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Application of a genetic algorithm to minimize agricultural nitrogen deposition in nature reserves

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Abstract

The quality of Dutch nature reserves is threatened by high nitrogen input, a problem which to a large extent is caused by agricultural activities. The Dutch government intends to solve this by designating some areas where the emission level is allowed to increase and other areas where the emission level will have to decrease. Theoretically, this problem can be seen as a reallocation of emission sources.

In earlier research, the optimal spatial distribution of agricultural ammonia emissions to minimize atmospheric nitrogen deposition in nature reserves was determined. Linear programming (LP) has been applied because of the approximately linear atmospheric transport relations between emission and deposition locations. A more thorough analysis necessitates the addition of other nitrogen contributions important for the quality of nature, such as by groundwater and surface water transport. These processes can no longer be considered linear, so the application of non-linear optimization methods is necessary. Several non-linear programming methods can solve large-scale problems, but are not capable of dealing with non-smoothness and qualitative relations, especially when the number of variables and/or relations is large. In this study, the potential of genetic algorithms (GA) is evaluated, by comparing the GA results for the linear atmospheric emission–deposition process with results of LP. Kappa statistics and regression analysis were used to test the similarity of the spatial emission and

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deposition distributions on the GA and LP output maps. GA was shown to perform well, producing similar results to LP. Calculations in this article also showed that almost identical minimal deposition patterns may be achieved with somewhat different emission patterns. This is a potentially interesting feature for policy-makers, who may evaluate alternative emission distributions on a small scale, each with their specific socio-economic impacts, while still achieving optimal results for nature quality.

Keywords: Spatial optimization; Genetic algorithms; Agricultural nitrogen emission; Critical load; Kappa statistics; Map comparison

1. Introduction

Many plant species and ecosystems are dependent on soils and solutions with low levels of available nitrogen. As a result of human activities the amount of nitrogen available to Earth's ecosystems has more than doubled globally over the past century, causing many plant and animal species to become completely or locally extinct (Vitousek et al., 1997). One of the major threats is the atmospheric input of nitrogen (Galloway et al., 1995). Lakes and streams in geologically sensitive regions of Scandinavia, western Europe, Canada and the USA were affected by an increase in acidic and acidifying compounds in atmospheric deposition. Characteristic *Sphagnum* species in bogs in Denmark and the Netherlands were replaced by more nitrophilous species (Bobbink et al., 1998).

Mean atmospheric deposition of nitrogen in the Netherlands consists mainly of ammonia (ca. 70%), of which 80% originates in Dutch intensive agricultural activities (RIVM, 2002). For nature areas, this contribution can be even higher because these are often located close to agricultural areas.

Dutch policy aims at reduction of nitrogen deposition in nature areas to halt the deterioration of ecosystems. Besides measures to reduce total nitrogen emission, reallocation of emissions (in terms of intensification or expansion) can be used to reduce nitrogen deposition in nearby nature areas. In previous studies, we have used optimization techniques study the potential of reallocation of emissions (Van Dam et al., 2001; Heuberger et al., 1997; Heuberger and Aben, 2002). These techniques were applied in determining the optimal spatial distribution of agricultural emission sources with minimal atmospheric nitrogen deposition in nature areas, given a fixed level of total agricultural atmospheric nitrogen emission in the Netherlands.

The background for this approach lies in the way emission and deposition data are obtained at the Netherlands Environmental Assessment Agency (MNP). The NH_3 emission data are obtained from the Dutch Agricultural Economical Institute (LEI). These data are based on (actual counts of) numbers of animals, location and type of farms, cultivated area, production capacities, etc. After dedicated calculations, using additional information from various other institutes, LEI produces NH_3 emission data on a 500×500 m. grid.