Agriculture and nitrate contamination in Austrian groundwater: An empirical analysis

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***Abstract* – Agriculture is one sector contributing to nitrate emissions in groundwater. Even though nitrate concentration in Austrian groundwater has been decreasing over the last two decades, a satisfactory explanation for the variation over municipalities as well as time is still missing. In the course of this study we investigate site characteristics and agricultural production factors influencing nitrate content in groundwater by means of regression analysis. Accounting for a time dimension, our explanatory variables include precipitation, soil characteristics, and crop cultivation choice. Preliminary results show that precipitation exerts a non-monotonous effect on nitrate concentration. In addition, higher soil quality, among others indicated by the *Bodenklimazahl,* is positively related to the variable of interest. Finally cropland cultivation impacts positively on nitrate concentration in groundwater whereas grassland has a negative effect.**

INTRODUCTION AND MOTIVATION

Nitrogen is one of the major nutrients applied in agriculture to increase crop production. Nitrate is highly soluble and excess easily leaches into groundwater aquifers, where it can become a contaminant of drinking water.[2] The EU directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources sets the acceptable threshold of nitrate concentration in groundwater to 50 mg/l.

This critical value is reached in some regions of Austria. Additionally, monitoring of groundwater aquifers shows a high variation of nitrate levels over time as well as over provinces (Umweltbundesamt, 2009). Nitrate concentration in the entire country has on average decreased over the past 18 years from 26 mg/l in 1992 to 21 mg/l in 2008. However, it can be seen in Figure 1 that there is a large variation among provinces. Nitrate concentration is traditionally low in Salzburg, Tirol and Vorarlberg, whereas in the regions of Wien, Niederösterreich and Burgenland the content is very high. A general downward trend is observed in all nine provinces of the country though.

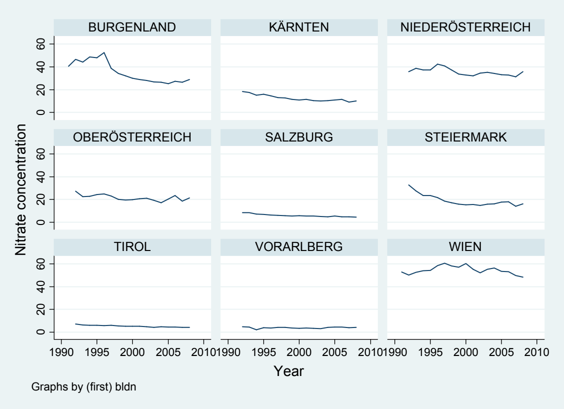

Figure 1. Average nitrate concentration in the nine Austrian provinces between 1991 and 2008 in mg/l

Since bio-physical and chemical aspects which influence the nitrate conversion are very complex, research into the proximate causes for this variation is still scarce. The tool of regression analysis can help to estimate a functional relationship between likely causes and effects. Having access to detailed data from various sources, we attempt to identify factors influencing nitrate concentration in groundwater aquifers.

In particular we investigate the following questions:

- What is the role of precipitation, different land categories, soil characteristics, land uses and animal husbandry in explaining the concentration of nitrate in groundwater?
- How can the difference of nitrate concentration over provinces be explained?
- What are the temporal dynamics of nitrate contamination over quarters?
- Are there spatial patterns of nitrate concentration in groundwater aquifers?

DATA

To answer these questions, variables provided by the following data sources are used: The data on nitrate concentration (*Nitrate*) in groundwater is taken from the water monitoring system of the Umweltbundesamt (2009). Data are available on a quarterly basis from 1991 to 2008 on municipality level for all of Austria. We further include data on precipitation (*Precip*) on a daily basis, taken from selected weather stations provided by ZAMG (Strauss et al., 2009). Data on soil characteristics (*SoilQu*) are from the European digital soil map (Balkovic et al., 2007), as well as the *Bodenschätzungsgesetz* (1970). Information on crop

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[2] http://www.nitrabar.eu/uk/2-2-nitrogen-cycle.html, August 2009

cultivation choices on farm level is taken from the IACS database and available for the year 1999 as well as 2002 to 2006. All data has been aggregated on a quarterly basis on municipality level, to make it comparable with the dependent variable measurements.

