involves various experts and stake holders. Their participation in the project is a primary concern and take place in a first step by interviews that are a widely applied and flexible method. In addition the interviews are used to collect the basic information needed. In subsequent workshops preliminary results are discussed in order to tailor strategies for an improved iteration loop.

Water users benefit from improved water quality. The value they attribute to this improvement is estimated within the REGFLUD project by the method of contingent valuation. Based on a survey using a standardized questionnaire in selected areas a benefit function transfer to other areas is determined. This requires the estimation of an econometric model for the derived willingness to pay. In order to apply the resulting function to regions instead of individuals an ancillary calibration function has to be estimated. This approach facilitates a quick subsequent application of results to additional regions.

The benefit cost analysis comprises a quantitative integration and evaluation of simulation results. The following issues are considered:

- assessment of environmental impacts of policies beyond the water balance (e.g. landscape),
- the determination of shadow prices on protected agricultural and distorted factor markets,
- the assessment of total economic cost of public expenses, of budget impacts ("cost of funds mark up") and possibly of consequential health costs as far as these costs are not contained in the willingness to pay,
- the consideration of different transaction costs, in particular administrative costs for alternative institutional organisation.

Within the REGFLUD project these factors can just partly be estimated or qualitatively characterized. For further details see Stonner (2003).

Efficiency analysis of institutional organisation

The efficiency analysis of institutional organisation mainly employs federal theory and economic theory of institutions. Social rules for organizing water protection are evaluated with respect to economic ratios. From an economic perspective it is important to identify qualified actors and institutions for an efficient river basin management, and to provide these actors with the necessary rights and duties.

Development of a decision support system

In the course of the REGFLUD project intermediate results are exchanged within the sub-projects and are used for an improved subsequent iteration loop forming an overall integrated project. Results are summarized and presented within an Online-DSS. The interested public can inquire information in the form of charts, tables, graphics and/or texts. The prototype of this information system uses Java Applets and is supported by standard internet browser such as Netscape or Explorer. The system follows an open modular design with sufficient flexibility to imple ment further developments. Currently, an interactive and flexible cartographic assessment of different results is possible, amended by information about the regional distribution of the selected parameters.

Selection of catchments

In the REGFLUD project two study areas in Germany (cp. Figure 4), both with size of about 25,000 km2, are selected in order to cover a wide range of different land scape units with different hydrological, hydro-geological and socio-economic characteristics. The river Ems basin (12,900 km2) is located in the North-German Plain. Due to less fertile sandy soils in this basin, land use is dominated by intensive animal husbandry. High ground water tables and/or artificial drainage make the direct runoff the dominant runoff component which accounts for the main discharge pathway of surplus nitrogen and phosphorus fertilizer into surface waters. Surplus nitrogen fertilizer is discharged with the leachate out of the soil and leads to an area wide problem of ground water pollution in many places.
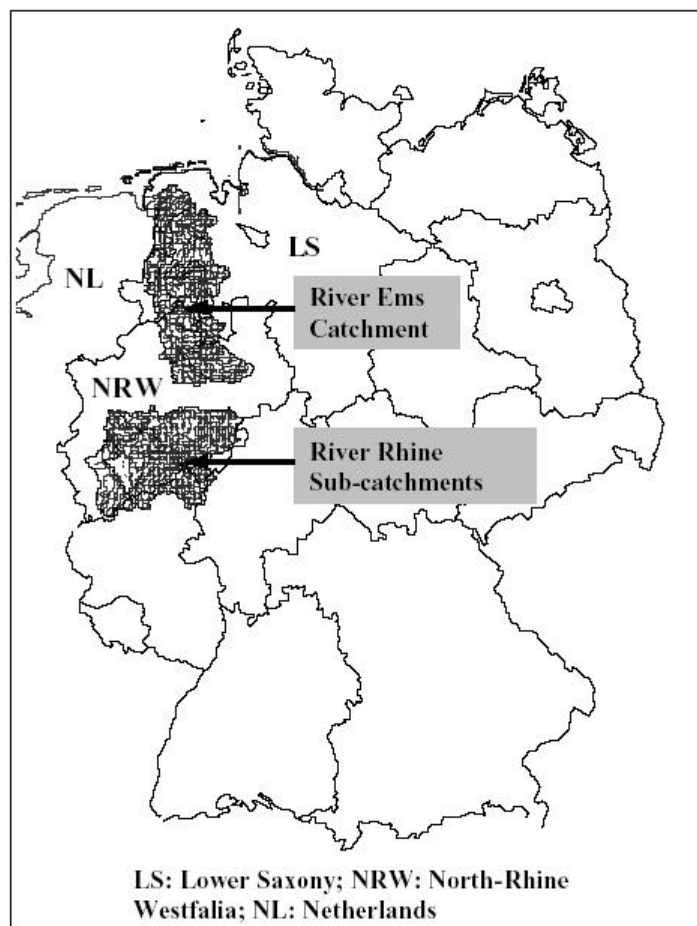

