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Calibration of DNDC model for nitrate leaching from an intensively cultivated region of Northern China

Hu Li [a,b,c], Ligang Wang [a,b,c], Jianjun Qiu [a,b,c,*], Changsheng Li [d], Maofang Gao [a,b,c], Chunyun Gao [a,b,c]

[a] Key Laboratory of Agricultural Non-point Source Pollution Control, Ministry of Agriculture, Beijing 100081, China
[b] Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China
[c] Joint Research Laboratory for Sustainable Agro-ecosystem Research between Chinese Academy of Agricultural Sciences and University of New Hampshire (CAAS–UNH), Beijing 100081, China
[d] Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03824, USA

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ABSTRACT

Nitrogen (N) loss through nitrate leaching in arable cropping systems in China has been recognized as one of the most common agricultural sources of groundwater contamination. The Denitrification–Decomposition or DNDC model, equipped with detailed soil hydrological and biogeochemical processes, was adopted in the study to quantify nitrate leaching for an intensively cultivated region in northern China. Several key parameters embedded in DNDC were calibrated against leaching data measured at a typical field with winter wheat–corn rotation within the target domain region. Five more sites representing the predominant cropping systems in the study region were selected for validating the modified model. In comparison with the original version of DNDC, the revised version yielded better results in simulated soil water and N leaching losses. To upscale the model simulation to regional level, we linked the validated DNDC to a regional database containing meteorological data, soil properties, vegetation types, and management practices for the target domain. Results from the regional simulation indicated that the total potential nitrate leaching load from the simulated 16.31 million ha croplands (sown area) ranged from 1.5 to 2.15 Tg N per year, with an average of 1.8 Tg N, which was equivalent to 26.1% of the total amount of N fertilizer applied in the region in 2009. The modeled results showed clear spatial patterns of nitrate leaching rates across the region due to the spatially differentiated fertilizer application rates as well as the soil water regimes. Alternative water management practices were suggested to effectively reduce nitrate leaching losses from the agricultural region in northern China.

1. Introduction

Nitrogen (N) is an essential nutrient needed to increase and maintain worldwide agricultural production. However, the overuse of N fertilizer for intensive farming and cropping systems with low N use efficiency is usually responsible for nitrate leaching into groundwater (McLay et al., 2001; Norse, 2005; Tilman et al. 2001). Groundwater contamination by nitrate is a growing problem driven by the burgeoning global population and its demand for food supplies. To meet the demand of food production, the N fertilizer consumption in China has been remarkably increased over the past 20 years. N losses through nitrate leaching in intensive farming regions in China has been recognized as one of the most common agricultural sources of groundwater contamination(Liu and Wu, 2002; Sun et al., 2008; Zhu et al. 2006). For example, Lu et al. (1998) reported that over 21.5% of wells' nitrate concentrations exceeded national standard in their analysis of 93 agricultural wells in Shaanxi province. In a survey across 14 provinces including Beijing, Shandong, Hebei, etc., Zhang et al. (1996) found that N fertilizer application rates in most counties were over 500 kg N ha^{-1}, leading to heavy groundwater contamination. This is particularly a problem in the main crop production areas in the North China Plain that is responsible for 42.5% of the total national food production, receives adequate irrigation water and fertilizers, and followed by intensive management (Bureau of Statistics of China, 2011). In this region, 73% of the cropping systems possess well developed irrigation facilities, and the average fertilizer application rates for these cropping systems were as high as 600 kg N ha^{-1} (Liu et al., 2006; Zhong et al., 2006).

Therefore, quantifying the impacts of alternative management practices on the N losses from croplands is essential for mitigating the N loading. A large number of experiments have been conducted to derive management practices to mitigate such losses, and the results indicated that appropriate fertilizer, water and soil management can minimize nitrate leaching and increase crop yields (Berstrom and Johansson, 2001; Kuo and Jellum, 2000). However, N transport and turnover processes are complex and are influenced by a number of soil and environmental variables, interacting soil water and N processes, crop uptake and management practices (Ma et al., 2007; Thompson et al., 2007; Whitmore

* Corresponding authors at: Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China. Tel.: +86 10 82106231.
E-mail addresses: lihu0728@163.com (H. Li), qiujianjun@caas.cn (J. Qiu).

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