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An integrated modelling and multicriteria analysis approach to managing nitrate diffuse pollution: 2. A case study for a chalk catchment in England

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Abstract

The site-specific land use optimisation methodology, suggested by the authors in the first part of this two-part paper, has been applied to the River Kennet catchment at Marlborough, Wiltshire, UK, for a case study. The Marlborough catchment (143 km^2) is an agriculture-dominated rural area over a deep chalk aquifer that is vulnerable to nitrate pollution from agricultural diffuse sources. For evaluation purposes, the catchment was discretised into a network of 1 km × 1 km grid cells. For each of the arable-land grid cells, seven land use alternatives (four arable-land alternatives and three grassland alternatives) were evaluated for their environmental and economic potential. For environmental evaluation, nitrate leaching rates of land use alternatives were estimated using SHETRAN simulations and groundwater pollution potential was evaluated using the DRASTIC index. For economic evaluation, economic gross margins were estimated using a simple agronomic model based on nitrogen response functions and agricultural land classification grades. In order to see whether the site-specific optimisation is efficient at the catchment scale, land use optimisation was carried out for four optimisation schemes (i.e. using four sets of criterion weights). Consequently, four land use scenarios were generated and the site-specifically optimised land use scenario was evaluated as the best compromise solution between long term nitrate pollution and agronomy at the catchment scale.

Keywords: River Kennet; SHETRAN; Nitrogen modelling; DRASTIC index; Agricultural land classification grade; Site-specific land use optimisation

1. Introduction

In order to pull together the range of existing European legislation on water in a coordinated manner, the EU Water Framework Directive (2000/60, WFD) came into force in December 2000, as a com-

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prehensive package to ensure all European waters are protected according to a common standard. The main purpose of the WFD is to establish a framework that prevents further deterioration and protects and enhances the status of aquatic and terrestrial ecosystems. The WFD adopts river basin districts as planning/management units to tackle water pollution from both point and diffuse sources. Under the WFD, catchment management plans must take into account various stakeholders' interests in diffuse pollution problems. As trade-off relationships between the agronomy and the environment are common over land uses within a catchment, one of major concerns of catchment management plans is how to balance the trade-offs over land uses at the catchment scale.

Every piece of land has its own unique characteristics with different potential. However, when a piece of land is used for certain purposes, it is very common that only some of the potential is taken into account and other potential is ignored. In such cases, the other potential that is ignored may in time cause unexpected, often troublesome consequences. Nitrate pollution of waters caused by agriculture can be regarded as an example of such ignorance—only agronomic potential of land is mostly considered and pollution potential is rather ignored.

As far as agriculture is concerned in the context of the WFD, there are two principal goals. One is to maximise the economic return and the other is to minimise the ecological damage. In practice, the latter means minimising diffuse pollution from the agricultural land. As these two goals generally conflict with each other, the question is how to maximise the economic return and, at the same time, minimise the diffuse pollution, both at the catchment scale. It is impossible to reach the ideal conditions of both goals at the same time because of the trade-off relationship between the two goals. It is therefore necessary to compromise between the two goals by improving the status of one goal at a cost of the other, or vice versa. If a catchment is physically homogeneous, the catchment can be treated as a whole and thus a compromise at the catchment scale is simple. However, if a catchment is not homogeneous, which is most often the case, it is difficult to make a compromise at the catchment scale because the catchment cannot be treated as a whole due to its physical heterogeneity. One solution is to divide the catchment into grid cells in each of which physical characteristics are assumed to be homogeneous and then compromise between the two goals for individual grid cells. A good compromise at the grid scale, however, does not necessarily mean a good compromise at the catchment scale. To assure the compromise is good at the catchment-scale, relative significance of physical characteristics across the catchment needs to be taken into account for the compromise at the grid scale. For example, for the overall efficiency at the catchment scale, some areas with a high pollution potential may need to be very strictly controlled rather than a moderate uniform control everywhere. This site-specific approach with a perspective view of the whole catchment may provide a good starting point for tackling diffuse nitrate pollution problems in the WFD participatory process.

This study aims to test the site-specific land use optimisation methodology suggested by the authors (Koo and O'Connell, this issue) by applying the methodology to the River Kennet catchment at Marlborough, Wiltshire, UK, where a deep chalk aquifer underlies well-draining soils. However, it should be noted that this study is a purely academic approach and involves no actual participatory processes.

2. SHETRAN simulations for the Marlborough catchment

2.1. Marlborough catchment

The River Kennet is the largest tributary of the River Thames. It rises to the north-west of Marlborough and flows southwards and then eastwards passing through the towns of Marlborough, Newbury and Thatcham to its confluence with the River Thames at Reading. The River Kennet is a designated habitat for both cyprinid and salmonid fishes by the EC Freshwater Fish Directive (78/659/EEC).

The Marlborough catchment lies in the western edge of the River Kennet catchment, being the uppermost upstream area (Fig. 1). The catchment area is approximately 143 km^2 and is a rural area dominated by agriculture. The high quality of the rural landscape and the archaeological importance of sites such as the Avebury complex, a designated World Heritage Site, located in the middle of the catchment, ensures that the catchment is strongly protected from large-scale development.