Cost-effectiveness of measures in agriculture to reduce the nitrogen load flowing via the Danube River into the Black Sea – A comparison of Austria, Hungary and Romania

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Abstract

The paper presents a short version of the basic method based on cost-effectiveness analysis of measures to assess the possible reductions of nitrogen loads in the water bodies of selected countries in the Danube catchment area originating from agriculture, applied in the daNUbs project. The effects on the national nitrogen soil surface balances of measures representing changed agricultural production techniques are determined by using the OECD method to calculate nitrogen input and output. Subsequently, the effects on the nitrogen load in the surface waters as well as in the Black Sea are calculated by the MONERIS model and additional factors for retention in surface waters and main streams. The internal costs of the measures considered take into account the induced changes of direct and indirect production costs and of gross output of all agricultural producers involved.

The comparison of cost-effectiveness ratios of different measures (supposed to be carried out in the countries selected) reveals great differences: Both, measures with positive cost-effectiveness ratios and measures with negative ones are identified, the latter indicating that they are commercially profitable to the agricultural producers. The cost-effectiveness ratios of the measures vary strongly, depending on the composition of agricultural production, the degree of retention of

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nitrogen in the soil and the water bodies as well as on the cost levels. Finally, for each country the different measures are ranked according to their cost-effectiveness ratios in order to combine them in a cost-optimal way.
Keywords cost-effectiveness analysis, nitrogen load, Black sea, agriculture

1. Introduction

The European research project daNUbs (daNUbs, 2005), funded under the 5th framework programme, aims at the reduction of nutrients flowing via the Danube River into the Black Sea. The goal is to establish or maintain an ecologically good condition in the Western Black Sea area. The most important nutrient sources considered are diffuse sources mainly from agricultural production and point sources mainly in urban areas and industrial facilities.
The present work focuses on the nutrient nitrogen, originating from agriculture. The main objective was to develop a suitable assessment method for agricultural production allowing a reduction of nitrogen load flowing into the Black Sea at minimal cost (see IFIP, 2005).
The Danube River Catchment (DRC) area covers 802,890 km^2 and comprises 13 countries either totally or partly. At present the nitrogen load flowing from the DRC into the Black Sea amounts to 386,816 t N per year (81% from anthropogenic sources, from which 46 percentage points originate from agricultural production). However, the main attention in the present paper is exemplarily given to Austria being an "old" EU-Member State, Hungary being a new EU Member State as well as Romania being an EU-accession candidate. Nearly the total of these three countries are part of the DRC, covering 49% of its area (daNUbs, 2005).

2. Measures and scenarios

The daNUbs project is based on the assumption that measures to reduce the contribution of agriculture to the nitrogen load flowing into the Black Sea should be implemented by the year 2015. A simple "High Production Scenario (HP 2015)" was defined, in which the agricultural production levels of Austria were assumed to remain roughly constant by 2015. The ones of Hungary and Romania are regaining the level of 1990 by 2015 because their agriculture goes through an intensification of production and reaches western agricultural productivity standards. Based on the assumption that no additional agro-environmental measures are implemented, in scenario HP 2015 the nitrogen load from agriculture in Austria remains approximately constant. The one from Hungary increases by 63% and the one from Romania increases by 60% compared to the level of 2000. Using the HP 2015 scenario as a reference, the impact of implementing Best Available Techniques (BAT) in agricultural production, i.e. in particular such to minimise nitrogen emissions to the hydrosphere, was studied. Within the daNUbs project the impact of four different measures M1 - M4, each defined as the aggregation of several BAT measures, was assessed (Table 1).

