Analyzing the effect of agri-environmental policies on nitrate concentration in groundwater

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***Abstract* - The Austrian agri-environmental program (ÖPUL) from 2000 to 2006 introduced a range of measures to reduce nitrate concentration in groundwater. By performing regression analyses on a country-wide data set, this study is the first attempt to measure the partial effects of ÖPUL on nitrate concentration in groundwater while controlling the effect of site specific factors (e.g. land cover, weather and soil types), known to influence nitrate concentration. Our results reveal that subsidies for organic farming, reduced use of production means on grassland, and prevention of soil-erosion on arable land have a measurable negative impact on nitrate in the groundwater. For other measures, no negative effects were found. While still preliminary, the results show how careful regression analyses can advice future agri-environmental program development.**

INTRODUCTION

To protect waters against pollution caused by nitrates from agricultural sources, the threshold of acceptable nitrate concentration in groundwater has been set to 50 mg/l by the EU Directive 91/676/EEC. In Austria, the average nitrate concentration in groundwater has on average decreased from 26 mg/l in 1992 to 21 mg/l in 2008, but there is a high variation among the nine provinces (Wick et al., 2012). From 1995 onwards a set of agri-environmental measures (ÖPUL – Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft) was introduced aiming to provide an integrated, horizontal approach covering the majority of Austrian farms. Already in 2004, ÖPUL covered 89% of agricultural lands and 78% of all farms. Within ÖPUL 2000-2006 (referred to as ÖPUL 2000) 32 specific programs are offered, of which 21 are supposed to be effective or strongly effective in reducing nitrate concentration in groundwater (BMLFUW, 2005).

Hence, we evaluate (i) which impact did the strongly effective and effective measures of ÖPUL 2000 have on nitrate concentration in Austrian groundwater? (ii) Which other determining, site-specific, factors (land cover, soil characteristic and weather) determine nitrate concentration in groundwater? We investigate these effects by regression analyses based on a data set with ~1200 Austrian municipalities from 1999 and 2002 to 2006.

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DETERMINING FACTORS OF NITRATE CONCENTRATION IN GROUNDWATER

Soil types and composition have been found to determine nitrate concentration in groundwater. E.g. high levels of water storage capacity may decrease and a high volume of stones may be prone to nitrate leaching (e.g. Donner et al., 2004). The effect of precipitation and maximum temperature on nitrate concentration is ambiguous: High levels of precipitation were found to correlate positively, due to nitrate leaching, (e.g. Davis and Sylvester-Bradley, 1995), but also negatively, due to dilution or fostering nitrogen uptake, with nitrate concentration in groundwater (e.g. Sieling and Kage, 2006). Annual average maximum temperature is suggested to lead to high soil mineralization rates, increasing nitrate concentration, or to lower nitrate concentration due to slowing process of mineralization (Schweigert et al., 2004, Wick et al., 2012). Investigations on farm/field-scale found that policies supporting fallow fields, the greening of agricultural land in fall/winter, reduction of nitrogen fertilizer, and the fertilization close to the soil could reduce nitrate concentration in groundwater (e.g. BWA and WPA 2008, WPA 2003).

MATERIALS AND METHODS

Data

We extend the dataset used in Wick et al. (2012) by the ÖPUL 2000 policies from the IACS (Integrated Administrative and Control System) database (BMLFUW, 2010). We included 12 ÖPUL measure as percentage share of total agricultural land in the municipality (Table 1 lists these measures). Nitrate concentration in groundwater (mg/l) is provided by the Federal Environment Agency Austria, of land cover from the CORINE Land Cover database 2006 (Umweltbundesamt, 2010), weather (precipitation in mm and maximum temperature in degrees Celsius from ZAMG (Central Institute for Meteorology and Geodynamics), and soil characteristics (field water capacity in cm3/cm3, volume of stones) from the European digital soil map (Balkovic et al., 2007). We use data from 1999 and 2002-2006, aggregated on annual and municipality level, in our analysis.

Method

We use pooled ordinary least square model with robust errors clustered by municipality to control for the panel structure, to calculate the partial effects of the ÖPUL measures on nitrate concentration. We consider three different model specifications:

$$(1)\ N_{i,t} = X\beta + u_{i,t}$$

$$(2)\ N_{i,t} = X\beta + \gamma N_{i,t-1} + u_{i,t}$$

$$(3)\ N_{i,t} - N_{i,t-1} = X\beta + u_{i,t}$$

where $N_{i,t}$ is the nitrate concentration in groundwater (mg/l) of municipality *i* in period *t*, *X* a matrix of explaining variables including a constant, and $u_{i,t}$ are the error terms. The coefficients β measure the impact of the explaining variables on nitrate concentration (1) or, the change of nitrate concentration compared to the previous year (3). Model (2) includes the lagged level of nitrate levels as explaining variable. We also include year dummies with year 1999 as reference period.

RESULTS AND CONCLUSION

The regression analysis (Table 1) yields the expected results for weather, land cover and soil variables. For all models, F-Test confirms that the ÖPUL 2000 measures have a jointly significant effect. Individually, only some ÖPUL 2000 measures have a significant influence on nitrate concentration in the groundwater. Model (1) reveals significant positive effects of several ÖPUL measures, which is surprising and might be due to omitted variables. Several ÖPUL measures will mainly be applied in municipalities with high share of agricultural land which might have high levels of nitrate concentration already. Model (3), with the first difference of nitrate concentration as dependent variable, suggests that organic farming, reduction of production means on grassland, and the prevention of soil-erosion on arable land significantly reduce nitrate concentration. The influence of other policies seems not measurable by the estimated model. The regional project of Salzburg has a significant positive coefficient. Possibly as the respective municipalities belong to the same groundwater body, in which nitrate concentration increased over the years. These results remain preliminary and future work, e.g. investigating the influence of combined measures or control for spatial correlations, is planned.

Table 1. Results of the regression models.

	Nitrate Model (1)	Nitrate Model (2)	Nitrate Model (3)
Constant	37.6***	9.9**	1.21
Lag nitrat level		0.8***	
Mean Precipitation	-0.3	-0.1	-0.07
Mean max. temperatur	-0.6*	-0.1	0.06
Share arable land	34.6***	10.8***	3.34**
Share grassland	2	0.4	-0.06
Field water capacity	-59***	-16.6**	-3.35
Volume of stones	0.2	0.1	0.07
Oranic farming aystems	-3	-2.6**	-2.53**
Abandonment prod. means grassland	4.5**	1.6	0.75
Abandonment prod. means arable land	19.1*	4.8	0.36
Reduction prod. means grassland	-1.1	-3.2	-3.82*
Reduction prod. means arable land	15.8***	3.2**	-0.78
Greening arable land	-1.4	0.3	0.85
Prevention of soil-erosion	-38**	-17***	-10.4*
Maintain. ecolog.relev. areas	-29.6**	-11**	-5.23
Newly devel. landscape elements	16.1	-45	-64.7
Regional measures Niederösterreich	13.9***	2.9*	-0.61
Regional measurs Salzburg	0.02	1.5	1.9**
Preventive water protection	8.2***	1.9**	-0.04
Observations	5,866	5,866	5,866
R-squared	0.37	0.74	0.01

Note: robust significance levels: ***p<0.01,** p<0.05, * p<0.1; Year dummies are not included in the results table

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