Geophysical Research Abstracts,
Vol. 10, EGU2008-A-10329, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-10329
EGU General Assembly 2008

A hydro-economic modelling framework for reducing groundwater nitrate concentration from agricultural sources

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Nitrate is among the most common and widespread pollutants in groundwater, mainly resulting from non-point source pollution from agriculture and livestock. In the last decades, the automation of the agriculture and the introduction of high-yielding crops have raised the use of fertilizer. The monitoring networks in the EU indicate that about 20% of groundwater bodies suffers nitrate concentrations over 50 mg/l, and 40% over 25 mg/l. Nitrogen from agricultural sources accounts for between 50 and 80% of the nitrates entering Europe's water. High nitrates concentration in groundwater deteriorates water quality inducing economic and ecological problems. Excessive amounts of nitrates in water can also generate eutrophication and are negative for human health. One must ensure that public funds are conveniently allocated to measures and regions according to their potential in reducing nitrate concentration. Therefore, it is important to compare the costs of different measures to their effectiveness in improving groundwater quality. Although the legislation on groundwater quality refers to the pollutant concentration, the effects of most measures on groundwater quality are often evaluated in terms of their emission reduction potential at the source, not on their capacity of reducing the pollutant concentration in groundwater.

The objective of this research is to develop a modelling framework for helping in decision-making on nitrogen use in agriculture for controlling non-point groundwater pollution while minimizing economic losses in agriculture. The management model seeks to maximize the benefits in agriculture, and it is based upon non-linear program-

ming and numerical simulation. The decision variables are the fertilizer applications, constrained by the maximum nitrate concentration allowed in groundwater at various observation wells. The methodology utilizes a concentration response matrix that shows the concentration over time at different points of interest throughout the aquifer, resulting from multiple pollutant sources distributed over time and space. Groundwater flow and solute transport simulation models were used to develop unit source solutions that were assembled into the concentration response matrix. The benefits in agriculture were determined through crop prices and crop production functions, and groundwater nitrate loads were obtained from nitrate leaching functions for each crop.

The management model has been applied to a complex hypothetical groundwater system, for which optimal solutions to problems with successively longer management time horizons were determined.

This methodology allows to determine the best allocation of fertilizer reduction among different sources and over time, so that the agricultural income losses that these reductions represent are minimized, in order to accomplish with the groundwater nitrate concentration limits. It aims to help in the definition of the most cost-efficient packages of measures to attain the objectives established in the EU Water Framework Directive. This methodology is also intended to be used in analyzing different policies to control non-point groundwater pollution and to estimate the efficiency of those measures in terms of its influence upon the reduction in the nitrate concentration. This methodology takes into account the aquifer characteristics, flow pattern, solute transport mechanisms, crop yields and nitrate leaching.