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Status of mineral nitrogen fertilization and net mitigation potential of the state fertilization recommendation in Chinese cropland

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ABSTRACT

The overuse of mineral nitrogen (N) fertilizer is widespread and affects greenhouse gas (GHG) emission in China. In 2013, the Ministry of Agriculture released the 'Recommendation for soil nutrient analysis-based mineral fertilizer application for corn, wheat and rice' (hereafter the Recommendation). The aims of this study were to estimate current mineral N fertilization and net mitigation potential (NMP) for the Recommendation in the three main crops in China. To estimate the NMP from the Recommendation concerning the fertilizer recommendation (FR) scenario, we designed a current situation (CS) scenario by conducting a field questionnaire survey across typical cropping regions in China. Our results indicate that annual N fertilization amount was 19.1 ± 1.2 (95% confidence interval) Mt N applied to the 66 M ha of Chinese cropland in the CS scenario and would decrease by about 7.1 Mt N in the FR scenario. This decrease might mitigate 37.4 ± 5.2% of GHG emissions including carbon dioxide (CO_2) from production and transport of N fertilizer, and nitrous oxide from soil due to N fertilization. Carbon (C) sequestration was 11.1 ± 0.71 Tg C yr^{-1} under both scenarios. The NMP was 23.9 ± 3.4 Tg Ceq yr^{-1} in the FR scenario and might offset 1.1 ± 0.16% of CO_2 emissions from fossil fuel combustion in 2011 in China. In conclusion, implementation of the Recommendation could be a sustainable and cost-effective N management system to mitigate GHG emissions in Chinese cropland.

1. Introduction

Mineral nitrogen (N) fertilization contributes to global climate change by affecting greenhouse gas (GHG) emissions and mitigation (Lu et al., 2009; Schlesinger, 2009). The production and transport of N fertilizer emit carbon dioxide (CO_2) from the fossil fuel used (Lal, 2004; West and Marland, 2002). Moreover, the N fertilizer application to cropland results in more nitrous oxide (N_2O) emission from soil (Lal, 2007). However, N fertilization can also improve soil carbon sequestration (SCS) by increasing crop yield and residue input (Du et al., 2014). Therefore, altering N fertilization affects GHG emissions and mitigation in cropland.

Suitable N fertilization is difficult to predict, and hence excessive N fertilization is popular in Chinese croplands (Ju et al., 2009). This overuse of N fertilization reduces N use efficiency (Ma et al., 2008) and increases GHG emissions (Schlesinger, 2009). Some management systems have been developed to improve N fertilization practices (Jia et al., 2013; Ju et al., 2009; Peng et al., 2010). For example, site-specific N management reduces N fertilizer application by 32% compared with farmers' N management in rice (Peng et al., 2010). The 'Soil Testing and Formulated Fertilization system' was conducted at a national scale, starting from 2005 and extended to 42.7 M ha of Chinese croplands in 2007 (Gao, 2008). Based on these studies, a fertilization system was released entitled 'Recommendation for soil nutrient analysis-based mineral fertilizer application for corn, wheat and rice' (hereafter the Recommendation) by the Ministry of Agriculture of the People's Republic of China (MOA, 2013). The Recommendation provides producing regions and crop yields specific criteria for suitable fertilizer management for each crop. Considering the regional heterogeneity of climate and cropping practices, the croplands were divided into four, five and five producing regions for corn, wheat and rice production, respectively (MOA, 2013). Therefore, the N fertilization suggestion in one province is available according to producing region and yield for each crop.

Any change in N fertilization has the potential to alter GHG emissions. However, the current status of N fertilization is little known in corn, wheat and rice throughout China. Furthermore, clarification is required concerning how implementation of the Recommendation would affect GHG emissions in cropland. Our hypothesis was that the implementation would decrease N fertilization and mitigate the resulting GHG emissions. Therefore, the objectives of this study were to estimate (1) the current mineral N fertilization and (2) net mitigation potential (NMP) of the Recommendation in these three crops in China. Thus, we conducted a field questionnaire survey across typical cropping regions in China during 2012–2013 and estimated the NMP of the Recommendation by designing two scenarios based on the survey and the Recommendation.

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2. Materials and methods

2.1. Study region

This study was conducted in mainland China, where rice, wheat and corn are the main cereal crops. In 2011, these crops occupied 54% of the total sown cropland area and 89% of the total cereal yield (NBS, 2012). Chinese cropland is divided into four cropping regions according to heterogeneity of climate, cropping systems and cultivation (Lu et al., 2009): Northeast, North, Northwest and South China (Fig. 1). The cropping system is mainly single crops of corn, rice or wheat in one year in Northeast and Northwest China. The rotation is mainly corn–wheat in North China and mainly wheat–rice or even wheat–rice–rice in South China (Lu et al., 2009). However, other cropping systems may be adopted in some provinces due to climate and small-scale farmers' choices, for example both single and double cropping systems in Shaanxi in Northwest China.