Table 1 Overview of the measures considered in Austria (AT), Hungary (HU) and Romania (RO)

	Objective of measure	Quantitative Objective	Best available technique
M1	Accurate application of fertilisers regarding fertiliser amount and time related application rates	Reduction of mineral fertilisers use by 10%	(1) Timely application rates (2) Chemical soil analysis (3) Soil surface balance on field level (4) Ban on application of fertilisers during winter
M2	Reduction of nitrogen emissions from manure	Reduction of Ammonia emissions from manure by 25%	(1) Use of hose spreader (2) Accurate manure storage capacity (3) Accurate straw bedding in animal housing
M3	Increase of plant productivity by applying production techniques being capital intensive	Increase in plant productivity AT: +10% ;HU; RO: +20%	(1) Demand-oriented irrigation (2) Accurate plant protection (3) Demand-oriented plant nutrition
M4	Reduction of direct nitrogen emissions to the hydrosphere	Reduction of erosion by 75% and surface runoff by 20%	(1) Minimum soil tillage (2) Zero tillage (3) Mulch seeding (4) Cover crops and intercropping

Source: IFIP, 2005

3. Calculation of costs and effects

The cost-effectiveness analysis of a measure to reduce the nitrogen load to the hydrosphere in the agricultural sector of a country considers, first of all, the annual internal costs of a measure. Secondly, the effect of a measure in terms of changed nitrogen load flowing into the Black Sea was calculated. Finally the cost-effectiveness ratios in terms of annual cost occurring per annually saved unit of nitrogen load are calculated for the measures considered.

The internal costs of a measure consisting the change of average direct production costs, average indirect production costs and the average sales revenues based on gross output and gross margins (BMLFUW, 2002, BMLFUW, 2002a, MANEA, 2005, BONAZZI et al., 2005, MENZI and REIDY, 2005, RYAN, 2005, INTERWIES et al., 2004) of the agricultural producer, induced by the measure are determined. In case national cost data were not available completely, Austrian data were used and adjusted by either the index of general cost level, the index of the cost level for agricultural machinery or the index of the cost level for agricultural wages (Table 2).

Table 2 Indices of general cost level, of cost level for agricultural machinery and agricultural wages (in 2015) in Austria, Hungary and Romania used in the cost calculations (Index Austria = 100)

Country	General cost level in 2015	Cost level for agricultural machinery in 2015	Agricultural wages in 2015
Austria	100	100	100
Hungary	66	89	22
Romania	41	80	4

Source: IFIP, 2005; WIIW, 2005

The analysis of costs is based on the price level 2002/03. In addition it is assumed that the real price level in Hungary and Romania increases by 2% annually up to 2015 compared to Austria (see also IFIP, 2003, WIIW, 2005). In the present paper subsidies (constituting the main part of governmental costs) remain out of consideration, following the principles of cost-benefit-analysis, which considers real costs exclusively. Real costs are defined as the cost of resources, such as land, labour and material expended by agricultural producers.

To calculate the effects of selected measures first their impacts on the soil surface are determined by calculating the national nitrogen soil surface balance before and after carrying out the measure. According to the OECD-calculation scheme (OECD, 2001), the nitrogen soil surface balance is calculated as the difference between the total quantity of nitrogen inputs entering the soil and the total quantity of nitrogen outputs leaving the soil annually, a positive balance is called surplus. For the calculations production data, fertiliser input, nitrogen emission coefficients for livestock and rates of nitrogen fixation by crops were taken from the FAOSTAT (2004) databases as well as from national statistics (daNUbs, 2005) and adjusted to the scenarios. To calculate the nitrogen balances, after carrying out a specific measure, the induced changes in production and fertiliser input of this measure were estimated (daNUbs, 2005, IFIP, 2005). Thus the first effect of carrying out a specific measure is the change in the nitrogen surplus on the soil surface level.

A decreasing nitrogen surplus in the soil leads to a decreasing nitrogen load in the Danube River and consequently in the Black Sea. The magnitude of this induced effect on the Danube River and the Black Sea depends considerably on geological and climatic conditions in the countries examined. In order to obtain the nitrogen load entering the surface waters the calculated nitrogen soil surface surplus is used as an input for the MONERIS-model. The MONERIS-(MOdelling Nutrient Emissions in RIver Systems) model allows to calculate of the nitrogen loads (of both: point and various diffuse sources) into the surface waters and the main streams in the Danube River Basin. Thus the MONERIS model shows the transition of nitrogen from the soil into the hydrosphere. The model is based on data of river flow and water quality and on a geographical information system (GIS), which includes digital maps and extensive statistical information (SCHREIBER et al., 2003).