Empirical Analysis & Preliminary Findings

The focus until now has been on two main model specifications:

First, given the new availability of detailed precipitation data, we pay special attention to its role in determining nitrate concentration levels in groundwater. Following the literature (Pardeller, 1996), precipitation is conjectured to play an important role through leaching as well as dilution processes. To account for these effects, we estimate a fixed effects panel data model with year dummies, thus controlling for time-constant characteristics of municipalities as well as annual effects, which impact on all municipalities in the same way. The time dimension (*t*) in this setting is given by quarters, whereas the cross-sectional dimension (*i*) are municipalities. We include a linear as well as a squared term measuring average daily precipitation levels of the preceding quarter to allow for rainfall to have a non-monotonous effect on nitrate concentration. The estimated equation takes on the following form:

$$Nitrate_{it} = a_i + \beta_1 Year_t + \beta_2 \mathrm{Precip}_{it-1} + \beta_3 \mathrm{Precip}^2_{it-1} + u_{it}$$

Our results indicate that precipitation initially has a negative effect on the concentration of nitrate in groundwater. As the amount of rainfall increases, this effect weakens (i.e. we find a statistically significant positive coefficient on the squared term). This non-monotonous effect of precipitation on nitrate contamination of groundwater might be explained by the two counteracting effects mentioned – the leaching and the dilution effect.

The second model investigated, concentrates on alternative factors influencing nitrate concentration. In particular special attention is paid to soil characteristics as well as land use choices. Since major soil characteristics are usually constant over time and also the latter variable offers very little within variation, we perform a pooled OLS regression analysis. The estimated regression equation is the following:

$$\begin{aligned}
Nitrate_{it} &= \beta_0 + \beta_1 Year_t + \sum_j (\beta_{2j} SoilQu_{ijt}) + \\
&+ \beta_{41} \mathrm{Prop\_crop}_{it} + \beta_{42} \mathrm{Prop\_grass}_{it} \\
&+ \beta_{51} \mathrm{Prop\_crop} * Hu1_{it} + \beta_{52} \mathrm{Prop\_crop} * Hu2_{it} \\
&+ \beta_{61} \mathrm{Precip}_{it-1} + \beta_{62} \mathrm{Precip}_{it-1} * Hu1 + \beta_{63} \mathrm{Precip}_{it-1} * Hu2 \\
&+ u_{it}
\end{aligned}$$

The subscript *j* in the above regression refers to a specific soil quality. The higher soil quality, reflected by the *Bodenklimazahl*, the higher the nitrate concentration in groundwater. This finding might be rationalized by the fact that soils with a higher *Bodenklimazahl* tend to be cultivated more intensely (Pardeller, 1996). The coefficient of field water capacity, is negative and significant. The higher the field water capacity, the more water is retained and thus the lower the leaching effect. Also, accounting for differing soil composition we find that the amount of humus in a specific layer is of importance when it comes to quantifying the effect of cropland on nitrate contamination (*Hu1, Hu2*).

The proportion of cropland (*Prop_crop*) in a municipality exerts a positive effect, whereas the proportion of grassland (*Prop_grass*) tends to be negatively related to nitrate contamination. These findings are most probably due to differing nitrate leaching potentials between the two land types. Finally, precipitation (*Precip*) has a positive coefficient in this setup. This is due to the fact that this particular regression only includes the years 1999 and 2002-2006 since data on cultivation choice was only available for this time span. In this subsample the mean precipitation level is significantly higher than in previous years, thereby confirming the results discussed above. The effect of precipitation is influenced by differing soil qualities. Much humus in the first layer (*Precip*Hu1*) weakens the positive effect of rainfall in this subsample, whereas high humus content in the second layer (*Precip*Hu2*) has the opposite effect.

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