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Nitrogen application rates need to be reduced for half of the rice paddy fields in China

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A B S T R A C T

Increasing nitrogen (N) application to croplands in order to support growing food demand is a major cause of environmental degradation. However, evaluations of suitable N application rates based on environmental benefit have rarely been carried out for paddy-rice at a national scale in China. To address this challenge, we investigated the current status of N management in 1531 counties, covering the primary agro-ecological regions of Chinese rice production in 2008, and conducted 12 field experiments with six N level practices for 3 years (2011–2013). Results showed that the highest yields for rice were 5.8–8.6 Mg ha^{-1} with N rates of 209.4–289.8 kg N ha^{-1}. Compared with the N rate for the highest yield (YHN), the environmentally optimal N rate (EnON) was lower by 20–39% and the corresponding N loss was reduced by 21–45%, while ensuring 95–99% of the highest crop yield. In China, the N inputs to paddy fields exceeded the YHN and EnON rates by 10% and 45%, respectively. After adjusting the N rate to paddy fields to the EnON rate, the N amount used in China and the corresponding N lost would be reduced by 0.9 and 0.5 Tg N yr^{-1}, respectively, which enable highly efficient production of food with the lowest N loss possible. Thus, we suggest that N use rates for 45% of rice paddy fields in China, for which N application rates exceed the EnON rate, need to be reduced to mitigate environmental damage, and this can be done while still meeting China's food demand.

1. Introduction

To meet the food and fiber demands of an increasing and gradually wealthier population, a series of policies were implemented to encourage synthetic fertilizer production and use in China during the last three decades (Li et al., 2013). However, nitrogen (N) fertilizer is substantially overused and misused in Chinese cropland, which is causing a series of environmental problems (Ju et al., 2009; Lu et al., 2015), such as greenhouse gas (GHG) emissions (Gu et al., 2012), eutrophication (Zhang et al., 2013), soil acidification (Guo et al., 2010), and a loss of biodiversity (Humbert et al., 2016; Zeng et al., 2016).

With the aggravation of environmental pollution, maintaining food production while reducing the detrimental effects of anthropogenic N application is an urgent priority for global food security and environmental sustainability (Erisman et al., 2011; Qiao et al., 2015). Ultimately, there is a need to balance the benefits derived from N applications with the associated environmental costs. The environmental cost assessment could provide guidance for emerging policy priorities in mitigating certain Greenhouse Gas (GHG) or reactive N (Nr) species, after quantifying their both release amounts and damage costs to ecosystems (Chen et al., 2011; Gu et al., 2012). However, previous studies have mostly focused on the optimal N rate to improve N use efficiency (NUE) and increase yield to its maximum potential (Xu et al., 2014), such as by testing the soil NO_3^--N content in the root zone (Cui et al., 2010), developing fertilizer recommendations based on soil testing, yield targets and crop responses (He et al., 2009) and fertilizer effect function equations (Sonar and Babhulkar, 2002), etc. Few studies have attempted to evaluate N input management and the associated

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