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Modeling nitrogen loading from a watershed consisting of cropland and livestock farms in China using Manure-DNDC

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ABSTRACT

Nitrogen (N) losses from agro-ecosystems have become a serious issue over the past decades, causing a series of environmental problems, such as water eutrophication and air pollution. Estimating N discharges at a watershed scale to quantify the N fluxes released across various land-use components has long been a problem, especially for croplands and livestock farms, the two major sources of excess N, because of fertilizer use and livestock manure management. This study used Manure-DNDC, a biogeochemical, process-based model, to calculate N discharge fluxes from both crop fields and livestock farms within the Xiaoqinghe watershed in Shandong Province, China. The newly developed Manure-DNDC was tested against the crop growth, soil climate, and N leaching loss data measured in the watershed and showed encouraging results. A database containing daily weather data, soil properties, livestock farms, and cropping systems for the 182 towns included in the watershed was created to provide input information to support the model simulations at a watershed scale. The Manure-DNDC model was used to evaluate the 652,881 ha of cropland and 728 livestock farms in the watershed in 2008. The modeled N influxes to and effluxes from the agro-ecosystem in all towns were summarized to obtain the watershed-scale N fluxes. The modeled results indicated that about 184 million kg of N was applied annually as synthetic fertilizer in croplands, 297 million kg of N as feed introduced into the livestock farms, and 9 million kg N came from atmospheric deposition in the Xiaoqinghe watershed in 2008. The cropland soils received about 260 million kg of N, of which only 25.6% (67 million kg of N) came from manure amendment. The entire watershed released 127 million kg of ammonia-N into the air, including 42% from croplands and 58% from livestock farms. Other N gases, such as nitrous oxide, nitric oxide, and dinitrogen, were released into the atmosphere at a rate of 35 million kg of N per year. The N loads to surface water from livestock farms and crop fields were 47 and 7 million kg of N, respectively. About 24 million kg of nitrate-N was leached from the cropping systems, which could be loaded to both surface water and groundwater. The modeled results were compared with observations, which yielded encouraging results.

1. Introduction

Chemical fertilizer application substantially increased crop production in China during the 20th Century. However, the overuse of nitrogenous fertilizer has introduced excess nitrogen (N) into the environment in various forms (Carpenter et al., 1998). Over the past decades, livestock industries have grown rapidly to meet the increasing demand for dairy and meat in China, which has increased the discharge of more activate N into the air, soil, and rivers (Fei et al., 2011). Surplus N from agriculture production has an important function in non-point source N pollution and water quality degradation, causing serious environmental problems across the country (Qin et al., 2011; Wang et al., 2011). Nitrous oxide (N_2O) and ammonia (NH_3) emissions from arable land and livestock manure management are vital atmospheric pollutants that contribute to global warming and acid precipitation. The Chinese First National Census on Pollution Sources showed that the national total N discharge in 2007 reached 4.7289 million t, with more than half coming from agricultural sources, i.e., 1.6 million t of N from crop production and 1.0 million t of N from livestock production (The Ministry of Environmental Protection, 2010). Livestock excreta and fertilizer are the two major N sources in agricultural land. An estimated 94 million t of N from livestock excreta was produced worldwide in 1996, 36% of which was recovered as manure (Sheldrick et al., 2003). N losses during livestock breeding and manure management have an important function in agricultural non-point source pollution (AGNPS) (Fei et al., 2011).

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