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Efficiency of agricultural measures to reduce nitrogen deposition in Natura 2000 sites

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ABSTRACT

This paper quantifies the efficiency of emission control measures in agriculture at landscape scale on the N deposition and critical N load exceedances in Natura 2000 sites. The model INITIATOR2 was run with spatially explicit farm data to predict atmospheric emissions of ammonia. These emissions were input of an atmospheric transport model to assess the N deposition in the Natura 2000 sites. Using the Dutch province of Overijssel as a case study, calculations for the year 2006 show that only 35% of the N deposition in the Natura 2000 sites were caused by agricultural NH_3 emissions within the province. Comparatively most cost-efficient measures were low-emission application, followed by measures to reduce the protein content in feed. Relocating farms out of the Natura 2000 sites was very cost inefficient. Since critical N depositions of the Natura 2000 sites in Overijssel are largely exceeded in more than 90% of the area, the evaluated abatement measures were, however, not effective to reduce the area exceeding critical loads when only applied within the province Overijssel. Reductions of N deposition to a level below critical loads can only be achieved with the support of national and international emission reductions.

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1. Introduction

1.1. *N deposition threatens Natura 2000 sites*

Within the framework of the Habitats Directive (EC, 1991), the Natura 2000 network has been established. The Natura 2000 network comprises an EU wide network of nature protection areas to assure the long-term survival of Europe's most valuable and threatened species and habitats and it forms the centre piece of EU nature & biodiversity policy (Young et al., 2004). The provisions of the Habitats Directive require strict site protection measures to avoid deterioration. By introducing a precautionary approach ''plans and projects'' can only be permitted if they are shown to have no significant adverse effect on a Natura 2000 site (Article 6.3 of the Habitat Directive).

An important threat to terrestrial Natura 2000 sites is atmospheric nitrogen (N) deposition. High N deposition may lead to adverse effect on terrestrial ecosystems, such as the loss of plant species diversity (Bobbink et al., 1998; Ellenberg, 1985), this is considered as a relevant threat in the UN Convention on Biological Diversity (UN, 1992). This threat occurs throughout Europe, but it is specifically the case in high N deposition areas, such as The Netherlands. In order to protect Natura 2000 sites in The Netherlands against high N deposition, deposition targets were derived based on critical loads for N deposition (Van Dobben and van Hinsberg, 2008), further denoted as CLN. In The Netherlands almost 70% of the N deposition in Natura 2000 sites is caused by ammonia emission from agricultural sources (De Haan et al., 2008). As a result, Dutch policies on N deposition reduction emphasize reduction of ammonia emission from agriculture.

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1.2. Need for assessments at landscape scale

Different spatial scales can be distinguished which are relevant for environmental decision making. In Europe, environmental regulations for agriculture are formulated at the European scale, the national scale and the farm scale. At the European scale directives such as the Nitrate directive (EC, 1991), the Water Framework Directive (EC, 2000) and the Directive on Emission Ceilings (EC, 2001) have been established. At the national scale, legislation is often implemented through regulations on production, application and storage of manure and fertilizers. Farmers have to incorporate these regulations in strategic (''long term planning'') and operational (''daily'') management at the farm scale. For an overview of international and national (Dutch) emission regulations and targets for ammonia, we refer to Melse et al. (2009).