The final effect of a measure is the change of the annual nitrogen load flowing into the Black Sea. It is estimated by using average retention and transport factors for nitrogen in small surface waters and main streams (IFIP, 2005).

3. Results

Using the described methodology the costs of the measures specified as well as their effects on the nitrogen soil surface surplus and the nitrogen load flowing into the Black Sea are calculated. Subsequently, cost-effectiveness ratios for each of the measures are derived (see Table 3).

Costs: The internal costs accruing to the agricultural producer when carrying out a measure differ strongly depending on the area on which it is applied, on the structure of production regarding the kinds of agricultural products as well as on the cost levels in the countries examined. Both, measures imposing additional costs to the agricultural producers and measures increasing net profits are identified. For instance: increasing plant productivity by applying production techniques being capital intensive (M3) is commercially profitable in Austria and Hungary; however, in Romania this measure imposes costs and thus decreases net profits, because the cost-level for machinery which is involved in applying the measure is high in comparison to the general cost-level. In particular irrigation is a major capital investment (BUCHANAN and CROSS, 2004), hardly affordable for many agricultural producers in eastern countries of the DRC.

The measure reduction of direct nitrogen emissions to the hydrosphere (M4) includes a variety of labour saving techniques (minimum soil tillage zero tillage). However the measure M4 is labour intensive as a whole, because of the additional labour requirements linked with mulch seeding (KLIK et al., 2004), cover crops (BRUMFIELD and BRENNAN, 2004, KLONSKY et al. 2002) and intercropping (DANO and MIDMORE, 2004, CARR, 2004). Hence this measure imposes costs to the agricultural producers in Austria and Hungary, while it is profitable in Romania because of labour costs being low.

Although the implementations of measures having a negative cost-effectiveness ratio would increase the profits of agricultural producers in specific countries, these measures may not be carried out because high investment costs and a general lack of information are obstacles.

Effects of the measures: First the effects of the measures on the nitrogen soil surface surplus are estimated. If all the measures are put into effect, the nitrogen surpluses are cut by a third in each of the countries compared to scenario HP 2015. The total reductions achieved in Hungary respectively Romania are 4 to 5 times higher than in Austria mainly caused by the size of their agricultural area within the Danube River Basin. Because of the retention capability of soil and surface waters the absolute, but also the relative effects on the Black Sea are strongly reduced compared to the effects regarding the soil surface surplus. The nitrogen load entering the Black Sea is reduced by around 20% (AT: 17%, HU: 18%, RO: 24%) in comparison to HP 2015. The retention capability of soil and surface waters differs strongly in the countries examined, the highest retention capability being in Hungary. Hence the absolute effect on the nitrogen load flowing into the Black Sea originating from measures in Hungary is small, although that the agricultural area of Hungary within the Danube River Basin is vast.

Table 3 Internal costs (C), effects (E) and cost-effectiveness ratio (CER) of measures in Austria, Hungary and Romania regarding the nitrogen load flowing into the Black Sea in €/kg

	M1		M2		M3		M4		Bundles	
	CER [€/kg]	C [k€/a] E [t/a]	CER [€/kg]	C [k€/a] E [t/a]	CER [€/kg]	C [k€/a] E [t/a]	CER [€/kg]	C [k€/a] E [t/a]	CER [€/kg]	C [k€/a] E [t/a]
Austria	136	30,118 222	382	291,569 764	-75	-56,950 757	83	99,543 1,201	124	364,280 2,944
Hungary	85	5,892 69	1,253	217,681 174	-75	-78,018 1,038	58	35,030 606	96	180,585 1,887
Romania	23	6,616 291	239	364,686 1,524	8	35,522 4,411	-9	-31,635 3,635	38	375,189 9,861

Notes: M1: Accurate application of fertilisers regarding fertiliser amount and time related application rates, M2: Reduction of nitrogen emissions from manure, M3: Increase of plant productivity by applying production techniques being capital intensive, M4: Reduction of direct nitrogen emissions to the hydrosphere; k€= 1000 €