Figure 4: Study Area of the REGFLUD-Project

The situation in the investigated sub-catchment areas i.e. Sieg, Wupper, Erft, Ruhr (12,100 km2) in the river Rhine basin is quite different. Parts of the catchment are located in consolidated Palaeozoic rock areas, which are characterized by less fertile soils, an extensive agricultural land use and high total area runoff levels, dominated by fast (direct) runoff components. These conditions suggest problems with nitrogen pollution of water in storage dams. Other parts of the investigated areas in the Rhine basin are located in the unconsolidated quaternary rock area of the lower Rhine bay, a fertile loess region, which is dominated by an intensive agricultural use and large ground water recharge levels. As described a wide range of problems concerning nutrient pollution of water bodies are prevalent in both study areas. It is expected that the impact of agri-environmental measures regionally vary with respect to the reduction of nitrogen and phosphorus in water bodies. The efficiency of measures has to be evaluated accordingly, taking into account the different historically evolved and partly established socio-economic conditions in the study area such as agricultural farm structures, the structure of water protection, as well as water supply and sewage disposal. Especially regarding the possibility of extending the REGFLUD project to other landscapes and river basins the coverage of a variety of typical areas is a prerequisite.

RESULTS AND DISCUSSIONS

In the following the impacts of a measure i.e. a restriction on phosphorus (P) manuring currently under discussion within the amendment of the German manure regulation are presented. The results demonstrate the functioning of the REGFLUD project and may contribute to the political discussion.

Phosphorus related measures of the currently discussed amendment of the German manure regulation

According to the amendment of the regulation, the P-supply must not exceed a certain percentage of the plant uptake whereby the determined percentages are subject to the above mentioned soil categories grade A to E. In the analysis at hand a P-supply limitation of 50% of plant-uptake for agricultural area (AA) ranked grade E and 100% for AA ranked grade C and D is assumed.
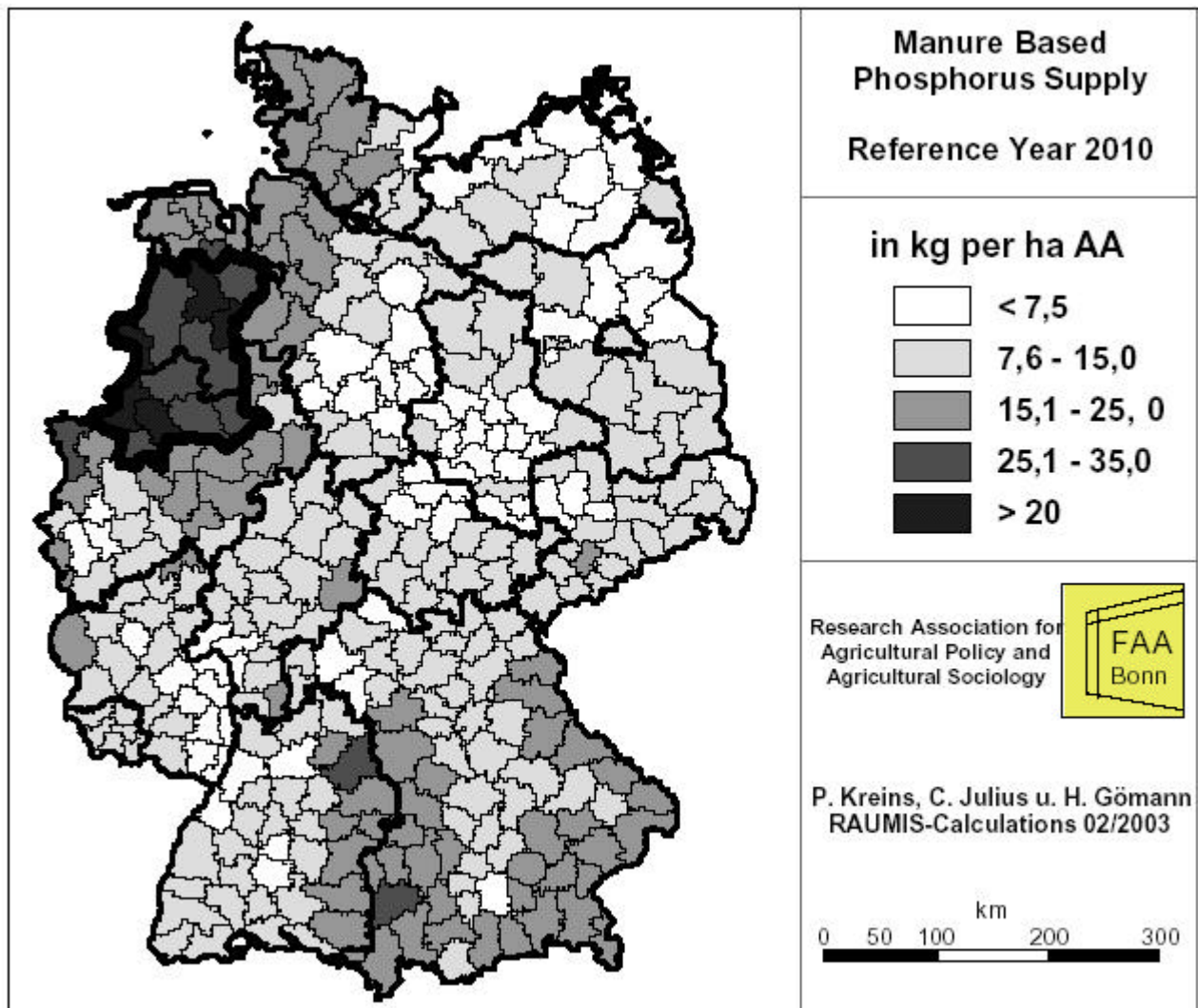