The landscape scale is often considered as a distinct scale for decision making within environmental policies (see e.g., Cellier et al., 2011). Therefore, in The Netherlands, generally provinces are responsible for the construction of maintenance plans that include region specific measures to protect the habitat from adverse effects, e.g., due to high N deposition. Especially for N deposition, the landscape scale is relevant because ammonia emission can be recaptured by the foliage of nearby ecosystems (Follador and Leip, 2009; Fowler et al., 1998). Sutton et al. (1998) showed that most of the emitted ammonia is deposited at a distance of less than 30 km. This is in line with the observation that habitats in the vicinity of livestock farms show marked changes in species diversity (Pitcairn et al., 1998). Furthermore, at the landscape scale the variability in both N deposition and CLN can accurately be taken into account. Dragosits et al. (1998), for example, show that deposition and expected impacts are highly spatially variable, with edges of woodland and small ''islands'' of semi-natural vegetation in intensive agricultural areas being most at risk from enhanced deposition. Conversely the centres of larger nature reserves receive less deposition than average. As a consequence of this local variability, national assessments at the 5 km grid level, as carried out in The Netherlands, underestimate and overestimate the occurrence of CLN exceedances due to NH_3 emissions in agricultural landscapes. Therefore, the need for N deposition estimates at a higher spatial resolution is imperative, e.g., a 250 m grid level or smaller. This holds also for CLNs that depend on special landscape features, such as different topography, soil types, hydrology and habitat type. The landscape scale thus seems an appropriate scale for assessing the efficiency of measures. The landscape scale may, however, become less relevant when the contribution of ammonia emissions to the ammonia deposition at this scale is small.

1.3. Assessing the cost efficiency of measures at landscape scale

The most important international policy in EU member states to protect the biodiversity of ecosystems, including Natura 2000 sites, against enhanced loads of reactive N is the Directive on Emission Ceilings (EC, 2001). However, even when countries are close to reach these emissions ceilings, there may still be a severe excess of CLN at local scale. For example, in 2008 the ammonia emission in The Netherlands was 131 kt NH_3, which was close to the ammonia ceiling of 128 kt NH_3, but CLNs were still largely exceeded, thus violating Article 6.3 of the Habitat Directive. This is because the current ammonia emission regulation is not strictly effect based, whereas the Habitats Directive implementation requires an effect based approach (see, e.g., Bealey et al., 2009).

To protect Natura 2000 sites against ammonia deposition and exceedances of CLN, regionally specific measures are thus needed, in addition to those taken to reach the national emission ceilings. In The Netherlands, provinces, which are in charge of the Natura 2000 network, focus on additional measures in spatial zones of 5–10 km surrounding the Natura 2000 sites. Insight is, however, needed in the efficiency of such measures, in terms of reduction of N deposition and exceedances of CLN, in relation to its associated costs. When the evidence about the benefits of environmental policy options is lacking, it may decrease motivation of farmers to implement measures. Stobbelaar et al. (2009), for example, indicated that environmental and conservation policies frequently fail to reach their targets.

To answer the question about cost-efficiency of measures at landscape scale, it is crucial that we accurately simulate the landscape scale link between agricultural management and environmental impact. This requires models that simultaneously assess atmospheric emissions from complex agricultural landscapes and deposition to nearby areas. An example of such a model is INITIATOR2 (Integrated NITrogen Impact Assessment Tool On a Regional scale) that can be used for an assessment of the efficiency of policies aiming at the simultaneous reduction of all relevant element fluxes (nutrients and contaminants) to atmosphere, ground water and surface water (De Vries et al., 2005).

This study quantifies the effects of a set of agricultural measures on the reduction in N deposition and CLN exceedance on Natura 2000 sites at landscape scale. The approach is illustrated for the Dutch province Overijssel, where measures are needed in addition to national and international policy to reduce CLN exceedance. For example, an evaluation of the Global Economy scenario for the N deposition in 2020 from The Netherlands Environmental Assessment Agency (MNP, 2006) resulted in a reduction of only 7% of the total N deposition in the Natura 2000 sites in Overijssel, i.e., 150 mol ha^{-1}, whereas the average exceedance is about 1250 mol ha^{-1} (Gies et al., 2008). The province is used as a case study, whose results are relevant throughout large parts of Europe, and aims to support policy development at landscape scale. The analysis starts with the assessment of the contribution of landscape-scale ammonia emissions to the N deposition in Natura 2000 sites, as this contribution largely determines the effects of measures at landscape scale. Furthermore, an indicative estimate is made of the costs of measures to gain insight in their cost-efficiency. Calculations are performed at a resolution of 250 m $\times$ 250 m grid cells, using the INITIATOR2 model (De Vries et al., 2005) coupled to the atmospheric transport model (OPS, Van Jaarsveld, 2004).

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