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Extended Abstracts

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Cost-effective measures to control and contain groundwater contamination

title: **Fertilizer standards vs fertilizer taxes to control groundwater nitrate pollution from agriculture**

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Economic theory mentions different control mechanisms of environmental externalities. Policy mechanisms used for agricultural non-point pollution control are direct regulations (emission standards), economic instruments (as pricing schemes or as incentives via subsidies) applied either directly to the emissions or based on some emission proxies (like polluting inputs or certain agricultural practices), and tradable emission or pollution permits.

In this paper we compare the cost-effectiveness of direct regulation (fertilizer application standards) and fertilizer taxes as policies to control groundwater nitrate pollution. A hydro-economic model is used to determine the most cost-efficient distribution of fertilizer standards constrained by the groundwater quality requirements at various control sites. These results are compared with farmer's response to an increase in fertilizer price. The modelling framework relates the fertilizer loads with the nitrate concentration at the control sites, i.e., the ambient standards (Peña-Haro et al., 2009). Agronomic simulations are used to obtain the nitrate leached, while numerical groundwater flow and solute transport simulation models are applied to develop unit source solutions assembled into a pollutant concentration response matrix. The benefits in agriculture were determined through crop prices and crop production functions. The methodology was applied to the El Salobral-Los Llanos aquifer in Spain, where nitrate concentrations in some water supply wells has reached values of 54.1 mg/l (Moratalla et al., 2009). This research aims to contribute to the ongoing policy process in the Europe Union (the Water Framework Directive) providing a tool for analyzing the cost of measures for reducing nitrogen loadings and assessing their effectiveness for maintaining groundwater nitrate concentration within the target levels.

1. FERTILIZER STANDARDS

The fertilizer standards to control GW nitrate pollution from agriculture are analyzed by means of different scenarios:

Scenario 1: Business-as-usual scenario, where nitrate concentrations are simulated considering the fertilizer application rates of 2005.

Scenario 2: Fertilizer application was optimized in order to maximize the total net benefits, without groundwater quality restrictions

Scenario 3: Maximum nitrate fertilizer application to control nitrate pollution (reference values) as defined by Castilla La Mancha regional government

Scenario 4: The optimal spatial distribution of fertilizer application over 50 years of planning horizon is determined by using the hydro-economic model (Peña-Haro et al., 2009). A recovery time in 2015 is defined based on the environmental objectives of the EU WFD.

Table 1. Results for the different scenarios.

	Average fertilizer application (kg/ha)	Is max nitrate concentration at control sites below WFD standards?	Total net benefits (M€/year)
Scenario 1. Business as usual	240.4	NO	96.6
Scenario 2. Maximum benefits	218.7	NO	96.7
Scenario 3. Reference values	157.8	NO	80.9
Scenario 4. Optimal fertilizer 2015	201.1	YES (after 2015)	95.4

2. FERTILIZER TAXES

Several optimizations were performed to obtain the fertilizer tax that would reduce its use to the WFD standards. The fertilizer price is increased until nitrate concentration in groundwater was below 50 mg/l. It seems that farmers are not sensitive to fertilizer tax until it reaches a very high level.

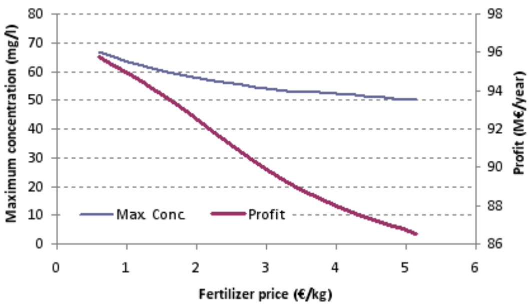

Figure 1. Maximum nitrate concentration forh different fertilizer price and total benefits.

CONCLUSIONS

The results obtained for the BAU or baseline scenario (scenario 1) show that following the current fertilizer application rates does not guarantee to comply with the "good groundwater chemical status" required by the WFD, since the standard of 50 mg/l of nitrates would be overpassed.). The fertilizer application that generates the maximum net benefits (scenario 2) are lower than those obtained by calibration of the nitrate transport model in order to reproduce the observed nitrate concentrations in scenario 1 (which are also a bit higher than those reported in the official surveys). The reference values requested by the authorities because of the definition as "nitrate vulnerable zone" maintain groundwater nitrate concentrations stable; however, the maximum nitrate concentrations are still over 50 mg/l, since the initial values (year 2005 concentrations) were already above the target value. The total net benefits of this scenario is lower than for the scenario 4 (optimal fertilizer application constrained by the quality standards) because the reduction was applied to all crops without taking into consideration the influence of the spatial distribution of the crops upon nitrate concentrations in the control sites. The scenario 4 showed the fertilizer application rates that will yield the maximum total net benefit while complying with the quality standards for two different horizons: year 2015 and year 2021. Therefore, these values can be interpreted as the "fertilizer standards" that should be imposed in order to meet the standards at the least cost. Even though the policy of fertilizer standards has appeared as more cost-efficient, in real applications it can be difficult to implement and to control. hen applying fertilizer taxes the fertilizer price has to be increased up to 5.15 €/kg to obtain nitrate concentrations below 50 mg/l in all control sites (Fig. 1). Therefore a tax of 858 % would be required, thus leading to a lower profit of 86.6 M€/year. The benefits obtained by increasing the fertilizer price are 8.9 M€/year, lower than those obtained from the fertilizer standards corresponding to scenario 4. Fertilizer taxes are a promising policy option, easier to apply and control. Some countries are now discussing its practical implementation.

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