2.2. Field survey

During 2012–2013, we conducted a survey with a field questionnaire for farmers concerning cropland management in main crops across 2011 throughout mainland China (Fig. 1). The survey questions included crop yields and mineral N fertilizations (Table A1 in Appendix). Meanwhile, the triangulation questions, including crop yield and fertilizer price, were designed to ensure questionnaires' validity (Table A1 in Appendix). The survey comprised four processes: (1) pilot survey: since there is huge spatial heterogeneity in fertilization due to climate, soil and cropping system in China, sampling size was a big challenge in the present study. We conducted a pilot survey in the counties of Yanzhou, Tengzhou and Tongcheng which are located in major production regions of wheat, corn and rice (Text A1 in Appendix). The pilot survey showed that N fertilization rate was 251 ± 51 kg N ha^{-1} yr^{-1} (mean $\pm$ standard deviation, n = 52). The sample size (n) of formal survey was estimated with Formula (1) (Townend, 2002):

$$n = (\mathrm{SD} * t_{n-1,0.05}/95\%\ \mathrm{CI})^2 \quad (1)$$

where SD is standard deviation of the N fertilization rate of the pilot survey, $t_{n-1,\,0.05} = 1.96$ obtained from *t*-tables and CI is confidence interval. Therefore, the sample size of 410 was suitable using an acceptable 95% CI = 5. To control the risk of uncertain factors, we adopted 850 as the sample size in the formal survey; (2) interviewer training: interviewers were solicited from China Agricultural University and trained concerning interview principles and respondent selection. They were also given detailed explanations of survey questions in a uniform questionnaire. The interviewer of the pilot survey served as not only the interviewer in the formal survey, but also the guiders in the training of the members solicited; (3) formal survey: in each province, two to five counties were randomly selected according to cropland area, with at least one village per county. In each village, five farmers were selected with a simple random sampling method during field-labor time by the interviewers. The interviewers spoke with the farmers selected and filled in the improved questionnaires based on the pilot survey. The

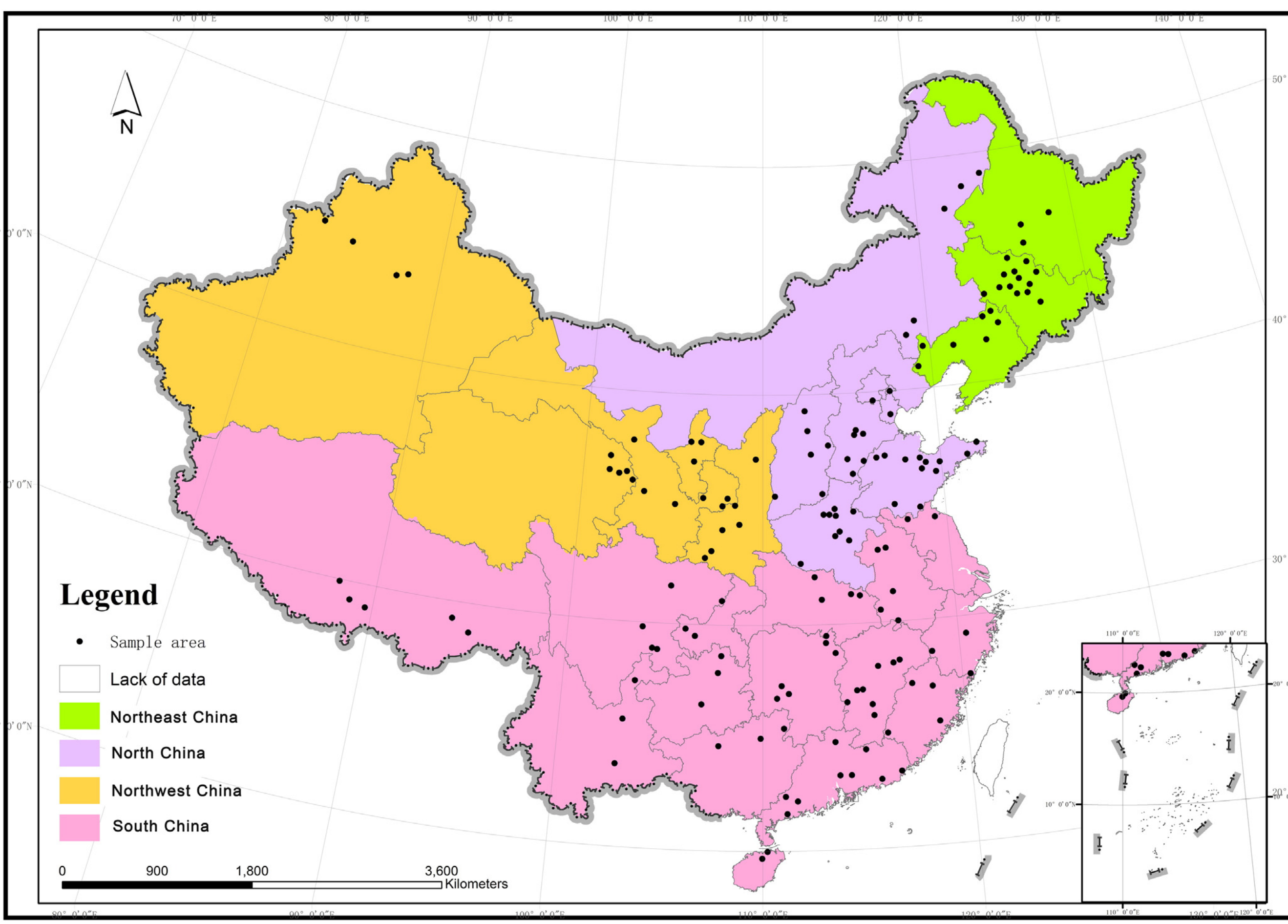

Fig. 1. The distribution of counties investigated in China mainland. The agricultural regions are Northeast China, North China, Northwest China, and South China.