Figure 5: Manure based phosphorus supply in 2010

Situation of phosphorus based on organic manuring in Germany

Figure 5 depicts a projection of the manure based P-supply for the year 2010. The projection is calculated with the model RAUMIS on the basis of the current EU-Common Agricultural Policy i.e. Agenda 2000 and represents a scenario of reference. Due to intensive livestock production in northwest Germany the regional P-supplies are above the German average and exceed significantly the uptake by plants. In the course of time this has contributed to a significant P-accumulation in the soil. In a survey conducted by the LUFA-Münster in 6 selected regions of North Rhine-Westphalia 25,000 samples of the soil were analysed with respect to the P-content. Assuming an homogenous sample distribution across the agricultural area (AA) the findings were that 20% of AA possess very high contents (grade E), 50% high contents (grade D), 25% medium contents (grade C), and just 5% low respectively very low contents. Because of similar agricultural production structures in the 6 adjacent regions in Lower Saxony these figures are assumed for these regions as well to form an area of 12 regions (cp. figure 5, area bordered by solid line). In this area with an average livestock density of 2.8 livestock units (LU) per hectare (ha) AA the total P-supply from manure amounts to more than 43,000 t (cp. table 1). A share of 31% of the manure supply originates from cattle, 52% from pigs, 15% from poultry, and 2% from other animals. Referring to the covered AA of approx. 1 mill. ha the P-supply averages 43 kg/ha AA with a range from 30 to 80 kg/ha.

Impacts on agriculture after compliance with the amended German manure regulation

The abidance by the determined (assumed) P-limitations would restrict its application to 26,000 t (cp. table 1). The required 17,000 t of P-reduction would either imply a cutback of livestock by 1 mill. LU (i.e. 39%) or an equivalent shipping of manure to regions with lower P-contents in the soil. Calculating the costs of manure transport pre-suppose a variety of assumptions regarding the technology etc. However, the costs may not exceed the agricultural income foregone

of reducing livestock within the 12 regions which would amount to 290 mill. EUR (or 17 EUR/kg P) in terms of net agricultural value added. This figure represents the maximum cost that the agricultural sector of these 12 regions would incur in the long run due to the amendment of the manure regulation.

		Status quo	Manure Regul.	Change in %
Livestock	1,000 LU	2,789	1,702	-39.0
Livestock Density	LU per ha	2.8	1.7	-39.0
Phosphorus supply	1,000 Mt	42.6	25.9	-39.2
Phosphorus supply	kg / ha AA	42.4	25.8	-39.2
Gross Value Added	Mill. EUR	3,939	3,180	-19.3
Net Value Added	Mill. EUR	2,334	2,045	-12.4
Emsland, Cloppenburg, Oldenburg, Vechta, Grafschaft-Bentheim, Osnabrück, Borken, Warendorf, Coesfeld, Recklinghausen, Gütersloh.				

Table 1 Impacts of a restriction of the phosphorus manuring on selected regions in Northwest Germany
(Source : FAA, April 2003, RAUMIS calculation)

CONCLUSIONS

The potentially severe income loss the agricultural sector would incur due to an implementation of the above mentioned restrictions on P- manuring is a striking result for the policy decision process. It points up that the enforcement of such an incisive measure requires long transition periods in particular because of the long-run investments that are typical fo r the affected livestock sector. Fur ther aspects that are not accounted for are impacts on the supplying and on processing sector. In order to quantify the P-emission into the surface water research within the REGFLUD project is focused on a coupling of the agricultural economic model RAUMIS and the hydrological models GROWA98 and WEKU for phosphorus as demonstrated by Kunkel (2003) for nitrogen. This link will be realized not before long. Additionally, the refinement of the spatial resolution of RAUMIS being in progress will improve the results.

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