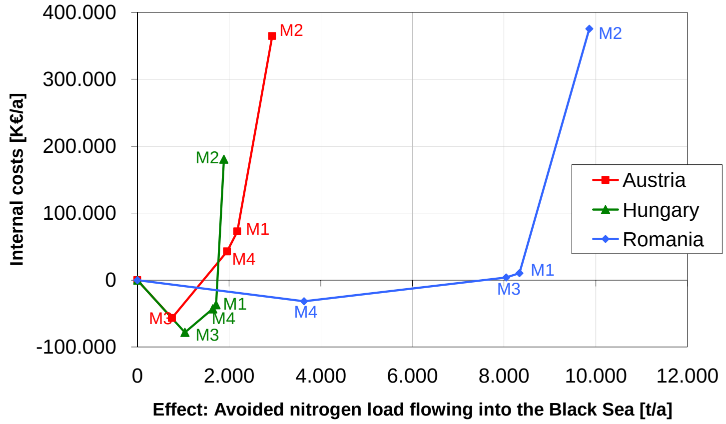
Source: IFIP, IGB, 2005

Cost-effectiveness ratios: From these results, costs of measures on the one hand and effects of measures regarding the reduction of the nitrogen load flowing into the Black Sea on the other hand, the cost-effectiveness ratios are calculated. In general the cost-effectiveness ratios in Austria are higher than in Hungary and Romania, because of the higher cost level in Austria. From the viewpoint of cost-effectiveness the most satisfactory measures are such measures that are commercially profitable and reduce the nitrogen load, like increasing plant productivity by applying production techniques being capital intensive (M3) in Austria and Hungary as well as reducing direct nitrogen emissions to the hydrosphere (M4) in Romania. The highest cost-effectiveness ratios are determined for the measure reduction of nitrogen emission from manure (M2) in all of the countries examined, because of the high degree of investment necessary. If all of the specific measures are carried out simultaneously the overall cost-effectiveness is positive in each of the countries. The lowest cost-effectiveness ratio is calculated for Romania, the highest for Austria.

Ranking and combining measures - an approach to optimisation based on cost-effectiveness: In case bundles of measures shall be assembled for each country examined, a cost optimal choice of measures is possible. On the one hand the minimal costs for a required reduction of the nitrogen load flowing into the Black Sea can be derived; on the other hand the highest possible effect with a given budget can be obtained.

The measures have to be ranked within the countries according to their cost-effectiveness ratios. The first measure that is to be chosen in a country is the measure with the lowest cost-effectiveness ratio (AT, HU: M3; RO: M4; a reduction of nitrogen load is achieved at negative costs i.e. carrying out these measures is profitable for the agricultural producers concerned). The second measure to be chosen is the one with the lowest cost-effectiveness ratio of the remaining measures (AT, HU: M4; RO: M3; a reduction of nitrogen load is achieved having positive costs), etc. Figure 1 shows the aggregated costs and effects of combined measures. In this way one measure after the other is chosen to be carried out, (a) as long as the total costs of carrying out all the selected measures (optimal combined measures) do not violate a specified budget constraint or (b) until a required effect is achieved.

Figure 1 – Cost optimal combination of measures in Austria, Hungary and Romania: Avoided nitrogen load flowing into the Black Sea and internal costs accruing to agricultural producers for ranked and combined measures according to their cost-effectiveness.



Notes: M1: Accurate application of fertilisers regarding fertiliser amount and time related application rates, M2: Reduction of nitrogen emissions from manure, M3: Increase of plant productivity by applying production techniques being capital intensive, M4: Reduction of direct nitrogen emissions to the hydrosphere
Source: IFIP, 2005.

4. Conclusions

The total effect, in terms of avoided nitrogen load flowing into the Black Sea, that could be achieved, is by far the highest in Romania, having in general also the lowest cost-effectiveness ratios. In each country, it would be possible to decrease the nitrogen load flowing into the Black Sea by implementing measures that are profitable to the agricultural producers. On average, one third of the reduction of nitrogen load could be achieved in a profitable way for the agricultural producers. However, in many cases obstacles like high investments linked with cost of capital and lack of information are not overcome and thus such measures are often not implemented.

A second third of the reduction of nitrogen load would require only slight costs which would be compensated by the costs of the profitable measures (first third). The last third could be achieved by measures with comparatively high costs per avoided unit of nitrogen.

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