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ANALYSIS

Agricultural water nonpoint pollution control under uncertainty and climate variability

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Abstract

The objective of this paper is to study the probabilistic cost-effectiveness of the farm management practices supported by the European Union for reducing nitrate pollution. Our method consists in using a bio-physical model to evaluate the environmental and economic impacts of various scenarios characterized by a set of farm practices. The cost-effectiveness of each scenario is calculated for a catchment area located in the northeast of France, for various climatic years and under different assumptions of crop prices. The results show that it is not realistic to obtain a rapid reduction of nitrate concentrations by implementing the scenarios tested. In the long run and irrespective of the economic context simulated, the optimum scenario in the case studied is one that combines integrated fertilization with the introduction of catch crops. Our findings thus highlight the effectiveness of catch crops that are able to reduce variability of nitrate concentration and thus significantly reduce the risk of exceeding environmental constraints. They therefore provide some recommendations for policy-makers.
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Keywords: Stochastic nitrate pollution; Interdisciplinary approach; Cost-effectiveness analysis; Cropping systems; Environmental policies; Environmental constraints

1. Introduction

For several years, scientists and environmental agencies have reported an increase in the water nitrate concentration, especially in Europe and the USA. It has been established that this pollution is due, for the most part, to agricultural activities especially to intensive farm management practices (European Environment Agency, 2001; US Geological Survey, 1999). Although the effect of high nitrate concentration on human health is still a controversial issue (Addiscott et al., 1991; Apfelbaum, 1998), several environmental policies have been defined in order to control agricultural nitrate pollution. Controlling nitrate pollution is usually considered as the first step towards a wider control of agricultural water pollution

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in the sense that a better management of the nitrogen cycle will initiate an essential process of technical and organizational learning-by-doing to control phosphorus and pesticide pollutions as well. These policies rely mainly on legal instruments (command and control approach), such as limitation on the authorized level of pollutants or the designation of protected areas, and rarely use economic instruments (incentive-based approach). Some economic incentives have nevertheless been implemented in order to encourage farmers to improve their practices. These schemes are voluntary and involve farmers entering into management agreements in return for financial compensation. Contractual obligations regulate such production practices as the 'best management practices' (Clean Water Act Amendments, 1987) in the USA, the 'agri-environmental measures' (Council Regulation No. 2078/92/EEC) in Europe and the 'Nitrate Sensitive Areas scheme' in the United Kingdom (Szoege et al., 1996). Similar environmental policies are likely to be more important in the near future, especially in European Union countries. Economic and environmental assessment of these policies is therefore of prime importance.

Contractual obligations are based on agronomic recommendations but their efficiency conditions have not been precisely assessed. The uncertainty and climate variability of their economic and environmental impacts have not been significantly explored. Can these standard practices have a significant environmental impact every year, in any agronomic and hydrologic system? Can they minimize the economic burden of pollution control in any context? This paper considers these questions. The aim is to provide useful assessments for policy makers in order to determine efficient management practices for controlling agricultural pollution.

Due to the complexity of interactions between economic, agronomic and hydrologic systems, to the stochastic nature of some factors (e.g. climate, soil, topographic conditions), and to the lack of knowledge, the consequences of management practices recommended by state authorities cannot be accurately predicted. Uncertainty is particularly high in the case of nitrate pollution because many factors are involved. For instance, climate and pests affect crop growth and nitrogen use efficiency, temperature influences the nitrogen cycle in the soil, especially nitrogen mineralization, and the nitrate runoff depends on rainfall and soil characteristics. Mc Sweeny and Shortle (1990) have developed the cost-effectiveness approach in order to take into account uncertainties in both the efficiency and the cost of the proposed management practices. In their approach, known as the probabilistic cost-effectiveness approach, the uncertainty in the runoff rate value is described by means of a random variable. Bystrom et al. (2000) used a similar approach to study the interest of wetlands for controlling nitrate pollution. The main limitation of these studies is that uncertainty is described very roughly by means of very simple probability functions. In these functions, uncertainty due to climate variability and uncertainty due to lack of knowledge are not distinguished. Moreover, the level of uncertainty (i.e. the variances of the random variables) is fixed arbitrarily.

An alternative solution would be to use bio-physical models. Such models can serve to predict crop yield, crop quality, water and nitrogen flows in relation to field characteristics and management practices (Wagenet and Hutson, 1996). Agronomists and economists have already explored this way (Ribaudo et al., 2001; Vatn et al., 1999; Weaver et al., 1996). However, they used a deterministic function for analyzing water-related environmental impacts of agriculture and did not study the influence of climate variability on the results of a pollution control policy. Most of the bio-physical models include climatic variables. Since they are linked with economic models, implemented at the catchment scale, such models can be interesting for studying the between-year variability of the cost-effectiveness of various farm management practices. Another advantage of bio-physical models is that, in some cases, the errors of the model have been extensively studied (Gorres and Gold, 1996). It is then possible to define realistic probability functions for describing model errors on the basis of large data sets. Such probability functions give a realistic representation of uncertainty due to the lack of knowledge.

In this paper we use a bio-physical model to assess the probabilistic cost-effectiveness of the farm management practices supported by the European Union for reducing nitrate pollution. Six nutrient management scenarios are examined. Each scenario is characterized by a set of farm practices defined for

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